Why is there Civilization? Game Theory has the answers.

Introduction

The success of the tit-for-tat strategy (and other "nice strategies") in Axelrod tournaments has been used to explain the evolution of cooperation. Anthropologists and social scientists have taken this a step further to explain how tribal societies first emerged from hunter-gathering communities. However, if cooperation is such a naturally stable state, why then do we have so many mechanisms to impose order and discipline in society? What purpose do these mechanisms fulfill? Or put otherwise, why did these tribal societies ultimately develop into coercive state polities?

This paper presents agent-based-model simulations to evaluate internally emergent norms (i.e. tit-for-tat, social norms) vs. externally imposed norms (i.e. government, law) to determine if there is a difference in their functionality. Is one of the two more effective in establishing cooperative behavior, or at least more effective in eliminating the "free-rider" problem? Additionally, we will explore how heterogenous population react to both types of enforcement, as well as if there is a difference within the context of the three main social dilemmas: Prisoner's Dilemma, Stag Hunt and Snowdrift games.

The discussion regarding human cooperation can be reduced to an argument over the very nature of humanity: is man, at heart, decent, kind, empathetic, or is he a competitive, self-interested boor? These competing models are attributed to the alternating philosophies argued by Enlightenment luminaries, Hobbes and Rousseau. In his *Leviathan*, Hobbes put forward his vision of mankind as brutish beasts. Man, without the civilizing force of government, is doomed to violence, struggle and strife. Unhappy with this unpleasant lifestyle, man decided to turn to his fellow man and establish a social contract, creating order and rules to stave off the violence and deceit. Thus, is born the state. Cooperation, according to Hobbes, is solely the result of this agreement with the state, where mankind gives over personal freedoms in return for protection and civil order.

In contrast, Rousseau believes that man is inherently good natured and if left to his own devices, would frolic happily in a state of kindness and cooperation. However, with all this brotherhood and cooperation came the amassment of wealth. Naturally, order was required to maintain this wealth, which ultimately resulted in the creation of civilization and the law. Sadly, with the creation of the state, man was corrupted and forgot his "natural" disposition in favor of one focused on accumulating more goods and power. It is only the result of the corrupting influence of civilization that man has forgotten his nature and has become competitive and deceitful.

The Hobbesian model resulted in the typology of *homo economicus* – a cutthroat, rational man who will always act in his own base self-interest. *Homo economicus* became the underlying actor in much economic theory of the 19th and 20th century and was further entrenched with early Game Theory principles, which demonstrated that often the rational and superior strategies were those that betrayed one's fellows for one's own benefit.

However, this conception of humans as *homo economicus* could be considered a relatively modern conception of mankind. Fukuyama in his [book] quite simply points out that both Hobbes and Rousseau are incorrect in their assessment of human nature. Drawing on more recent anthropological and biological studies, specifically in the behavior of primates, Fukuyama points out that humans, or more specifically as a subspecies of the larger family of primates, is naturally cooperative. Although many studies have explored cooperation among different species, primates clearly display high levels of cooperation, social cohesion and prosocial behaviors, such as grooming. Primates operate in bands of

12-20 individuals, usually within kin groups, and have high levels of intragroup cooperation, while exhibiting intergroup aggression. A strong social hierarchy is present in many primate groups, especially among our closest cousins, the chimpanzee.

Humans and chimpanzees last shared a common relative over 6 million years ago, but it can be assumed that this relative was also highly social and lived in similar social kin-groups. Thus, as the branch of primates that eventually would become *homo sapiens* broke off form this this common ancestor, it was already a highly cooperative being. Although not limited to *homo sapiens*, two cooperative behaviors are predominant among the species: strong kinship ties and reciprocal altruism. With kin relationships, the degree to which one is willing to cooperate with another is directly related to the amount of DNA that they share – the more related people are, the more likely they will cooperate. Additionally, humans will cooperate with others with whom they have cooperated in the past, i.e. have established trusting relationships. With these two characteristics in mind, we reject *homo economicus* and turn to a more accurate term for humans, *homo reciprocans*, which emphasizes man's cooperative nature and willingness to extend trust to others as long as they reciprocate.

Up until x, years ago, humans continued to live as their ancestors did, in small kin-based hunter gatherer groups. The archeological record indicates that at this time, these groups banded together to form the first tribes and chiefdoms. Tribes that practice non-coercive states continue to exist today and are studied by anthropologists with the assumption that the early tribal structures were similar in function and form.

Tribes are led by elected leaders and leadership is always contingent on the will of the people, i.e. the chief's authority is not coercive. Chiefs are usually chosen for their reputations as successful mediators in disputes, rather than their military prowess. They are also known for their oratory skills, and as their authority is bestowed by the community, must constantly sway local opinion in their favor. The chief usually does not make unilateral decisions but must consult with the tribe to determine appropriate action. Decisions, therefore, are reached by consensus and not by coercion. It should be noted that being chief is not necessarily a stable position - many chiefs must constantly be wary of losing their sway within the community in favor of someone else.

Social cohesion is kept in balance with a mix of social norms, customs, rituals and taboos. These conventions ensure that everyone living within the community cooperates with one another and those that do not are subjected to communal shunning. Cooperation is also encouraged with shared rituals, usually connected to shared ancestry and religion. The enforcement of these norms and rituals are entirely community based, with no outright force from the tribe leader.

Beginning 5,000 year ago, however, the story changes with the rise of coercive states headed by autocratic rulers. These states first cropped up in Mesopotamia, but also developed in South America, China, and India. These states are categorized by high levels of social inequality and use of coercive force by the state to maintain order and collect resources. 4,500 years later Hobbes and Rousseau would argue over the nature of man and the state, without realizing that other forms of leadership and cohesion had been mankind's organizing principle for tens of thousands of years.

Tribes are extremely stable forms of government. In fact, several studies[sources] have proven how social norms and rituals are utilized by the tribe to keep in check those ambitious leaders who wish to hoard control and resources. In such scenarios, the rituals and norms act as a natural defense, removing such threats and maintaining communal stability. We are left with the question: Why did humans give up this egalitarian form of leadership and accept a coercive, unequal state?

[segue]

Game Theory (GT) aims to establish the best and rational course of action given another, rational actor's behavior. Therefore, the games used by game theorists are not inherently valuable but are merely constructs for exploring these rational strategies. The first breakthrough in GT came with Von Neumann's creation of the minimax strategy, which posits that where you are competing for the same resource (also known as a zero-sum-game), the best thing you can do is minimize the maximum payoff for your opponent. As an example, we put forward the cake cutting game:

Cake Cutting Game

Two siblings are arguing over a piece of cake. Their mother, wary of hearing yells of "their piece is bigger than mine" offers the following solution: one child will cut the cake, and the other will get to select who receives which piece.

The first child must determine how to divide the cake. Knowing that her sibling will choose the larger of the two pieces, the first child aims to minimize the size of this "larger" piece, thus ending up with roughly two equal pieces. [diagram]

Von Neumann's minimax strategy worked very well on zero-sum-games, but was less helpful for non-zero-sum games. Nash equilibrium, developed a few years later by Nash, presented a solution to these types of games. A Nash equilibrium is the best course of action to take, given another person's strategy. Or put otherwise, if you were to know how another person were to act, would you change your course of action? If the answer is no, this action is a Nash equilibrium.

The quintessential example of a Nash equilibrium is demonstrated in the Prisoner's Dilemma (PD). Although almost synonymous with GT, the game was not actually developed by either of the two leaders of the field, Nash or Von Neumann, but by [Miles and Moody??] in [date]. In fact, the first presentation of the game was not with prisoners at all, but was later added to provide more drama.

Prisoner's Dilemma

Two criminals are captured by the police and kept in custody. Each prisoner is offered the same deal: stay quiet and receive a sentence for 3 months in jail, or inform on your comrade who will receive a maximum term in jail of 10 months, but you get to walk out free. However, if both prisoners implicate each other, they will split the difference, and both receive 5 months in jail.

Essentially, each prisoner has two options: stay quiet (cooperate) or snitch (defect). At first glance, it appears that the best course of action would be for both to cooperate and receive the minimum term (3 months) in jail. However, the Nash equilibrium for this game is for both to defect. To determine the Nash equilibrium, the first prisoner must put himself in the shoes of his comrade. If his partner stays quiet, then the best course of action would be to defect as it would mean no jail time. Alternatively, if his comrade is already planning on betrayal, then it also makes sense to defect as it will result in less jail time. Thus, defection is the best course of action regardless of whatever strategy his partner will take.

This tension between what ultimately is the best outcome for both players and base-self-interest has led to the PD becoming one of the most studied and popular games in GT. There are two other games that also highlight this tension that we will explore.

The Stag Hunt

Two hunters set out to collect their daily catch. It takes two hunters to bring in big game, the stag. If they both set out to catch the stag, they will both go home very happy. However, it is much easier to catch smaller game, like hares, which each hunter can do on her own. The

hunters therefore must decide whether to trust that the other hunter will come ready to hunt stag, or to take the safer route and just hunt for a hare alone.

Unlike the PD there are two Nash equilibrium for this game. If each hunter knows that other will hunt stag, then they too will choose to hunt the stag. However, if each hunter knows that the other will choose to hunt the hare, then they too will switch to hunting the easier catch, since if they went out to hunt stag and their partner showed up hunting hare, they would go home empty handed. Like the PD the choice that is socially optimal, that both cooperate with each other and hunt stag is not necessarily the best strategy.

The Snowdrift

After a big snow storm two neighbors eye each other over who will shovel the shared path. Obviously, both would prefer if the walkway is shoveled, but it takes a tremendous amount of effort to do so. If the walkway is not shoveled it will remain dangerous and someone might even get hurt. The question is, who will crack first and shovel the snow.

Also known as the Hawk-Dove game and the game of Chicken, this game has two Nash equilibrium. If one neighbor knows that the other will shovel the snow, then obviously they will sit back and relax. However, this Nash equilibrium is not very satisfying, and neither of them are socially optimal where both cooperate and shovel the walkway together.

Collectively, these games are referred to as social dilemmas. It is important to note that the specifics of the game are meaningless (as should be clear with the numerous names given to the Snowdrift game), as are the exact amounts of each payoff for a certain strategy (10 months in jail vs. 3 months, etc.). What is important is the preference of the four payoff elements: The Reward (R) for cooperating, the Punishment (P) for both defecting, the Temptation (T) for betraying your fellow, and the Sucker payoff (S) for being betrayed.

Prisoner's Dilemma	T > R > P > S
Stag Hunt	R > T = P > S
Snowdrift	T > R = S > P

One of the most counter-intuitive component of these social dilemmas, and especially for PD, is that the rational strategy is not necessarily aligned with the optimal outcome. Both prisoners get a smaller sentence if they both cooperate, but as they are reduced to acting out of selfish-interest resulting in a worse payoff. On further inspection, though, this makes a bit more sense when one considers that these games all last only one-round. If the hunter knows he will never work again with the other hunter, he will probably opt for the easiest and safest option. However, if he knows that they may hunt again, he may be more inclined to try for the stag. Similarly, the prisoner knows that if he ever wants to pull another heist with his partner he may want to keep quiet. On the other hand, if he'll never see this person again, why not defect?

It stands to reason, then, that the best strategy for a one-round game, is not the best strategy for repeated rounds. This was further explored in the now famous Axelrod tournaments. In 1984[?], Axelrod hosted a tournament that would pit different computer simulated strategies against each other in a repeated PD game. Axelrod asked game theorists to submit the strategy they think would work best in a repeated game, for example, a strategy that always cooperated every round, or cooperated on every

other round. The strategy that won the most points in the competition was called Tit-for-Tat (TFT). This strategy cooperated on the first round, and then copied the behavior of its opponent. If its opponent cooperated in one round, then the TFT strategy would cooperate on the next round; if its opponent defected, then in the subsequent round TFT would defect.

In subsequent tournaments run by Axelrod, TFT continued its dominance as the most successful strategy. Other strategies emerged as successful; the common thread was that these strategies were: nice (chose cooperate first), generous (waited before retaliating), blah and blah. The success of TFT and these other nice strategies was the clear indication that cooperation could naturally emerge and overcome selfish strategies.

Another exploration into repeated games resulted in the emergence of cooperative behavior, albeit in a different form. May in [article] explored the PD on a grid of cells, with each cell interacting with its neighbors. At the beginning of the simulation, the grid is randomly populated with cells that either will play a "cooperate with everyone" strategy, or a "defect with everyone" strategy. Each cell then plays PD round with each of its neighbors. At the end of each round, the cell "evaluates" how it did in relation to its cell mates. The cell then "chooses" the strategy of the most successful neighbor. If this neighbor defected in the last round, then the cell chooses this strategy for the next round, and vice versa. The cells then all proceed to the next round and play the game again, followed by a round of evaluating the best strategy. Called the Spatial, Geographic or Demographic Prisoner's Dilemma, the eventual outcome of this game is that the grid is dominated by cooperators. However, a small pocket of defectors can continue to exist within the grid as they are able to "free-ride" by preying off the cooperators in return for temptation payoffs.

One of the solutions to the free-rider problem is to establish governments that can compel people to cooperate. However, an equally strong force are social norms. A classic free-rider example is a subway turnstile-jumper who relies on fare-paying commuters to finance his transportation. The subway will proceed regardless so what's the harm in jumping the turnstile? On the other hand, if everyone thought this way then the entire transportation authority would go bankrupt and cease to operate. Government can step in and monitor turnstile-jumpers and dole out fines accordingly. Alternatively, fellow subway-commuters can shame turnstile-jumpers, discouraging this behavior. Society can also instill in its members while still youths a sense of wrongness in jumping the turnstile. This sense of right and wrong will then be internalized by its members who will choose to pay their share out a of sense of morality or "what is right." Taking this a bit further, religious leaders can point to a deity who will punish turnstile-jumpers for their non-cooperative behavior, and religious followers will avoid this behavior to please their god. All of these non-governmental forms of solving the free-rider problem can be described as social norms and have also been explored through Game Theory.

Following up on his success with his tournaments, Axelrod went on to simulate how norms can quickly develop within a population by adding another phase to the PD. After playing each round, players can choose to punish those players that defected. By adding a punishment round, the rate of cooperation in subsequent rounds dramatically increases. Similarly, exploration by Hauert on a spatial grid indicated that adding a punishment dramatically decreased the free-rider rate. However, like Axelrod's simulations, there still remains a population willing defect primarily because of a problem known as the second-degree collective action problem. It is costly to punish a person and so, if you can depend on your neighbors to enforce the punishment, wouldn't it be better if you just let them take care of it? What emerges is another round of the free-rider problem where people are relying on their peers to enact the punishment.

The second-degree collective action problem completely disappears if you add another phase to the game where players will punish those who they noticed did not punish defectors. Called meta-norm games these games completely reduce the temptation for free-riding, both in the initial phase and in the punishment phase. These meta-games explain why social norms can be so entrenched in society and often members will ostracize others for being associated with a non-conformist. Although sinister in some applications, it is also the underpinning of the egalitarian tribal communities, where authority is non-coercive and community cooperation is at its highest.

We return to our initial question – if social norms are so stable and cohesive, why did community members decide to give up their freedom in favor of state-controlled governments? The free-rider problem is not sufficient an explanation as we have shown that social norms are quite effective in eliminating this problem. Therefore, there must be some other reason why social cohesion failed and coercive governments developed.

One theory posits that with the advent of agriculture, population sizes grew dramatically, as did population density. Social norms and tribal structures rely on shared ancestry for community cohesion and with the growing population size this is no longer possible. As humans multiplied and the relationships between neighbors frayed from family to strangers, cooperation began to breakdown. As a result, a state stepped in to force cooperation between members.

A related theory points to tension between ethnic groups as the cause of the rise of states. Tribes have very strong intra-group cohesion, but this is primarily a response to inter-group conflict. Inter-tribe warfare is quite common and can also be a tool used to promote bonding within a tribe. According to this theory, one tribe conquered another waring tribe. The defeated tribe was relegated to lower status, creating an ethnic division and increased resentment. In addition, as the two communities followed different social norms, they were not motivated to cooperate with one another. In fact, they specifically cooperated only with their own group and defected with members of the other tribe. Therefore, a state had to be set up to force cooperation between two ethnic groups who refused to cooperate with each other.

A third theory, called the irrigation theory, believes that it is no coincidence that the development of states coincided with the advent of agriculture. The theory claims that the state came into being in order to oversee large-scale projects, such as the digging of irrigation ditches, which could not have otherwise been orchestrated on a tribal level.

Lastly, the containment theory claims that states came into being through forcefully imposing a ruler on a trapped population that could not escape due to geographic boundaries. This theory explains why states cropped up in Egypt and Mesopotamia which were surrounded by deserts or mountains but not in Papua New Guinea where chiefdoms continue to this day.

Anthropologists, economists, philosophers and archaeologists have all thrown in their hats into this fight. We will now throw game theory in as well and see if through simulations we may see any patterns that emerge that might support one of the theories mentioned above. While it is out of scope to explore simulations of all these theories, we will focus on the first two: population size as a factor and population ethnicity. Game theory has already been used to explore how ethnic groups can quite easily become segregated and non-cooperative [source]. We will expand upon these models and determine if by adding an authority figure into spatial games, we can increase inter-ethnic cooperation.