"From Each According to His Ability": The Evolution of Respect for Needs

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Abstract

Much work has been done attempting to show how processes of cultural evolution can give rise to a general tendency to share-and-share alike. However, one shortcoming with these models is that they tend to assume perfect symmetry between players and, at the same time, to omit differences in need. In developing a more sophisticated bargaining model which includes both resource production and resource division, we show how cultural evolutionary processes can give rise, under certain circumstances, to a universal respect for needs.

1. Introduction

Marx and Darwin make strange bedfellows. It is difficult to reconcile the sense of necessity with which the bourgeosis are to be crushed under a proletariat revolution with the historical contingency permeating evolutionary theory. In what sense is the proletariat uprising *necessary*? From a Darwinian point of view, there is no sense in which humans are a physically necessary, much less logically necessary, consequence of evolution. This is problematic because one cannot have a proletariat revolution without proletariats. Yet even if we view Marx's claim of historical necessity as conditional upon the existence of humans, we still run afoul of evolutionary considerations. The material preconditions for the industrial revolution and the rise of the bourgeosis depend crucially on a host of factors which evolution — not human nature — had the final hand in establishing.

Consider, for example, the geographical explanation for the rise of Europe as a world power offered in Jared Diamond's *Guns, Germs, and Steel*. If his account is correct[1], we would not have the most basic material preconditions required for the industrial revolution — cities with a dense labour force untied to the land — without the fortuitous provision of Mother Nature. The existence of domisticable plants and animals, of which Eurasia had more of than all other continents, is again an evolutionary accident. Had Eurasia and the rest of the world been more like Australia, human societies would have never moved beyond the hunter-gatherer stage as they would have lacked the basic means to do so. Marx's claim of historical necessity founders again upon the contingent nature of evolution.

Another point of difficulty exists. Not long after Darwin published *The Origin of Species*, many social theorists were quick to identify similarities between the action of natural selection upon a population and the competition between individuals under the economic arrangement of *laissez-faire* capitalism. This stark social Darwinism transplanted the view of nature as "red in tooth and claw" into the realm of social interaction and became part of the general consciousness, as the following satirical protest poem indicates:

> "Dost thou know, deluded one,
> What Adam Smith has clearly proved,
> That 'tis self-interest alone
> by which the wheels of life are moved?
> This competition is the law
> By which we either live or die;
> I've no demand thy labor for,
> Why, then, should I thy wants supply?
> And Herbert Spencer's active brain
> Shows how the social struggle ends;
> The weak die out the strong remain;
> 'Tis this that nature's plan intends.
> Now really 'tis absurd of you
> To think I'd interfere at all;
> Just grasp the scientific view,
> The weakest must go to the wall." (Thompson, 1878)

The above association of Spencer with social Darwinism is an unfortunate historical injustice. Spencer — a self-described "rational utilitarian"

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[1] Diamond's explanation is by no means uncontroversial. However, most of the points of controversy do not address issues which directly pertain to our discussion here.

— is more properly viewed as working within the more tolerant philosophical tradition of Mill and Bentham. But there are plenty of other apologists for *laissez-faire* capitalism whom one could substitute for Spencer in the above quote, such as William Graham Sumner, the influential chair of Political and Social Science at Yale during the latter half of the nineteenth century.

Social Darwinism does not necessarily exist in tension with basic principles of Marxist thought. The competitive, cut-throat nature of social interaction, if seen as deriving from the declining rate of profit and the corresponding squeeze placed upon the working class, is indeed very much what one would expect were the Marxist analysis correct. However, if the competitive nature of social interaction derives from the primacy of self-interest alone, one would find it impossible to implement the ideal society sketched in the Communist Manifesto. The importance of positional goods, and the fact that they cannot, by their very nature, be provided to all, ensures that the social struggle would remain even in a society stripped of bourgeois production.

Yet is evolution really at such odds with Marxian intuitions? A fundamental error made by the social Darwinists was thinking that evolution entailed antagonistic relations among members of society. Much of animal behaviour involves cooperative interactions, in addition to antagonistic interaction. This point was well understood by the Russian naturalist Peter Kropotkin, who made it the central topic of study in his work *Mutual Aid:*

> "In the animal world we have seen that the vast majority of species live in societies, and that they find in association the best arms for the struggle for life: understood, of course, in its wide Darwinian sense – not as a struggle for the sheer means of existence, but as a struggle against all natural conditions unfavourable to the species. The animal species, in which individual struggle has been reduced to its narrowest limits, and the practice of mutual aid has attained the greatest development, are invariably the most numerous, the most prosperous, and the most open to further progress." (Kropotkin, 1902)

It is now well understood that evolution — under the right conditions — can support cooperative outcomes as well as antagonistic outcomes. If one takes the Prisoner's Dilemma as a problem of cooperation, socially structured interactions among boundedly rational agents allow Cooperate to persist, and even to be the unique evolutionarily stable strategy in certain models of the indefinitely iterated Prisoner's Dilemma

(Nowak and May, 1992, 1993; Alexander, 2007). Alternatively, if one thinks of the Stag Hunt as a problem of cooperation (it is often viewed as a model of trust, but trust and cooperation are closely related), then social structured interactions among boundedly rational agents allow Hunt Stag to persist indefinitely, and also to be the unique evolutionarily stable strategy in certain models of the indefinitely iterated Stag Hunt (Skyrms, 2003; Alexander, 2007).

What of *needs*? Part of the Marxist concern, and part of the objection raised against social Darwinism, is that it strikes some as blatently *unfair* that the "weak shall go to the wall" simply because they are not as capable as others. One important motivator for both communism and socialism is that society ought to provide some sort of safety net to assist those who, through no fault of their own, are not as capable as others and, consequently, less able to fend for themselves. The fact that evolution permits cooperative outcomes to emerge does not automatically mean that concern for the needs of others shall emerge as well.

Evolution is capable of producing individuals with concern for the needs of others. Human infants are incapable of taking care of themselves, and are raised at considerable cost (in terms of individual labour) by their parents. Vampire bats regurgitate blood to those who are less successful in their hunting endeavours. This requires sensitivity to the needs of others. This same behaviour, though, could be expected to obtain for those who are not one's own offspring, by appealing to Hamilton's concept of inclusive fitness. Provided that the target of one's concern is reasonably closely related to oneself, showing concern for their needs can be fitness-enhancing, even if the cost of attending to their needs is significant.

These biological examples of attending to needs, though, typically rely on some degree of genetic relatedness. Is it possible to have concern for needs arise in other contexts? If we turn to the attempt to ground morality upon principles of rational choice, we find that this point was one of the criticisms raised against Gauthier's *Morals By Agreement*. In Gauthier's analysis, only those individuals capable of entering into bargaining contexts had moral status. Individuals who were unable to enter into bargaining problem — because they either had nothing to contribute, or were otherwise unable to represent their own interests — were forced to rely on the good will of others. This result seems unsettling. How might universal respect for the needs of others — including those not related to oneself — evolve?

2. Cooperation, fairness, and concern for needs

Although evolutionary models have been developed which show how a basic conception of *fairness* can evolve (Skyrms, 1996, 2003; Alexander and Skyrms, 1999; Alexander, 2000, 2007), one basic shortcomining of these models has been their assumption of the fundamental symmetry of all players. In particular, none of these models have attempted to incorporate a concern for individual needs. This has been a frequent target of criticism for it is a simple fact that the assumption of symmetry across players is false.

In what follows, we introduce a hybrid collective action and distribution problem which allows for basic elements of the concern for needs to be studied. While more complex models of the role of needs in bargaining and resource allocation are undoubtedly required, this particular model provides a reasonable first approximation to what is a difficult and thorny problem. The primary difficulty in adding concern for needs into bargaining and resource allocation problems is to find a way to do so without begging the question and thereby making the solution trivial. For example, incorporating a "concern for needs" into the utility function of each player — along the lines of, say, how Bicchieri (2005) incorporates the social norm into her proposed utility function — explains how agents respect the needs of others by building respect for needs right into their preferences. This simply pushes the question back a step, for one can then ask why we would expect individual agents to have utility functions of *that* form rather than some other form.[2]

The model consists of a two-stage game. In the first stage, individuals for groups according to some assortment procedure and play a collective action problem by which a good (the "cake") is produced. In the second stage, individuals play an N-player version of divide-the-cake in order to split the resource amongst themselves. Needs are incorporated as a basic metabolic rate which individuals must satisfy at the end of each round otherwise they are eliminated from the population.

More formally, suppose we have a population of N agents, each of whom has a basic need n_i where $0 \leq n_i \leq 100$. The need assigned to an

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[2] It is worth noting that Bicchieri (2005) does not quite fall prey to this criticism because she is engaged in a rather different explanatory task. Her concern in the *Grammar of Society* is twofold: first, to introduce a precise theory of social norms; second, to make sense of the variegated results on ultimatum game behaviour uncovered by experimental economics. Insofar as her proposed utility function succeeds in doing the second, she has provided a unified explanation for what was previously a disconnected set of experimental results. The question as to *why* individuals have that particular utility function, rather than some other one, still remains, but she is not begging the question.

agent is assumed to be fixed for as long as that agent survives, although not every agent has the same need. In addition, each individual agent has a "productive capacity" p_i where $0 < p_i \leq 100$. The productive capacity of an agent is also fixed for as long as the agent survives, and not every agent has the same productive capacity.

Initially, we shall not include an explicit component which captures concern for the needs of others. Once we've studied this model in some detail, we shall add this component to the model. To begin, then, we assume that an agent's strategy consists of three parts:

1. When presented with the opportunity to join a collective action problem, do you opt out?
2. If you do not opt out of a collective action problem, do you cooperate?
3. When presented with a resource allocation problem, how much do you insist on (as a percentage on a scale from 0 to 100, in increments of 10)?

In each round of play, the dynamics are as follows:

- Each player initially has a score of 0.
- The population is partitioned into groups of size G.
- Individuals who Opt Out are removed from the group, as they choose to "go it alone". Each individual who Opts Out receives a payoff equal to $p_i - n_i$, i.e., her productive capacity minus her need.
- A collective action problem is played. Let C_i^t denote the set of cooperators in group i at time t. The total amount of resource produced by the group equals

  $$\left(\sum_{j \in C_i^t} p_j \right) \cdot \kappa^{|C_i^t|-1}$$

  where $\kappa > 1$ is a coefficient measuring the "economies of scale" generated by having more than one person working on the collective action problem. Intuitively, the thought is that when more than one person works on the collective action problem, each is a little bit more efficient as a result. Hence, the total resource produced is strictly greater than the sum of the individual cooperators' productive capacities.

- A bargaining problem is then played between all members of the group according to the rules of N-player divide-the-dollar. If the sum of the demands of all members of the group (which includes noncooperating members who did not elect to opt out) is less than or equal to 100%, each player gets what she asked for. If the sum exceeds 100%, no player receives anything. (In the limiting case where the group consists of a single player, she receives the whole cake.)
- Each player's need is deducted from the amount received at the end of the multiplayer divide-the-cake game.
- A modified Moran process is then run to replicate strategies according to their effectiveness.

A Moran process describes the stochastic evolution of a population of constant size. Suppose we have a population of size N, where f_i denotes the fitness of the ith member of the population.[3] The probability of player i propagating his strategy is $\frac{f_i}{f_1+\cdots+f_N}$. One player is drawn at random from the population and replicated, and the player (but not the replicant) is then returned to the population. Using a uniform distribution, another player is randomly selected from the population and exterminated, and the replicant inserted to take his place.

The modified Moran process used proceeds as follows. Suppose that, once the good produced by the collective action problem has been distributed amongst each group member and each player's need is deducted from the amount they have, k players have a negative score. Then all those players are eliminated from the population and k replacements are identified from the remaining individuals with positive scores by repeating the ordinary Moran process k times.[4] (None of the replacements are introduced to the population until all k replacements have been selected, so as to prevent bias favouring those individuals chosen to reproduce towards the beginning.) In the event that no player has a negative score, the ordinary Moran process described above is used.

The proposed model can be viewed as a generalisation of both the haystack model of Maynard Smith (1964) and multiplayer divide-the-dollar. When all individuals Opt In and demand $\frac{1}{n}$, the repeated formation and dissolution of groups creates an environment similar, although not exactly identical, to that of Maynard Smith's haystack model. Likewise, if

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[3] Assume, for now, that all fitnesses are nonnegative and that at least one player has a strictly positive fitness.

[4] If every player in the population has a negative score, the population goes extinct and the simulation terminates.

one fixes the group size at G and assumes that all individuals Opt In, Cooperate, and have a common productive capacity c, the dynamics of the model reduce to that of a multiplayer divide-the-dollar with a cake size of $(Gc)\kappa^{G-1}$.

3. Preliminary results

Figure 1 illustrates the outcome of one simulation begun in a state where roughly half of the population Opts Out of participating in the collective action problem. Among those who Opt In, roughly half Cooperate in the production of the collective good with the remainder choosing to Defect (i.e., not help produce). Strategies used in the multiplayer divide-the-cake are randomly assigned with all strategies equally likely. Players are restricted to demanding between 10% and 100% of the cake, in ten-percent increments. Needs are also randomly assigned, and can be any integer between 1 and 100. The group size used in this simulation is 3. The coefficient κ representing the "economies of scale" was set at 1.1.

Within 5,000 iterations, the evolutionary dynamics carry the population to a state where everyone chooses to Opt Out of the collective action problem. No significance should be attributed to the fact that, in figure 1(b), the majority of the population has the strategy of demanding 100% when playing multiplayer divide-the-dollar, as in choosing to Opt Out of the collective action problem this component of the strategy is never actually invoked.[5] The distribution of needs present in the population has also shifted dramatically from those present at the start, as shown in figure 2(b). Most of those present have a very low need.

This result can be easily explained: choosing to Opt Out is a risk-free strategy provided that one's productive capacity exceeds one's need. Choosing to Opt In is risky for a variety of reasons. First, recall that groups are initially formed by randomly partitioning the whole population, with those who choose to Opt Out leaving the group to which they are originally assigned before the collective action problem is played.[6] When this happens, some groups will have less than the maximum possible size,

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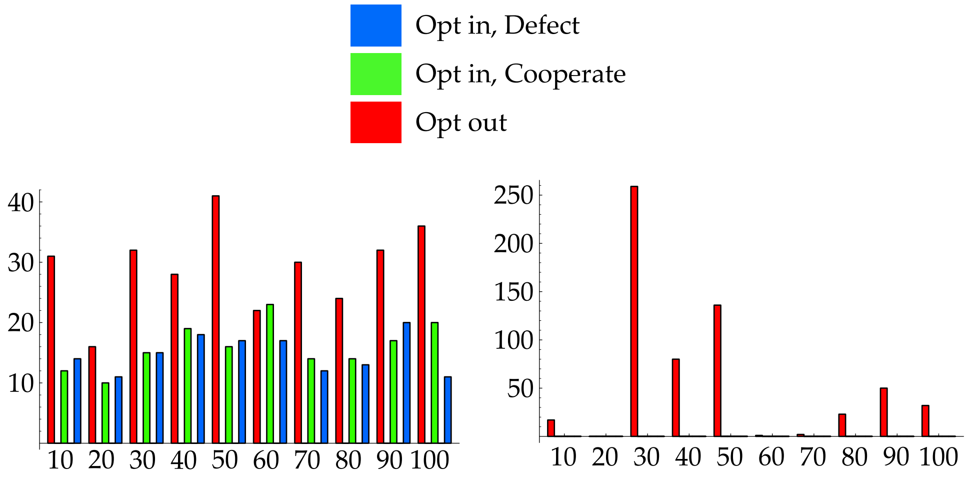
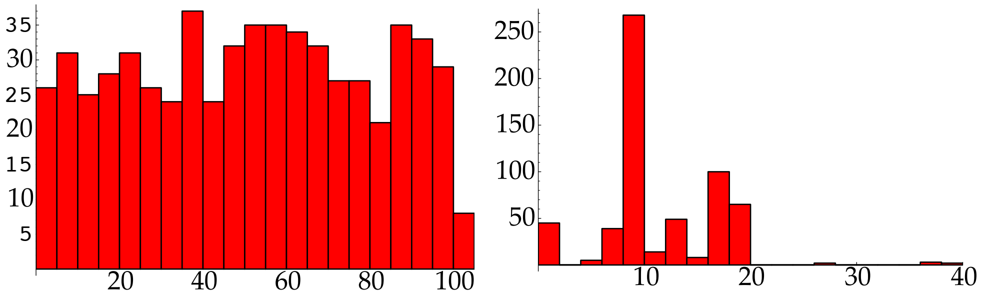
[5] The reason that the majority of the population has this strategy component is that the initial random assignment of strategies gave some individual (or individuals) who Opted Out a high productive capacity and low need, thus making it more likely that they would be chosen to replicate their strategy during the reproductive phase.

[6] One might think that this modelling assumption does not seem right. The exact dynamics of group formation are, of course, an empirical question and open to debate. Later on, we shall relax this assumption by allowing for the possibility of preferential pairing; i.e., those who choose to Opt In seek each other out and form groups, thereby allowing



(a) Initial conditions (b) 5,000 iterations later

Figure 1: Modified Moran process run on a population of 600 individuals.



(a) Initial conditions (b) 2,000 iterations later

Figure 2: Distribution of needs for the simulation of figure 1.

thereby eliminating the possible benefits than can be generated through the economies of scale. Secondly, not everyone who chooses to Opt In also Cooperates in the production of the good. Some individuals Defect from the collective action problem, contributing nothing, yet benefiting from the efforts of others. An individual who Opts In and Cooperates might therefore find himself doubly disadvantaged: if the original partitioning put him in a group with one who Opts Out and one who Opts In but Defects, the Cooperator will find the fruits of his labour significantly reduced. He produces according to his own productive capacity (with benefit due to economies of scale) but has to split this with the Defector who did not assist. Finally, there also remains the possibility of disagreement occurring during the division phase. If the Cooperator and Defector have incompatible demands for the divide-the-cake game, neither person receives anything. Given these three complicating factors, choosing to Opt In does not seem a prudent choice!

In fact, the presence of Defectors who Opt In contributes surprisingly little to the elimination of Cooperators who Opt In, as figure 3 shows. In the simulation under discussion, Defectors who Opt In go extinct by the end of the second generation. This makes sense: because Defectors contribute nothing towards the collective action problem, they depend entirely on the efforts of others to satisfy their own needs. Any group consisting of all Defectors thus results in those individuals being eliminated at the end of the generation. However, given the small size of the groups, even if a Defector is paired with Cooperators, the chances are not good that they will be paired with Cooperators who produce enough to satisfy them once the resource is divided. Keep in mind, too, that during the first few generations there is a very high chance that groups who do successfully produce resources will be unable to divide them successfully because of incompatible strategies being used during the divide-the-cake phase. Defecting, if one Opts In, is clearly not rational, so there is little surprise that it disappears so quickly.

Yet even if the initial population consists only of players who Opt Out and Cooperators who Opt In, the strategy with the greatest tendency to survive remains Out Out. Figure 4 illustrates the initial state and the final state (after 2,000 generations) for one simulation which begun with only approximately equal numbers of those two types of players present. In the first few generations, Cooperators are eliminated for one of two reasons:

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every group to have the maximum possible size. (At least to the extent this is possible. If there are 122 individuals who Opt In, and the maximum group size is 3, then 40 groups will have three members and one group will have two.)

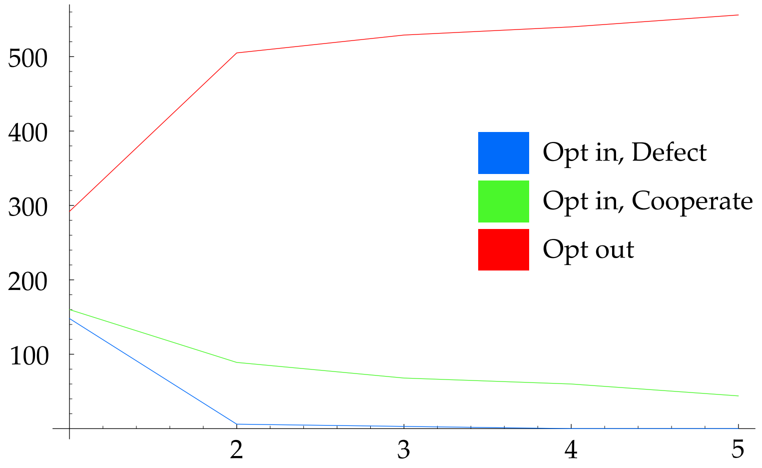
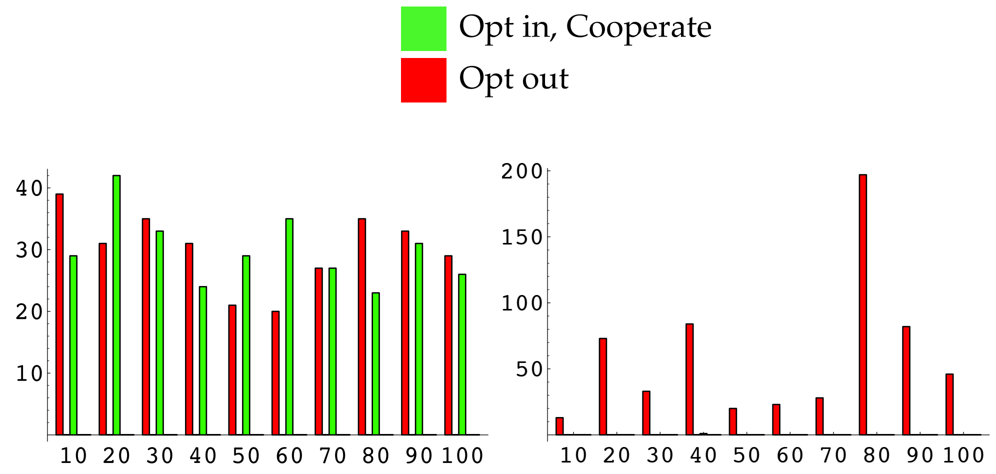


Figure 3: The first five generations of the simulation illustrated in figure 1.

either they cannot produce enough to meet their needs (even with the assistance of others), or they ask for too much during the divide-the-cake phase.

Regarding this latter point, figure 5 illustrates the evolution of the distribution of strategies used in divide-the-cake for all Cooperators who Opt In over the first 20 generations. Recall that the initial group size formed by random partitioning of the population is three. Initially, we would expect at least one individual of each group to Opt Out, meaning that the expected number of individuals who actually participate in the resource allocation problem will be two. Given this, it's not surprising that the population seems to be favouring the 60–40 split after 20 generations, with a significant number of individuals also requesting 30%. The 60–40 split provides an efficient allocation of the resource when two players play the game. Yet a substantial number of players ask for 30% because there is relatively little difference between receiving 40% of the resource and receiving 30% of the resource, and asking for 30% is good because this strategy plays well with itself when a group contains three Cooperators.

After twenty generations or so, the population has settled into a state where most Cooperators are capable of meeting their needs regardless of whom they are paired with. (After the first generation, every remaining individual who Opts Out must be capable of meeting his need, by definition.) From this point on, all individuals receive positive scores, and hence reproduction of strategies will take place via an ordinary Moran process. Figure 6 plots the reproduction probabilities for the two types of players at the end of the twentieth generation (hence, right after the simulation was



(a) Initial conditions. (b) After 2,000 generations.

Figure 4: Elimination of Cooperators who Opt In after 2,000 generations.

interrupted for the production of figure 5).[7] There we see that a player who Opts Out is roughly ten times more likely to be selected to replicate his strategy than a player who Opts In. The evolutionary pressures greatly favour Opt Out.

Some may object to the underlying dynamics regarding group formation. It may seem strange that we first partition the population into groups of the specified size, and then allow individuals who Opt Out to leave. Why would players who Opt In provisionally include such a person, only to find that they leave before the collective action problem begins?[8] A more realistic group formation dynamic, so the thought goes, would allow individuals who Opt In to be able to identify each other. Groups would then only contain individuals who Opt In, so as many groups as possible would be of the maximal size.

Figure 7 illustrates the outcome of one simulation run with preferential assortment during the group formation phase. For this particular sim-

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[7] If f_i denotes the fitness of player i, then the probability of i being chosen to replicate his strategy is $\frac{f_i}{f_1+\cdots+f_N}$. Let O_t be the set of players who Opt Out at time t. Then the probability that the individual chosen to replicate his strategy Opts Out is $\sum_{j\in O_t} \frac{f_j}{f_1+\cdots+f_N}$.

[8] An important difference between individuals who Opt Out and individuals who Defect is that Defectors give the impression that they will actually participate in the collective action problem, yet fail to do so when the moment of action arrives. Opt Outers are more honest in that they make it clear from the very beginning that they have no intention to make any contribution to the collective action problem.

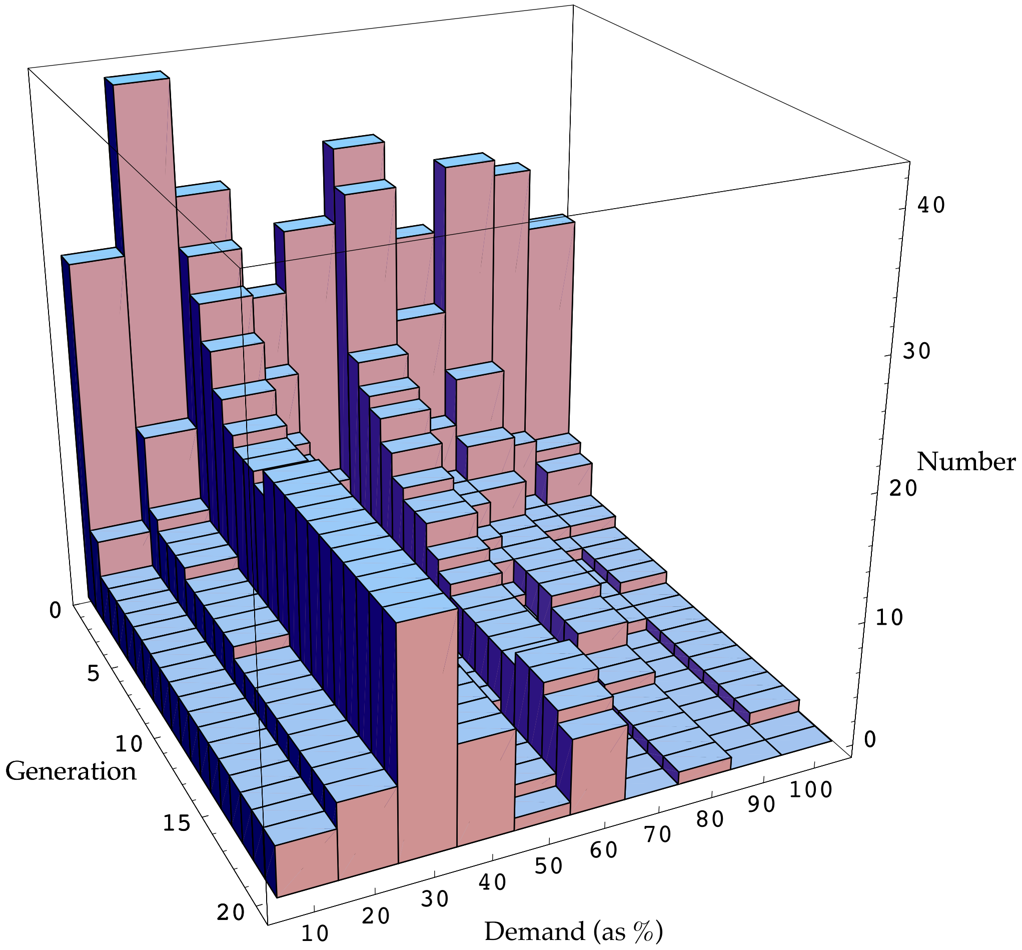


Figure 5: Time-series plot of the distribution of demands for divide-the-cake amongst Cooperators who Opt In, for the simulation shown in figure 4.

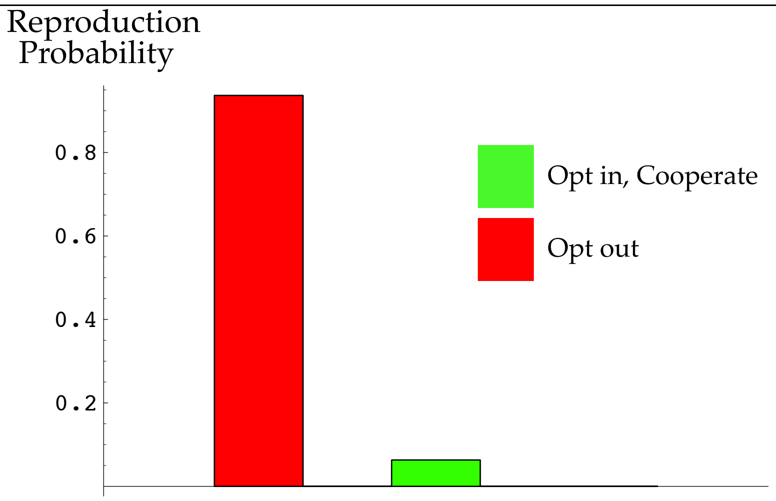
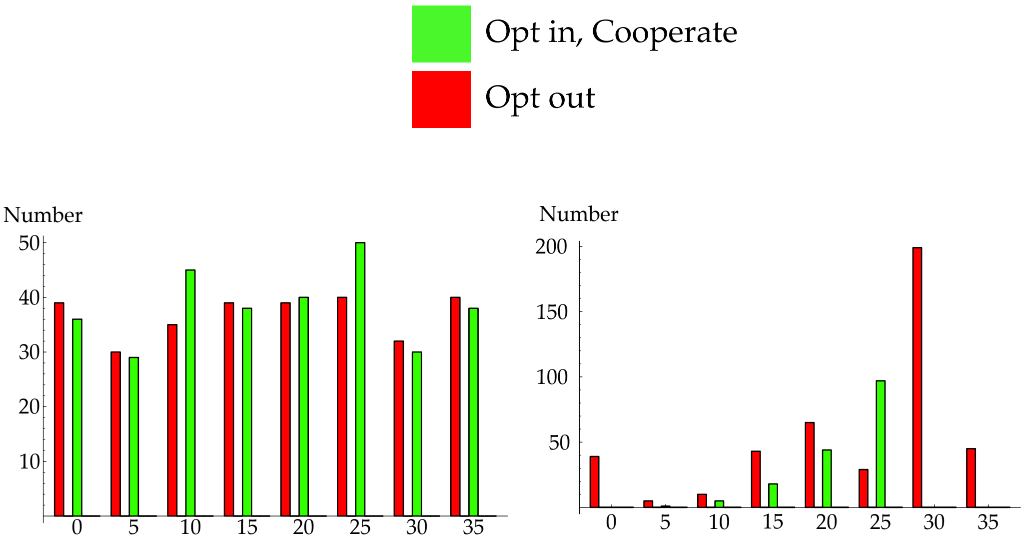


Figure 6: The probability of a player of either type being selected to replicate his strategy, twenty generations into the simulation of figure 4.

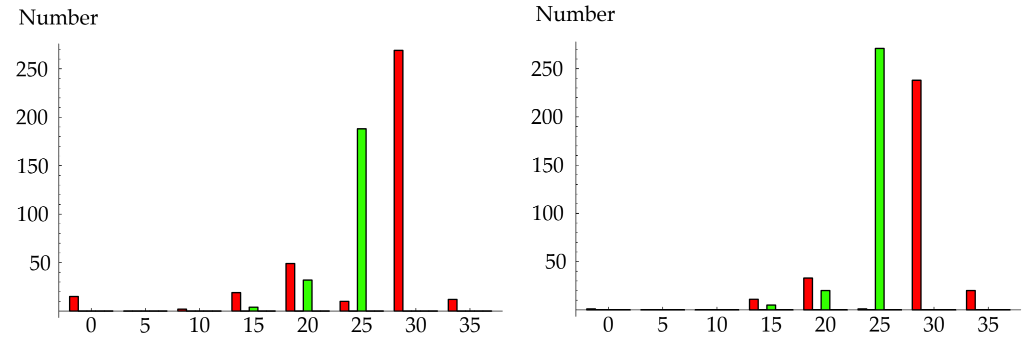
ulation, groups have a maximal size of four, the coefficient κ representing economies of scale equals 1.2, and the range of possible demands for divide-the-cake was set between 0 and 35 in increments of 5. As one can see, allowing for preferential assortment provides Cooperators who Opt In the opportunity to leverage the benefit of economies of scale. Over 6,000 generations, Cooperators were found to dominate the population and, in this particular trial, eventually drove all competitors to extinction. In addition, note that individuals arrived at the Pareto-efficient solution to multiplayer divide-the-cake played among four people.

Although one might think that increasing the maximal group size with preferential assortment stacks the deck in favour of Cooperators, because of the increased amount of resources produced in the collective action problem, this is not true. While increasing the group size *does* enable a group of Cooperators to produce more in the collective action problem, it also serves to increase the chance that a group will fail to agree on how to allocate the resources produced during the divide-the-cake phase. Failing to reach agreement on the division of resources is just as lethal to group members as failing to produce enough resources in the first place. This was sole reason for restricting the range of possible demands in the divide-the-cake game to the interval $[0, 35]$. When we used the original range of possible demands (0 to 100 in increments of 10), Cooperation went extinct very quickly — even with preferential assortment — simply because groups failed to reach agreement on the division of the resource.



(a) Initial configuration.

(b) 2,000 generations.



(c) 4,000 generations.

(d) 6,000 generations.

Figure 7: The bargaining model with preferential assortment, a group size of 4, and $\kappa = 1.2$.

4. Taking needs into account

Thus far, nothing in the model explicitly addresses the evolution of concern for the needs of others because no part of a player's strategy is conditional upon a player's need. In this section we expand the set of strategies to take this into account; the dynamics will, of necessity, become a little more complicated. To begin, each agent's strategy now consists of four parts:

1. Whether a player Opts Out of the collective action problem.
2. If the player Opts In, whether he Cooperates or Defects in the collective action problem.
3. Whether the player is inclined to "respect the needs" of others.
4. The player's demand (expressed as a percentage of the cake) for the game of multiplayer divide-the-dollar.

A concern for needs appears as the third component of a player's strategy, and takes a simple boolean value. If this component has the value `True`, then the player is the kind of person who approaches the resource allocation problem with some concern for the needs of others. If this component has the value `False`, then the player does not have any concern for the needs of other.

One natural objection needs to be addressed straight away: one might say that this simply builds "respect for needs" into the very nature of the model, and hence begs the question. This is false. Firstly, evolutionary models, by their very nature, only address the fitness effects of certain forms of behaviour. In attempting to explain the origin of respect for the needs of others, we must first reduce talk of "respect for the needs of others" to talk of behaviour. Thus, when we incorporate an inclination to "respect the needs of others" as the third component of a player's strategy, all this refers to is a player's inclination to engage in a certain form of behaviour. Secondly, in attempting to model a relatively complicated problem like the one under investigation, it is important to realise that the logical space of *possible* behaviours (or strategies) is far greater than that which can be actually modelled. Construction of a model, then, involves identifying a subset of behaviours as the ones of interest, and specifying how those behaviours (or strategies) interact dynamically. The behaviour which corresponds to "respecting the needs of others", in the sense to be defined below, is a logically possible behaviour, and hence is a candidate for inclusion or exclusion in an evolutionary model. There are, no doubt, other ways of incorporating respect for the needs of others into a bargaining model, but this seems a reasonable first approximation.

It is important to realise that modelling respect for the needs of others, in this way, makes *no claim whatsoever* about the underlying psychological states or motivational structure that gives rise to such behaviour, except that whatever psychological states or motivational structure exists for the agent does not preclude behaving in this way. One may well want an explanation for how we come to develop *concern* for the needs of others, or *respect* (in the emotional sense) for the needs of others. Asking for such an explanation is certainly warranted, but this amounts to asking for an evolutionary explanation of our psychological states — a very difficult, and different, task.

That said, respect for needs is taken into account during the round of multiplayer divide-the-cake as follows: If a group contains a single player who Respects Needs, the dynamics of resource allocation proceeds differently. Let C denote the amount of cake produced by the group, k the group size, and m the number of group members who respect needs. Finally, let N be the sum of all needs of individuals in the group.

What happens when some members of the group respect needs? In this case, each person receives a fraction of their need, where the fraction is determined by (1) the proportion of group members who respect needs, and (2) the total amount of resource available. Let $\langle n_1, \ldots, n_k \rangle$ denote the needs of all members of the group under consideration. If $\frac{m}{k}N \leq C$, the amount awarded to each is $\frac{m}{k} \cdot n_i$, for each player i. This is in the spirit of the Kalai-Smorodinsky solution to the bargaining problem: if $\langle n_1, \ldots, n_k \rangle$ represents the "utopia point" of needs satisfaction, then the outcome when only some members respect needs corresponds to drawing a line from the origin to the utopia point, dividing this line into k segments, and awarding the amount conferred by taking m steps along this line. Once this amount has been awarded, multiplayer divide-the-cake is played to divide the remainder. In the limiting case where all members of the group respect needs, each group member receives what he needs before individuals divvy up the remainder of the good.

If $\frac{m}{k}N > C$, then not enough resources were produced during the collective action phase to handle all of the group's needs. In this case, the members do as well as they can, meaning that each person receives $n_i \frac{C}{N}$. Strictly speaking, it does not matter how we divide the cake in this instance since our modified Moran dynamics eliminates all people with negative scores, and in this case every individual in the group will have a negative score at the end of this round of play.

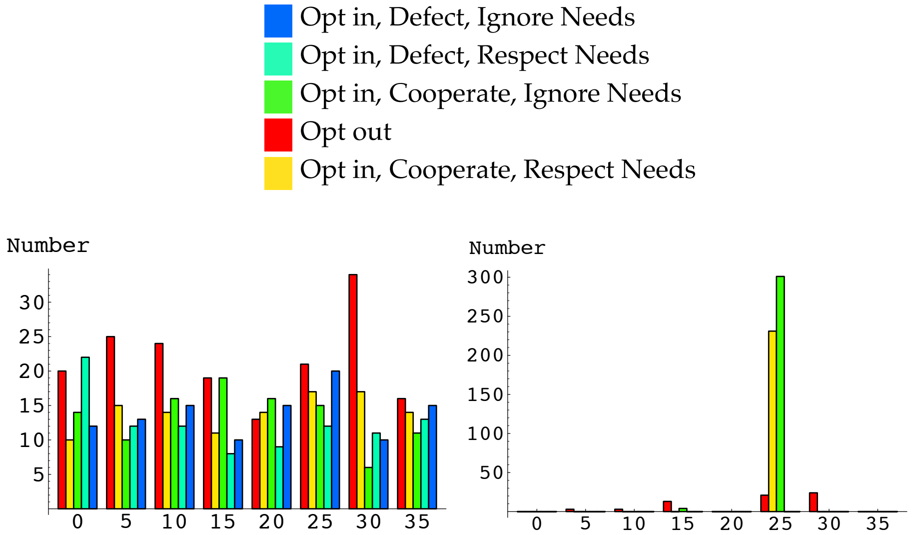


Figure 8: The survival of individuals who show respect for needs.

Figure 8 illustrates the outcome of one simulation which incorporates individuals showing a concern for the needs of others.[9] After 5,000 generations, one can see that not only do almost all surviving members Opt In and Cooperate, but of those who do, nearly half choose to respect the needs of others. It is also worth noting that there was convergence to the equal split of the resource after needs were (partially) taken into account. Once convergence to a mixed population state of Opt In, Cooperate, and (some) Respect for Needs occurs, this state will persist until random fluctuations of the Moran process eventually drive one strategy to extinction.

In some instances, showing respect for needs violates modular rationality (see Skyrms, 1996). An individual with a low need who also Opts In and Cooperates does not have, from considerations of pure fitness, an overwhelming reason for Respecting Needs. Such an individual will, quite likely, be capable of satisfying his needs solely through the normal process of resource production and allocation.

Are there conditions under which evolution will lead to universal respect for needs? Suppose, for the sake of argument, that needs are correlated with one's productive capacity, so that the more productive a person is, the more likely it is that they have a greater need. Figure 9 plots a

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[9] Initially, 30% of the population Opts Out with the remainder Opting In. Half of those who Opt In choose to Cooperate, and half of those who Opt In show respect for the needs of others. The distribution of demands for the multiplayer divide-the-cake were uniformly distributed between 0 and 35% in 5% increments. The maximal group size was 4 with a κ value of 1.2.

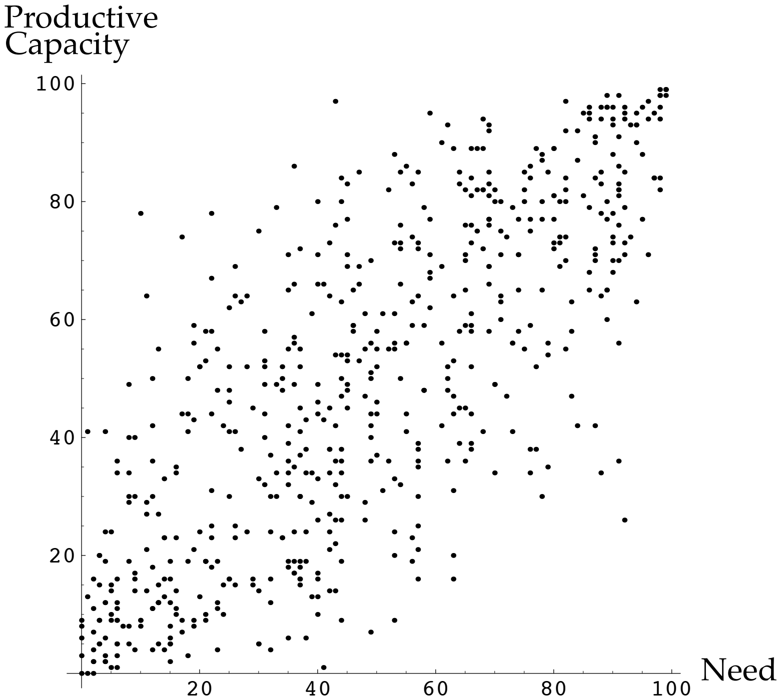
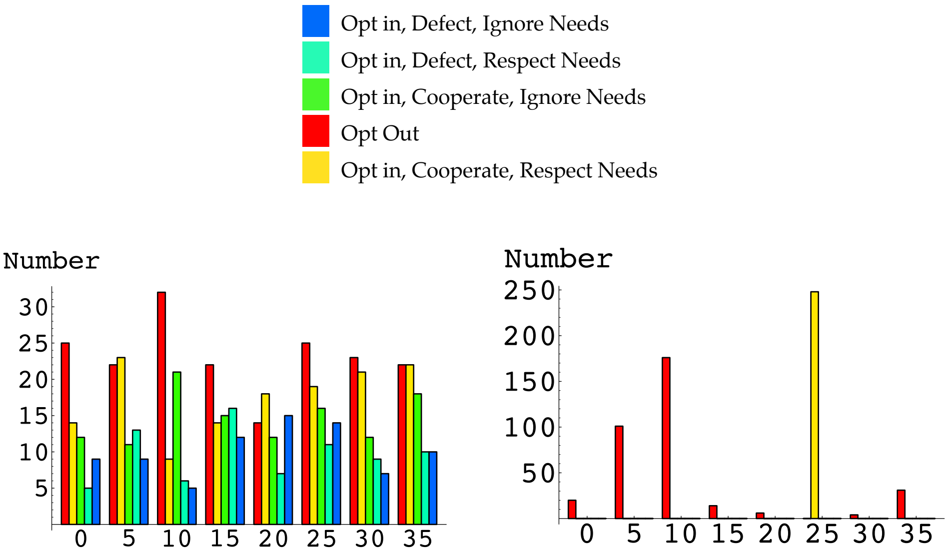


Figure 9: The correlation of needs with productive capacity.

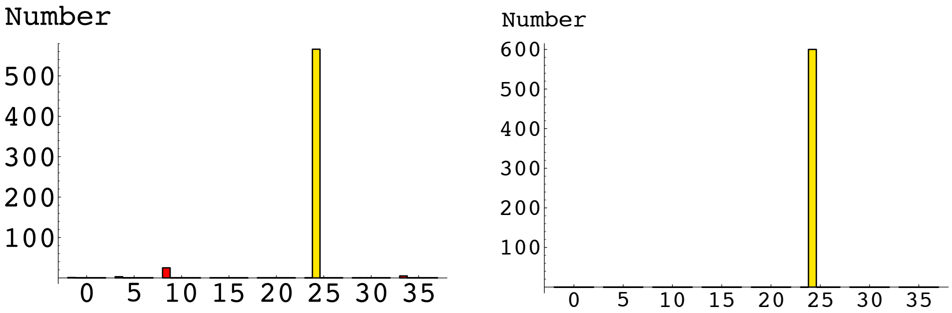
distribution of needs and productive capacities over a population of 600 individuals, with a correlation coefficient of 0.8. Looking at such a plot, it's not immediately clear what allowing for such correlation would encourage: although more needy individuals tend to produce more, they also consume more during the pre-bargaining phase when resources are distributed according to needs.

Figure 10 illustrates the outcome of one simulation initialised using the following conditions: approximately 30% of the population chooses to Opt Out of the collective action problem. Among those who Opt In, the other strategy components are distributed with 60% Cooperate, 50% Respect Needs, and the demands for multiplayer divide-the-cake uniformly distributed between 0 and 35% of the cake. The Need and Production Capacity of the players was initialised with the two having a correlation coefficient of 0.8. The maximum size of the groups was 4 with $\kappa = 1.2$. From such an initial state, individuals who Respect Needs have a significant presence after 4,000 generations. Within 12,000 generations, they have driven all other strategies to extinction.



(a) Initial configuration

(b) 4,000 generations



(c) 8,000 generations

(d) 12,000 generations

Figure 10: The evolution of respect for needs.

It is important to note that these simulation results do not hold all the time. Given the random nature of the Moran process, and the fact that so many individuals die off in the first few generations (where much mismatching occurs in the various phases of the game), Opt Out does tend to be the most frequently occurring outcome. Yet, even so, it is still noteworthy that evolution is not completely opposed to establishing concern for the needs of others. Indeed, at times evolution even supports the Marxist principle of "from each according to his ability, to each according to his need."

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