Inequality and Inequity in the Emergence of Norms

Calvin Cochran and Cailin O'Connor

Many societies have state norms of equity—that those who make symmetric social contributions deserve symmetric rewards. Despite this, there are widespread patterns of social inequity, especially along gender and racial lines. It is often the case that members of certain social groups receive greater rewards per contribution than others. In this paper, we draw on evolutionary game theory to show that the emergence of this sort of inequitable convention is far from surprising. In simple cultural evolutionary models, inequity is much more likely to emerge than equity, despite the presence of stable, equitable outcomes that groups might instead learn. As we outline, social groups provide a way to break symmetry between actors in determining both contributions and rewards in joint projects.

1 Introduction

It has been widely observed that cross-culturally women tend to do more overall work supporting households, and tend to have less free time, than men do (Coltrane, 2000; Bianchi et al., 2006; Treas and Drobnic, 2010). Despite this, women are poorer, on average, than men even in highly developed nations (Casper et al., 1994; Pressman, 2002). When it comes to collaborative research in science, it also seems to be the case that in some disciplines women's contributions to the production of research are under-compensated. They get less credit for collaborative projects than men do, even when doing a large portion of work (West et al., 2013; Sugimoto, 2013; Feldon et al., 2017).

These are examples of inequality in the sense that the division of social resources favors those in one social group. They are also examples of inequity, by which we mean that symmetric contributions to a social good are not met with symmetric rewards. Women garner less economic compensation per hour contributed to household production. Women get less academic credit per time spent on scientific research. These observations are perhaps surprising given social norms supporting equity (Adams and Freedman, 1976; Freedman and Montanari, 1980).[1] One question we might ask is: despite explicit endorsement for equitable reward structures, what sorts of social processes might lead to inequitable ones?

[1] Starting with Adams (1963), equity theory—which posits that in many societies people find inequity highly unpleasant and seek to minimize it—has had many explanatory successes. See Van den Bos (2001) for an overview.

Previous authors have used evolutionary game theoretic models to help illuminate how inherently unequal conventions and norms can emerge between social groups.[2] In particular, these models show that when societies are divided into social categories (men and women, black and white people, Christians and Muslims) the dynamics of social learning and cultural evolution can lead to unequal divisions of resources for no particular reason.[3] In other words, in these models completely identical groups with an option to divide resources equally often end up doing it unequally simply as a result of their different group memberships.

In this paper, we look to explore not the emergence of inequality, but the emergence of inequity. We ask: can these sorts of simple cultural dynamics drive groups to reward labor inequitably on the basis of meaningless social identities? To address this question, we introduce a game where actors first produce some social good, and where their contributions to this production may vary. They then must divide the products of their joint labor. We model the emergence of norms to regulate this sort of interaction in a group with social categories like gender or race.

These models allow us to pull apart unequal norms from inequitable ones. Outcomes where two groups receive unequal levels of resource may be equitable if one side did more work in the first place. Outcomes where the two groups receive equal resources may be inequitable if one side did more work. We find that there are many stable outcomes where members of one group do more work per level of compensation. In other words, explicit inequity can emerge via cultural evolution under very minimal conditions, even between groups that are completely identical in terms of skills, preferences, etc. In fact, in every model we investigate, we find that inequity is the much more likely outcome than equity. This is the case even when we give actors the ability to condition their demands for compensation based on the contributions made by their partners in joint labor. The take-away is that, despite norms of equity, outcomes like those described above, where members of one social group receive inequitable rewards for labor, should be expected to arise under minimal conditions from simple dynamics of social interaction.

The paper will proceed as follows. In section 2 we introduce the main models that will be used in this paper—Nash bargaining games that involve a production stage and a division of resources stage. We also describe previous results on the emergence of unequal norms in models of the evolution of bargaining. In sections 3 and 4 we describe the main results of the paper. These two sections consider models where individuals do and do not condition their demands for compensation based on the level of work done by their interactive partners. As we will elaborate, both variations allow for the robust emergence of inequitable norms. In section 5 we conclude.

[2]See, for example, Axtell et al. (2000); Poza et al. (2011); Gallo (2014); Bruner (2017); Bruner and O'Connor (2015); O'Connor and Bruner (2017); Rubin and O'Connor (2017); O'Connor (2017a).

[3]To be clear, we are not making any claims here about the similarities of these various social categories—race is not the same as gender is not the same as religious affiliation. This said, the highly simplified models we will explore here capture broad, general aspects of social categories, and so can be applied to various cases.

2 The Bargaining Game and the Two-Step Bargaining Game

The Nash demand game was introduced by Nash (1950) to represent scenarios where two individuals divide a resource (money, goods, free time), where there are different plausible divisions that are more or less preferable to each of the actors, and where highly aggressive individuals will fail to successfully agree on a division. In representing divisions of social resources, we will employ a simplified version of his model, a 'mini-game', that captures these features, and is computationally tractable.[4]

Suppose two actors divide a resource of value 10, and each can make a low, medium, or high demand, corresponding to a request for 4, 5, or 6 units of the good. Further suppose that if these requests are compatible, each actor gets what they ask for. If they over-demand the resource, though, each gets a low payoff, sometimes called the *disagreement point*, of 0. The *payoff table* of this game is pictured in figure 2. Rows represent the possible demands for player 1, and columns for player 2, while entries to the table list what payoffs each player gets for some combination of demands.

		Player 2		
		Low	**Med**	**High**
Player 1	**Low**	4,4	4,5	4,6
	Med	5,4	5,5	0,0
	High	6,4	0,0	0,0

Figure 1: Payoff table for a mini Nash demand game.

This game has three *Nash equilibria*.[5] This solution concept refers to sets of strategies where no actors can change behaviors and improve their payoff. For this reason, Nash equilibria tend to be stable in the sense that no one is incentivized to change. As we will see they also tend to be the endpoints of evolutionary processes. These equilibria are the strategy pairings where the actors perfectly divide the resource: Low vs. High, Med vs. Med, or High vs. Low. At these pairings, an actor who changes to demand less simply gets less, while one who tries demanding more over-demands the resource and gets nothing.

Now imagine a model where actors in a society play this game with each other repeatedly, and where these actors belong to two different social identity groups. Suppose that they are able to choose how aggressively to bargain based on the identity group membership of each partner they encounter. (For example, a latinx person might choose medium demands with other latinx people, but low demands when meeting white people.) Further suppose that over time, this group culturally evolves—individuals update their behaviors in ways that benefit themselves, so that, eventually, some stable pattern

[4]See Sigmund et al. (2001) for more on the mini-game approach.

[5]We will only worry about pure strategy Nash equilibria in this paper since they are most relevant to evolutionary dynamics.

of group behavior emerges. This model might represent actors of two different races learning how to bargain over salary in the workforce, or men and women developing norms to divide household labor.[6]

Under many dynamics—rules that model cultural change or learning—there are three outcomes that tend to emerge between groups in this sort of model, corresponding to the three equilibria. Either group A demands High and B Low, or they make medium demands, or group A demands Low and B High. Notice that one of these outcomes looks something like a 'fair' norm of bargaining, and the other two are discriminatory in the sense that individuals treat in- and out-group members differently to the detriment of one out-group. Indeed, starting with Axtell et al. (2000), this sort of model has been used as a bare bones representation of the emergence of discrimination and of inequality between groups.[7] The remarkable thing about this model is that we see inequality emerge endogenously among actors who simply engage in reasonable learning given their environments. This is despite any sort of justifying asymmetry between the groups in terms of skills, preferences, or starting conditions, and without any assumptions about biases, stereotypes, or the psychology of in-group/out-group interaction. Follow up results have demonstrated the robustness of this emergence of inequality to modeling choices, and have proven the flexibility of this framework to illuminate issues surrounding inequality (Poza et al., 2011; Gallo, 2014; Bruner, 2017; O'Connor and Bruner, 2017; Rubin and O'Connor, 2017).

A suggestion raised by Wagner (2012) is that the simplified Nash demand game can, with slight modifications, be taken to represent a situation where actors do not divide a windfall resource, but instead divide the fruits of joint labor. In particular, Wagner suggests that a combination of the stag hunt game (where actors choose between mutually beneficial, but risky, joint action, and risk-free solo production) and the Nash demand game can represent a case where two actors first decide whether to produce a good together and then decide who gets how much of it.[8]

The game we explore in this paper is similar to the stag hunt/Nash demand game, but adds the feature that actors can make differential contributions to the jointly produced good, rather than just deciding to opt in or opt out of it. We'll call this the produce and partition game. We suppose that actors first play a Nash demand game to divide labor. We might think of the resource as representing free time, or time away from the joint product which can be used for personal gain. An aggressive demand, then, is a demand for a small amount of labor, while an accommodating demand represents a willingness

[6]As noted, social categories, like gender and race, are importantly different from each other, and the processes that govern interactions between these categories will be very different as well. We are working within a tradition of social modeling that privileges simplicity, tractability, and causal clarity over realism. (See Weisberg (2012) for an analysis of the trade-offs between these various modeling virtues.) This allows us to illustrate minimal conditions for the emergence of inequitable norms in the sense outlined by O'Connor (2017c). It also allows us to apply the same models to social processes that may have different details, as long as we understand this application to be a course grained one.

[7]Their model is very similar to those introduced by Young (1993a,b).

[8]O'Connor and Bruner (2017) explore the emergence of unequal norms between groups in this stag hunt/Nash demand combo, which they call 'the collaboration game'. Inequality emerges endogenously in this model, and is particularly likely when actors have low payoffs for hare hunting, or solo work.

to make a large contribution to the good produced. If actors reach the disagreement point in this part of the game, their project fails. They did not jointly contribute enough time to succeed. This choice assumes that the good is either produced or not, rather than varying in benefit based on the level of contribution as in, for example, a public goods game. While this is a simplifying assumption, it also corresponds to many realistic scenarios. In an actual stag hunt, for example, you either get the stag or you do not. In many work collaborations, you either land the big client or you don't.[9] This said, one natural extension to the work we present here is to models where greater levels of contribution correspond to a more valuable good.

If actors do enough labor to produce a good, they then have to decide how to divvy it out. This is done via a second round of the Nash demand game where the demands are now for an amount of the resource produced. Payoffs for the entire interaction then represent a combination of preferences for less work/external work in stage one and more reward in stage two.[10] (Notice that even actors who do not produce a good get some payoff, from lazing around in stage one, or else from using their extra time to produce solo payoffs.)

To be concrete, assume there are three levels of contribution in the first stage: Low, Medium, and High. Because actors are dividing labor, Low is actually the aggressive demand, and generates a payoff of 6. Medium and High contributions generate payoffs of 5, and 4, respectively. The players fail to complete the project if both players make Low efforts, or if one contributes Low and the other Medium. Otherwise they invest enough for the joint project to reach completion—generating a resource of value 10. At this point, they each make a Low, Medium, or High demand (for 4, 5, or 6) of this resource. If their demands sum to 10 or less, then the payoff for each player is the sum of their effort payoff and their demand. Otherwise, the agents cannot agree on how the resource should be split, and each walks away with only their effort payoff. Each player then has nine distinct (Contribution, Demand) strategies: (L,L), (L,M), (L,H), (M,L), (M,M), (M,H), (H,L), (H,M), and (H,H). The payoff table in Figure 2 gives the payoff table for two individuals playing produce and partition.

In the basic Nash demand game, the equilibria are the strategy profiles where players divide the resource without waste. Given that produce and partition is akin to two Nash demand games strung together, one might expect its Nash equilibria to be the the strategy sets where the two resources (effort and reward) are divided efficiently. This intuition turns out to be correct in many cases. The structure of the game is such that given another player's work contribution, the best response usually involves doing just enough work to complete the project (i.e., contributing Low when the other

[9]For other cases, there are levels of contribution below which essentially no payoff is generated and above which extra effort produces small differences. In building a house, the amount of effort which makes it livable creates a large payoff, and extra effort to improve the dwelling will generate smaller surpluses. A model like the one just described is a decent match to such scenarios.

[10]To our knowledge, this kind of two-part bargaining game has never appeared in the literature before as a model for equity (evolutionary or otherwise). The closest replication might be Kazemi et al. (2017) in which participants produced a public good which could be divided unevenly. This split was determined unilaterally by a predetermined leader, however, and not via a bargaining game.

	L, L	**L, M**	**L, H**	**M, L**	**M, M**	**M, H**	**H, L**	**H, M**	**H, H**
L, L	6, 6	6, 6	6, 6	6, 5	6, 5	6, 5	10, 8	10, 9	**10,10**
L, M	6, 6	6, 6	6, 6	6, 5	6, 5	6, 5	11, 8	**11, 9**	6, 4
L, H	6, 6	6, 6	6, 6	6, 5	6, 5	6, 5	**12, 8**	6, 4	6, 4
M, L	5, 6	5, 6	5, 6	9, 9	9, 10	**9, 11**	9, 8	9, 9	9, 10
M, M	5, 6	5, 6	5, 6	10, 9	**10, 10**	5, 5	10, 8	10, 9	5, 4
M, H	5, 6	5, 6	5, 6	**11, 9**	5, 5	5, 5	11, 8	5, 4	5, 4
H, L	8, 10	8, 11	**8, 12**	8, 9	8, 10	8, 11	8, 8	8, 9	8, 10
H, M	9, 10	**9, 11**	4, 6	9, 9	9, 10	4, 5	9, 8	9, 9	4, 4
H, H	**10, 10**	4, 6	4, 6	10, 9	4, 5	4, 5	10, 8	4, 4	4, 4

Figure 2: Payoff table for Produce and partition.

player chooses High).[11] And once a project is completed, a player does best to match their expectations for compensation to the demand of their partner. The Nash equilibria for produce and partition are then the strategy pairs which waste neither effort nor any of the produced good: (L,M)/(H,M), (L,L)/(H,H), (L,H)/(H,L), (M,L)/(M,H), and (M,M)/(M,M), and all the flipped versions of these. (I.e., both (L,M)/(H,M) and (H,M)/(L,M) are equilibria. In the first, player 1 gets a preferable outcome, and in the second player 2 does. From an equity standpoint, they are equivalent.) The payoffs for these equilibria are bolded in Figure 2.

As we will see, these equilibria will be the endpoints of our evolutionary models, meaning that they represent the possible, stable social arrangements between social groups. Before moving on to these models, though, we would like to pull out in more detail the characters of these various possibilities.

In the first three types of equilibria, ((L,M)/(H,M), (L,L)/(H,H), (L,H)/(H,L)), one group is systematically bearing more of the work. In the middle three, ((L,L)/(H,H), (L,H)/(H,L), (M,L)/(M,H)), one group is consistently taking home more of the spoils. These unequal partitions of labor and rewards might be tolerable if they are at least equitable, however. Most academics, for instance, would agree that if one co-author does more work than the other, then he deserves the more prestigious author position. This scenario might be captured by equilibrium (L,L)/(H,H), where one group consistently invests and reaps less and the other invests and reaps more. While such an equilibrium is unequal in the sense that one group earns less, it is at least equitable. This and the (M,M)/(M,M) equilibrium are actually the only equitable outcomes. Rest point (M,L)/(M,H), for instance, resembles the plight of women described in the introduction: equal work reaps unequal reward. Anyone who has participated in a group project at school is familiar with (L,M)/(H,M): industrious students put forth more effort than

[11] An exception to this occurs when a player expects such a low payoff from later bargaining that they do better to just slack off in round one and never complete the project at all. We will return to this possibility later.

lazy ones, but all group members receive the same grade. Finally, (L,H)/(H,L) is the most inequitable of these norms, with one party working hard to receive little pay and the other barely working to obtain a fortune. One might imagine this is the relation some CEO's have with their employees.

So we see that this game has equilibria that are inequitable in two different ways—actors work equally hard to different rewards, or actors make different contributions to equal rewards (or even to unequal rewards that do not correspond to their levels of contribution). Now we ask: do these equilibria emerge endogenously between social groups under circumstances of learning or cultural evolution? And: in such scenarios, how likely is it that we see inequity emerge?

3 The Emergence of Inequity

In the models we focus on now, as mentioned above, populations are divided into two groups that are identical modulo some arbitrary marker. We assume that actors can play produce and partition with all members of the population, and that they condition their strategies on the marker of their opponent. In other words, they choose a (Contribution,Demand) combination based on what sort of individual they interact with. The stable group level equilibria of this model will involve three conventions: one for interaction within group A, one for interaction within group B, and one for interaction between the two groups. Since we are interested in the emergence of inequitable norms between those in different social categories, we will focus here on the between-group equilibria. These are exactly those equilibria described in the last section, but extended to an entire group. In this model, (L,H)/(H,L) would correspond to a scenario where, for example, whenever women and men form a household women contribute more labor than men, and reap less reward. This tells us that, at very least, the sorts of inequitable patterns described in the introduction are plausible, stable social conventions.

While the Nash equilibrium solution concept is one of the hallmarks of classical game theory, it is deficient in that is does not specify *how* these equilibria are reached. In addition, while some games like the ubiquitous prisoner's dilemma have exactly one Nash equilibrium, others may have several. Ours, in fact, has nine (of five different types). Even if we observe that the populations will always converge to the set of Nash equilibria under some dynamic, classical game theory says nothing about which of these outcomes are more or less likely to be realized

In order to develop a model for the emergence of equity/inequity, then, we look to *evolutionary game theory.* This branch of modeling was originally developed to capture the evolution of competitive behavior in animals (Maynard-Smith and Price, 1973), but it has since found applications in the social sciences to the study cultural evolution in humans. Agents in these models play a game repeatedly and update their strategy over time based on past success. This gives us a compelling story for how agents might actually move towards equilibria and gives the equilibrium selection problem some tractability. We will use this methodology to estimate which of our equilibria are likely to be reached, if any.

Table 1: Basins of attraction with contribution payoffs 6, 5, 4 and demands 4, 5, 6

Equilibrium	M,M/M,M	M,L/M,H	L,H/H,L	L,M/H,M	L,L/H,H
Basin of attraction	20.00%	16.64%	18.55%	33.43%	11.38%

Imagine our two populations locked in repeated play of produce and partition. Since, as mentioned, we focus on between-group interactions, suppose that during every round, each agent from the first population is randomly paired with an agent from the second to play the game once. After each round, players in population 1 look around to see how the rest of the agents in their group did. Players who did worse than average will imitate the strategies of players who performed well in the previous round. This imitation is done in proportion to relative success i.e. players who perform well below average are more likely to abandon their strategy and players who perform well above average are more likely to be copied. Players use their new strategies in the next round, and the process repeats. These are the fundamental updating rules for the *replicator dynamics*, the most common evolution dynamic employed in evolutionary game theory. Strategies that perform above average proliferate, while those that underachieve are gradually abandoned. While this is almost certainly an oversimplification of how strategy updating actually occurs in actual human groups, the replicator dynamics provide a plausible and computationally simple learning rule that represents some realistic aspects of human cultural change.[12]

One important quality of the replicator dynamics is that they are deterministic. This essentially means that there is no randomness to the dynamics. One can repeatedly start the populations in strategy distribution state p and the replicator dynamics will always carry the system to the same Nash equilibrium.[13] One method of estimating the frequency with which each equilibrium is realized, then, is to initialize our two populations repeatedly with each actor assigned a random strategy.[14] Recording the end point at which the players arrive each time gives us an estimate of the *basins of attraction* for each equilibrium, the probability that players will settle on this norm in the long run. Since there are many (in fact infinite) potential strategy initializations, we simulate a random sample of 10^8 strategy initializations and record the basins of attraction in Table 3.[15] We collapse the nine possible equilibria into their five types.

Two major results can be gleamed from this table. Perhaps most immediately, the basin of attraction percentages sum to 100%, meaning that all simulations eventually

[12]Weibull (1997) shows that the replicator dynamics can be explicitly used to model cultural change via differential imitation of successful group members. Lancy (1996); Fiske (1999); Henrich and Gil-White (2001); Henrich and Henrich (2007); Richerson and Boyd (2008) provide evidence that this sort of imitation occurs in real human societies.

[13]Unless the dynamics never settle at an equilibrium, but this type of outcome is beyond the purview of this paper.

[14]For the purposes of this paper, strategies are initially chosen with uniform probability over the nine previously identified. There is nothing special about this choice, however, and there may in some cases be grounds to assume some other probability distribution over initial strategy selection. A future study might investigate the potential effects of outgroup bias on equity, for instance, by increasing the probability of demanding high initially.

[15]All simulations were run in Eclipse, a Java based IDE.

Table 2: Produce and partition with modified payoffs

	L, L	**L, M**	**L, H**	**M, L**	**M, M**	**M, H**	**H, L**	**H, M**	**H, H**
L, L	5, 5	5, 5	5, 5	5, 3	5, 3	5, 3	8, 4	8, 6	**8, 8**
L, M	5, 5	5, 5	5, 5	5, 3	5, 3	5, 3	10, 4	**10, 6**	5, 1
L, H	5, 5	5, 5	**5, 5**	5, 3	5, 3	5, 3	12, 4	5, 1	5, 1
M, L	3, 5	3, 5	3, 5	6, 6	6, 8	**6, 10**	6, 4	6, 6	6, 8
M, M	3, 5	3, 5	3, 5	8, 6	**8, 8**	3, 3	8, 4	8, 6	3, 1
M, H	3, 5	3, 5	3, 5	**10, 6**	3, 3	3, 3	10, 4	3, 1	3, 1
H, L	4, 8	4, 10	4, 12	4, 6	4, 8	4, 10	4, 4	4, 6	4, 8
H, M	6, 8	**6, 10**	1, 5	6, 6	6, 8	1, 3	6, 4	6, 6	1, 1
H, H	**8, 8**	1, 5	1, 5	8, 6	1, 3	1, 3	8, 4	1, 1	1, 1

approached one of the Nash equilibria. While not entirely unexpected, this result is important because it suggests that two social classes repeatedly given the opportunity to produce some shared joint good will almost always converge to some norm that allows them to do so. In the long run, one group will come to uniformly contribute a set amount and demand a set amount, as will the other group. Unilateral deviation from this arrangement will only lead to a lower payoff, so such norms are generally hard to leave and may become even more entrenched over time.

The other notable result is the ubiquity of unequal and inequitable outcomes. As noted in section two, (M,M)/(M,M) is the only norm where all players put forth equal effort and reap equal rewards. The probability of arriving at this outcome is estimated at 20.00%, meaning that work and pay are not equally split in 80.00% of cases. What about equitability? Nash equilibria (M,M)/(M,M) and (L,L)/(H,H) are the only perfectly equitable outcomes and have combined basins of attraction of 31.38%. Inequitable outcomes, then, emerge in over two-thirds of all runs and can be further broken into somewhat inequitable outcomes (M,L)/(M,H) and (L,M)/(H,M) occuring 50.07% of the time and the extremely inequitable outcome (L,H)/(H,L) emerging in 18.55% of trials. Overall these results suggest that inequity is not only possible but is in fact quite likely to emerge endogenously between two social groups interacting over time.

The payoffs used in this game are not, of course, unique. Utilities may be tailored to the particular joint project and to players' values. In a situation where the High and Low payoffs and contributions are more disparate, it may not be worthwhile for an individual to make a High contribution if they expect Low compensation. Our current payoff table does not fully capture this situation. Consider instead the payoffs in Table 2.

In this new payoff table, utilities for contributions are 5, 3, and 1 for Low, Medium, and High investments, respectively. Similarly, 3, 5 and 7 are the available demands for resource produced. While this game retains most of its Nash equilibria from the first edition, it loses (L,H)/(H,L), since (H,L) is a dominated strategy. (One can always earn higher by playing (L,H).) A new equilibrium arises at (L,H)/(L,H), where agents from

Table 3: Basins of attraction for Produce and partition with modified payoffs.

Equilibrium	M,M/M,M	M,L/M,H	Predominantly L,H/L,H	L,M/H,M	L,L/H,H
Basin of attraction	9.05%	4.42%	11.89%	52.17%	22.47%

both populations invest very little into the project, which is never completed.[16] Given that (L,H)/(H,L) was the most inequitable outcome and is no longer a Nash equilibrium, one might expect the basins of attraction for inequitability to shrink and equitability to become more likely. Inspection of Table 5 reveals that this is partially true. While the basin of attraction for inequitable outcomes has indeed decreased from 68.62% to 56.59%, the roughly 12% difference has been funnelled not into the basin of attraction for equitability but instead into the non-cooperative (L,H)/(L,H) equilibrium's basin. The probability of ending up at an equitable outcome remains at just above 31%. Despite modifications to the payoffs and the removal of the least equitable solution, inequitability persists more often than not.

4 Inequity and Conditioned Demands

In the previous section we assumed that players select both their contribution level and demand before ever encountering their opponent. Actors make the same demand regardless of what their opponent contributes. In many cases, however, actors in real life choose demands for compensation based in part on an interactive partner's contribution. Imagine that two college roommates Amy and Brenda love throwing parties at their apartment. In addition, the apartment must be at a minimal level of cleanliness for any parties to be thrown. Both women refraining from cleaning will result in a filthy, uninhabitable apartment. If Amy spends the week scrubbing the house furiously while Brenda slacks off and plays video games, Amy may feel more deserving and might request that she get to use the apartment to party that weekend (a high demand). How might this sort of conditional demand framework affect the probability of reaching an equitable norm? Do actors resolve to reward those who work hard, conforming to our intuitions on equitability? Or is inequity robust across these models?

A major difference in this conditional strategy framework is that player strategies have four parts: (Contribution, Demand vs Low Contribution, Demand vs Medium Contribution, Demand vs High Contribution). A player using strategy (L, M, L, H) would contribute low, demand medium if her opponent contributes low, demand low if her opponent contributes medium, and demand high if her opponent contributes high.

[16] While (L,H)/(L,H) is a pure Nash equilibrium, it is not a strict one, meaning that each actor can change strategies and get an equal payoff to their expected one. As a result, the system seldom converges to two populations of (L,H) players but rather results in two populations made up predominantly of (L,H) players with a scattering of (L,L) and (L,M) players. This is sustainable because contributing Low, paired with any demand, is a best response to (L,H). The project is never completed and bargained over, so these strategies all earn the same payoff.

Table 4: Basins of attraction for conditional produce and partition

Equilibrium	M,M/M,M	M,L/M,H	L,H/H,L	L,M/H,M	L,L/H,H
Basin of attraction	31.44%	4.33%	5.83%	46.19%	2.97%

There are a total of $3^4 = 81$ distinct strategies of this form, so we omit the payoff matrix here. Using the original contribution payoffs (6, 5, 4) and demands (4, 5, 6), one might expect that the increase in strategies will lead to an increase in Nash equilibria. While this is true, most of the equilibria are equivalent to one of the original five from section 3: (L,M)/(H,M), (L,L)/(H,H), (L,H)/(H,L), (M,L)/(M,H), and (M,M)/(M,M).[17]

Inspecting the basins of attraction for the conditional produce and Partition in Table 4 yields two final results. The first is that inequitable outcomes still occur with high probability (56.35%). This phenomenon has manifested itself throughout all three variations of produce and partition considered in this paper. The other result is that the Nash equilibria basins of attraction in Table 4 only sum to about 91%. To illustrate what happens the other 9% of the time, imagine an employee and employer running a small business. Both must put forward some minimum amount of effort at work for the business to stay afloat. An employee who invests the minimum amount of effort for the business to succeed will walk home with their promised paycheck. An employee who goes above and beyond to excel at her tasks may warrant a bonus from the employer who hopes to incentivize the employee's good work (and not lose the employee to another company).

This is the essence of what occurs in these 9% of runs. One population is split between two strategies: one investing smaller and demanding smaller, the other investing larger and demanding larger. The second population discerns these discrepancies in contribution and adjusts their demands for resources accordingly for each population 1 agent encountered. They always contribute medium, so that the good is produced, and then demand less resource from harder workers and more from slackers. While these cases are relatively rare, one might classify them as among the more equitable outcomes: greater effort is being rewarded with greater spoils.

5 Conclusion

One might wonder at this point: given the robustness with which inequitable norms of various sorts emerge in these simple models, how do we explain the prevalence of equity norms? Remember that the models we have considered always involve a population divided into two groups or social categories. Things turn out differently in a group without these sorts of divisions. If we consider a single population, the symmetric,

[17]Consider two strategies (M, L, L, L) and (M, H, L, H) composing population 1, while population 2 plays (M, L, H, M) uniformly. Although the strategies (M, L, L, L) and (M, H, L, H) are technically distinct based on their demands, observe that both of them contribute medium and both of them only ever demand low, since their population 2 opponents uniformly contribute medium. This state looks like equilibrium (M,L)/(M,H), though it is composed of many technically distinct strategies.

equitable outcome (M,M)/(M,M) emerges 60% of the time. Another 27.4% of the time, all agents end up demanding medium in the end, and some make high contributions, while others make low contributions. The rest of the time, a number of equilibria emerge that involve a mixture of high and low contributions, and different demands. Notice that at these equilibria, though, despite the fact that individual interactions will be inequitable, it is nonetheless the case that all actors have the same expected payoffs. Otherwise, of course, they would not be equilibria in a single population.

Why does the simple addition or subtraction of categories from the model so radically alter the cultural evolution that occurs? One way to explain it appeals to symmetry and symmetry breaking. In the contribution part of the model, actors are most efficient if they perfectly divide the labor. (I.e., no extra work is done to produce the good, and the opportunity to create a joint surplus is taken advantage of.) In a population without categories, the only way to guarantee that every pairing of actors will efficiently divide labor is for everyone to make a medium contribution. Otherwise, sometimes low contributors will meet each other and fail to produce the good, and sometimes high contributors will meet each other and put too much work into the project. With categories, actors can use category membership as a symmetry-breaking mechanism. There is an extra piece of information in interactions between those in different categories (i.e., I am type A and you are type B), which allows them to efficiently break symmetry with respect to contributions (type A always contributes more, type B less).[18]

This same sort of reasoning applies to bargaining over rewards from joint labor. With one exception—when it comes to this stage of the process, information about earlier contributions can be used as a symmetry breaker. But, of course, a dependence between contribution and reward is what we expect from an equitable norm.[19] When we have two different categories of actors, there is a symmetry breaker available at the reward stage that has nothing to do with contribution. In other words, once we get to the second stage, there is no particular reason to coordinate reward based on contribution compared to coordinating reward based on irrelevant group membership.

This is perhaps the central insight of the paper. From a standpoint where we think of conventions and norms as facilitating social coordination, equity is special in groups where everyone is the same, but its specialness disappears as soon as any sort of further social information in the form of social category membership is added. What we see here is that it is quite easy to evolve conventions that do not involve equitable divisions

[18] See O'Connor (2017b) for an in-depth discussion of this sort of symmetry breaking. Similar reasoning can be applied to work in philosophy of science explaining the emergence of fairness norms. Skyrms (1994); Alexander and Skyrms (1999); Skyrms (2014); Alexander (2007) show that in simplified Nash demand games the equal outcome is special from an evolutionary point of view. Because it is the only symmetric outcome, it is more likely to evolve. In contrast, when Axtell et al. (2000); Bruner (2017); Bruner and O'Connor (2015); O'Connor and Bruner (2017); Rubin and O'Connor (2017) add categories to the same sort of model, the fairness norm is no longer special because the categories break symmetry between actors of different types.

[19] In the models just described, we do not see this because actors have no good way to coordinate their first stage contributions besides demanding medium. We also do not shape payoffs so that there is enough fine-grainedness to get exactly equal payoffs through different contribution/reward combinations, which is necessary to reach equilibria in this sort of model.

of jointly produced social resources if we have groups divided into categories.

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