Prisoner's dilemma

Captured 5/3/13

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The **prisoner's dilemma** is a canonical example of a game analyzed in game theory that shows why two individuals might not cooperate, even if it appears that it is in their best interests to do so. It was originally framed by Merrill Flood and Melvin Dresher working at RAND in 1950. Albert W. Tucker formalized the game with prison sentence rewards and gave it the name "prisoner's dilemma" (Poundstone, 1992), presenting it as follows:

> Two members of a criminal gang are arrested and imprisoned. Each prisoner is in solitary confinement with no means of speaking to or exchanging messages with the other. The police admit they don't have enough evidence to convict the pair on the principal charge. They plan to sentence both to a year in prison on a lesser charge. Simultaneously, the police offer each prisoner a Faustian bargain. If he testifies against his partner, he will go free while the partner will get three years in prison on the main charge. Oh, yes, there is a catch ... If *both* prisoners testify against each other, both will be sentenced to two years in jail.

In this classic version of the game, collaboration is dominated by betrayal; if the other prisoner chooses to stay silent, then betraying them gives a better reward (no sentence instead of one year), and if the other prisoner chooses to betray then betraying them also gives a better reward (two years instead of three). Because betrayal always rewards more than cooperation, rational self-interested prisoners would betray their counterparts, and the only possible outcome for two rational self-interested prisoners is for them to betray each other. The interesting part of this result is that pursuing individual reward logically leads the prisoners to both betray, but they would get a better reward if they both cooperated. In reality, humans display a systematic bias towards cooperative behavior in this and similar games, much more so than predicted by simple models of "rational" self-interested action.[1][2][3][4]

There is also an extended "iterative" version of the game, where the classic game is played over and over between the same prisoners, and consequently, both prisoners continuously have an opportunity to penalize the other for previous decisions. If the number of times the game will be played is known to the players, the finite aspect of the game means that (by backward induction) the two prisoners will betray each other repeatedly. Game theory does not claim, however, that *real human players* will actually betray each other continuously. In an infinite or unknown length game there is no fixed optimum strategy, and Prisoner's Dilemma tournaments have been held to compete and test algorithms.

In casual usage, the label "prisoner's dilemma" may be applied to situations not strictly matching the formal criteria of the classic or iterative games: for instance, those in which two entities could gain important benefits from cooperating or suffer from the failure to do so, but find it merely difficult or expensive, not necessarily impossible, to coordinate their activities to achieve cooperation.

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The normal game is shown below:

	Prisoner B stays silent (*cooperates*)	**Prisoner B betrays (*defects*)**
Prisoner A stays silent (*cooperates*)	Each serves 1 year	Prisoner A: 3 years Prisoner B: goes free
Prisoner A betrays (*defects*)	Prisoner A: goes free Prisoner B: 3 years	Each serves 2 years

Here, regardless of what the other decides, each prisoner gets a higher pay-off by betraying the other. For example, Prisoner A can (according to the payoffs above) state that no matter what prisoner B chooses, prisoner A is better off 'ratting him out' (defecting) than staying silent (cooperating).

In traditional game theory, some very restrictive assumptions on prisoner behaviour are made. It is assumed that both understand the nature of the game, and that despite being members of the same gang, they have no loyalty to each other and will have no opportunity for retribution or reward outside the game. Most importantly, a very narrow interpretation of "rationality" is applied in defining the decision-making strategies of the prisoners. Given these conditions and the payoffs above, prisoner A will betray prisoner B. The game is symmetric, so Prisoner B should act the same way. Since both "rationally" decide to defect, each receives a lower reward than if both were to stay quiet. Traditional game theory results in both players being worse off than if each chose to lessen the sentence of his accomplice at the cost of spending more time in jail himself.

Generalized form

The structure of the traditional Prisoners' Dilemma can be generalized from its original prisoner setting. Suppose that the two players are represented by the colors, red and blue, and that each player chooses to either "Cooperate" or "Defect".

If both players cooperate, they both receive the *reward*, *R*, for cooperating. If Blue defects while Red cooperates, then Blue receives the *temptation*, *T* payoff while Red receives the "sucker's", *S,* payoff. Similarly, if Blue cooperates while Red defects, then Blue receives the sucker's payoff *S* while Red receives the temptation payoff T. If both players defect, they both receive the punishment payoff P.

This can be expressed in normal form:

Canonical PD payoff matrix

	Cooperate	**Defect**
Cooperate	R, R	S, T
Defect	T, S	P, P

and to be a prisoner's dilemma game in the strong sense, the following condition must hold for the payoffs:

$T > R > P > S$

The payoff relationship $R > P$ implies that mutual cooperation is superior to mutual defection, while the payoff relationships $T > R$ and $P > S$ imply that defection is the dominant strategy for both agents. That is, mutual defection is the only strong Nash equilibrium in the game (i.e., the only outcome from which each player could only do worse by unilaterally changing strategy). The dilemma then is that mutual cooperation yields a better outcome than mutual defection but it is not the rational outcome because the choice to cooperate, at the individual level, is not rational from a self-interested point of view.

The iterated prisoners' dilemma

If two players play prisoners' dilemma more than once in succession and they remember previous actions of their opponent and change their strategy accordingly, the game is called iterated prisoners' dilemma.

In addition to the general form above, the iterative version also requires that $2R > T + S$, to prevent alternating cooperation and defection giving a greater reward than mutual cooperation.

The iterated prisoners' dilemma game is fundamental to certain theories of human cooperation and trust. On the assumption that the game can model transactions between two people requiring trust, cooperative behaviour in populations may be modeled by a multi-player, iterated, version of the game. It has, consequently, fascinated many scholars over the years. In 1975, Grofman and Pool estimated the count of scholarly articles devoted to it at over 2,000. The iterated prisoners' dilemma has also been referred to as the "Peace-War game".[5]

If the game is played exactly N times and both players know this, then it is always game theoretically optimal to defect in all rounds. The only possible Nash equilibrium is to always defect. The proof is inductive: one might as well defect on the last turn, since the opponent will not have a chance to punish the player. Therefore, both will defect on the last turn. Thus, the player might as well defect on the second-to-last turn, since the opponent will defect on the last no matter what is done, and so on. The same applies if the game length is unknown but has a known upper limit.

Unlike the standard prisoners' dilemma, in the iterated prisoners' dilemma the defection strategy is counter-intuitive and fails badly to predict the behavior of human players. Within standard economic theory, though, this is the only correct answer. The superrational strategy in the iterated prisoners' dilemma with fixed N is to cooperate against a superrational opponent, and in the limit of large N, experimental results on strategies agree with the superrational version, not the game-theoretic rational one.

For cooperation to emerge between game theoretic rational players, the total number of rounds N must be random, or at least unknown to the players. In this case 'always defect' may no longer be a strictly dominant strategy, only a Nash equilibrium. Amongst results shown by Robert Aumann in a 1959 paper, rational players repeatedly interacting for indefinitely long games can sustain the cooperative outcome.

Strategy for the iterated prisoners' dilemma

Interest in the iterated prisoners' dilemma (IPD) was kindled by Robert Axelrod in his book *The Evolution of Cooperation* (1984). In it he reports on a tournament he organized of the *N* step prisoners' dilemma (with *N* fixed) in which participants have to choose their mutual strategy again and again, and have memory of their previous encounters. Axelrod invited academic colleagues all over the world to devise computer strategies to compete in an IPD tournament. The programs that were entered varied widely in algorithmic complexity, initial hostility, capacity for forgiveness, and so forth.

Axelrod discovered that when these encounters were repeated over a long period of time with many players, each with different strategies, greedy strategies tended to do very poorly in the long run while more altruistic strategies did better, as judged purely by self-interest. He used this to show a possible mechanism for the evolution of altruistic behaviour from mechanisms that are initially purely selfish, by natural selection.

The winning deterministic strategy was tit for tat, which Anatol Rapoport developed and entered into the tournament. It was the simplest of any program entered, containing only four lines of BASIC, and won the contest. The strategy is simply to cooperate on the first iteration of the game; after that, the player does what his or her opponent did on the previous move. Depending on the situation, a slightly better strategy can be "tit for tat with forgiveness." When the opponent defects, on the next move, the player sometimes cooperates anyway, with a small probability (around 1–5%). This allows for occasional recovery from getting trapped in a cycle of defections. The exact probability depends on the line-up of opponents.

By analysing the top-scoring strategies, Axelrod stated several conditions necessary for a strategy to be successful.

Nice
: The most important condition is that the strategy must be "nice", that is, it will not defect before its opponent does (this is sometimes referred to as an "optimistic" algorithm). Almost all of the top-scoring strategies were nice; therefore, a purely selfish strategy will not "cheat" on its opponent, for purely self-interested reasons first.

Retaliating
: However, Axelrod contended, the successful strategy must not be a blind optimist. It must sometimes retaliate. An example of a non-retaliating strategy is Always Cooperate. This is a very bad choice, as "nasty" strategies will ruthlessly exploit such players.

Forgiving
: Successful strategies must also be forgiving. Though players will retaliate, they will once again fall back to cooperating if the opponent does not continue to defect. This stops long runs of revenge and counter-revenge, maximizing points.

Non-envious
: The last quality is being non-envious, that is not striving to score more than the opponent (note that a "nice" strategy can never score more than the opponent).

The optimal (points-maximizing) strategy for the one-time PD game is simply defection; as explained above, this is true whatever the composition of opponents may be. However, in the iterated-PD game the optimal strategy depends upon the strategies of likely opponents, and how they will react to defections and cooperations. For example, consider a population where everyone defects every time, except for a single individual following the tit for tat strategy. That individual is at a slight disadvantage because of the loss on the first turn. In such a population, the optimal strategy for that individual is to defect every time. In a population with a certain percentage of always-defectors and the rest being tit for tat players, the optimal strategy for an individual depends on the percentage, and on the length of the game.

In the strategy called Pavlov, win-stay, lose-switch, If the last round outcome was *P,P*, a Pavlov player switches strategy the next turn, which means *P,P* would be considered as a failure to cooperate.[*citation needed*] For a certain range of parameters, Pavlov beats all other strategies by giving preferential treatment to co-players which resemble Pavlov.

Deriving the optimal strategy is generally done in two ways:

1. Bayesian Nash Equilibrium: If the statistical distribution of opposing strategies can be determined (e.g. 50% tit for tat, 50% always cooperate) an optimal counter-strategy can be derived analytically.[6]
2. Monte Carlo simulations of populations have been made, where individuals with low scores die off, and those with high scores reproduce (a genetic algorithm for finding an optimal strategy). The mix of algorithms in the final population generally depends on the mix in the initial population. The introduction of mutation (random variation during reproduction) lessens the dependency on the initial population; empirical experiments with such systems tend to produce tit for tat players (see for instance Chess 1988), but there is no analytic proof that this will always occur.

Although tit for tat is considered to be the most robust basic strategy, a team from Southampton University in England (led by Professor Nicholas Jennings [1] (http://www.ecs.soton.ac.uk/~nrj) and consisting of Rajdeep Dash, Sarvapali Ramchurn, Alex Rogers, Perukrishnen Vytelingum) introduced a new strategy at the 20th-anniversary iterated prisoners' dilemma competition, which proved to be more successful than tit for tat. This strategy relied on cooperation between programs to achieve the highest number of points for a single program. The university submitted 60 programs to the competition, which were designed to recognize each other through a series of five to ten moves at the start.[7] Once this recognition was made, one program would always cooperate and the other would always defect, assuring the maximum number of points for the defector. If the program realized that it was playing a non-Southampton player, it would continuously defect in an attempt to minimize the score of the competing program. As a result,[8] this strategy ended up taking the top three positions in the competition, as well as a number of positions towards the bottom.

This strategy takes advantage of the fact that multiple entries were allowed in this particular competition and that the performance of a team was measured by that of the highest-scoring player (meaning that the use of self-sacrificing players was a form of minmaxing). In a competition where one has control of only a single player, tit for tat is certainly a better strategy. Because of this new rule, this competition also has little theoretical significance when analysing single agent strategies as compared to Axelrod's seminal tournament. However, it provided the framework for analysing how to achieve cooperative strategies in multi-agent frameworks, especially in the presence of noise. In fact, long before this new-rules tournament was played, Richard Dawkins in his book *The Selfish Gene* pointed out the possibility of such strategies winning if multiple entries were allowed, but he remarked that most probably Axelrod would not have allowed them if they had been submitted. It also relies on circumventing rules about the prisoners' dilemma in that there is no communication allowed between the two players. When the Southampton programs engage in an opening "ten move dance" to recognize one another, this only reinforces just how valuable communication can be in shifting the balance of the game.

Continuous iterated prisoners' dilemma

Most work on the iterated prisoners' dilemma has focused on the discrete case, in which players either cooperate or defect, because this model is relatively simple to analyze. However, some researchers have looked at models of the continuous iterated prisoners' dilemma, in which players are able to make a variable contribution to the other player. Le and Boyd[9] found that in such situations, cooperation is much harder to evolve than in the discrete iterated prisoners' dilemma. The basic intuition for this result is straightforward: in a continuous prisoners' dilemma, if a population starts off in a non-cooperative equilibrium, players who are only marginally more cooperative than non-cooperators get little benefit from assorting with one another. By contrast, in a discrete prisoners' dilemma, tit for tat cooperators get a big payoff boost from assorting with one another in a non-cooperative equilibrium, relative to non-cooperators. Since nature arguably offers more opportunities for variable cooperation rather than a strict dichotomy of cooperation or defection, the continuous prisoners' dilemma may help explain why real-life examples of tit for tat-like cooperation are extremely rare in nature (ex. Hammerstein[10]) even though tit for tat seems robust in theoretical models.

Real-life examples

These particular examples, involving prisoners and bag switching and so forth, may seem contrived, but there are in fact many examples in human interaction as well as interactions in nature that have the same payoff matrix. The prisoner's dilemma is therefore of interest to the social sciences such as economics, politics, and sociology, as well as to the biological sciences such as ethology and evolutionary biology. Many natural processes have been abstracted into models in which living beings are engaged in endless games of prisoner's dilemma. This wide applicability of the PD gives the game its substantial importance.

In environmental studies

In environmental studies, the PD is evident in crises such as global climate change. It is argued all countries will benefit from a stable climate, but any single country is often hesitant to curb CO_2 emissions. The immediate benefit to an individual country to maintain current behavior is perceived to be greater than the purported eventual benefit to all countries if behavior was changed, therefore explaining the current impasse concerning climate change.[11]

An important difference between climate change politics and the prisoner's dilemma is uncertainty. The pace at which pollution will change climate is not known precisely. The dilemma faced by government is therefore different from the prisoner's dilemma in that the payoffs of cooperation are largely unknown. This difference suggests states will cooperate much less than in a real iterated prisoner's dilemma, so that the probability of avoiding a climate catastrophe is much smaller than that suggested by a game-theoretical analysis of the situation using a real iterated prisoner's dilemma.[12]

In psychology

In addiction research/behavioral economics, George Ainslie points out[13] that addiction can be cast as an intertemporal PD problem between the present and future selves of the addict. In this case, *defecting* means *relapsing*, and it is easy to see that not defecting both today and in the future is by far the best outcome, and that defecting both today and in the future is the worst outcome. The case where one abstains today but relapses in the future is clearly a bad outcome – in some sense the discipline and self-sacrifice involved in abstaining today have been "wasted" because the future relapse means that the addict is right back where he started and will have to start over (which is quite demoralizing, and makes starting over more difficult). The final case, where one engages in the addictive behavior today while abstaining "tomorrow" will be familiar to anyone who has struggled with an addiction. The problem here is that (as in other PDs) there is an obvious benefit to defecting "today", but tomorrow one will face the same PD, and the same obvious benefit will be present then, ultimately leading to an endless string of defections.

John Gottman in his research described in "the science of trust" defines good relationships as those where partners know not to enter the (D,D) cell or at least not to get dynamically stuck there in a loop.

In economics

Advertising is sometimes cited as a real life example of the prisoner's dilemma. When cigarette advertising was legal in the United States, competing cigarette manufacturers had to decide how much money to spend on advertising. The effectiveness of Firm A's advertising was partially determined by the advertising conducted by Firm B. Likewise, the profit derived from advertising for Firm B is affected by the advertising conducted by Firm A. If both Firm A and Firm B chose to advertise during a given period the advertising cancels out, receipts remain constant, and expenses increase due to the cost of advertising. Both firms would benefit from a reduction in advertising. However, should Firm B choose not to advertise, Firm A could benefit greatly by advertising. Nevertheless, the optimal amount of advertising by one firm depends on how much advertising the other undertakes. As the best strategy is dependent on what the other firm chooses there is no dominant strategy, which makes it slightly different than a prisoner's dilemma. The outcome is similar, though, in that both firms would be better off were they to advertise less than in the equilibrium. Sometimes cooperative behaviors do emerge in business situations. For instance, cigarette manufacturers endorsed the creation of laws banning cigarette advertising, understanding that this would reduce costs and increase profits across the industry.[14] This analysis is likely to be pertinent in many other business situations involving advertising.[*citation needed*]

Without enforceable agreements, members of a cartel are also involved in a (multi-player) prisoners' dilemma.[15] 'Cooperating' typically means keeping prices at a pre-agreed minimum level. 'Defecting' means selling under this minimum level, instantly taking business (and profits) from other cartel members. Anti-trust authorities want potential cartel members to mutually defect, ensuring the lowest possible prices for consumers.

In sport

Doping in sport has been cited as an example of a prisoner's dilemma.[16]

If two competing athletes have the option to use an illegal and dangerous drug to boost their performance, then they must also consider the likely behaviour of their competitor. If neither athlete takes the drug, then neither gains an advantage. If only one does, then that athlete gains a significant advantage over their competitor (reduced only by the legal or medical dangers of having taken the drug). If both athletes take the drug, however, the benefits cancel out and only the drawbacks remain, putting them both in a worse position than if neither had used doping.[16]

Multiplayer dilemmas

Many real-life dilemmas involve multiple players. Although metaphorical, Hardin's tragedy of the commons may be viewed as an example of a multi-player generalization of the PD: Each villager makes a choice for personal gain or restraint. The collective reward for unanimous (or even frequent) defection is very low payoffs (representing the destruction of the "commons"). The commons are not always exploited: William Poundstone, in a book about the prisoner's dilemma (see References below), describes a situation in New Zealand where newspaper boxes are left unlocked. It is possible for people to take a paper without paying (*defecting*) but very few do, feeling that if they do not pay then neither will others, destroying the system. Subsequent research by Elinor Ostrom, winner of the 2009 Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel, hypothesized that the tragedy of the commons is oversimplified, with the negative outcome influenced by outside influences. Without complicating pressures, groups communicate and manage the commons among themselves for their mutual benefit, enforcing social norms to preserve the resource and achieve the maximum good for the group, an example of effecting the best case outcome for PD.[17]

The Cold War

The Cold War and similar arms races can be modelled as a Prisoner's Dilemma situation.[18] During the Cold War the opposing alliances of NATO and the Warsaw Pact both had the choice to arm or disarm. From each side's point of view: Disarming whilst your opponent continues to arm would have led to military inferiority and possible annihilation. If both sides chose to arm, neither could afford to attack each other, but at the high cost of maintaining and developing a nuclear arsenal. If both sides chose to disarm, war would be avoided and there would be no costs. If your opponent disarmed while you continue to arm, then you achieve superiority.

Although the 'best' overall outcome is for both sides to disarm, the rational course for both sides is to arm. This is indeed what happened, and both sides poured enormous resources into military research and armament for the next thirty years until the dissolution of the Soviet Union broke the deadlock.

Related games

Closed-bag exchange

Hofstadter[19] once suggested that people often find problems such as the PD problem easier to understand when it is illustrated in the form of a simple game, or trade-off. One of several examples he used was "closed bag exchange":

> Two people meet and exchange closed bags, with the understanding that one of them contains money, and the other contains a purchase. Either player can choose to honor the deal by putting into his or her bag what he or she agreed, or he or she can defect by handing over an empty bag.

In this game, defection is always the best course, implying that rational agents will never play. However, in this case both players cooperating and both players defecting actually give the same result, assuming there are no gains from trade, so chances of mutual cooperation, even in repeated games, are few.

Friend or Foe?

Friend or Foe? is a game show that aired from 2002 to 2005 on the Game Show Network in the USA. It is an example of the prisoner's dilemma game tested on real people, but in an artificial setting. On the game show, three pairs of people compete. When a pair is eliminated, they play a game similar to the prisoner's dilemma to determine how the winnings are split. If they both cooperate (Friend), they share the winnings 50–50. If one cooperates and the other defects (Foe), the defector gets all the winnings and the cooperator gets nothing. If both defect, both leave with nothing. Notice that the payoff matrix is slightly different from the standard one given above, as the payouts for the "both defect" and the "cooperate while the opponent defects" cases are identical. This makes the "both defect" case a weak equilibrium, compared with being a strict equilibrium in the standard prisoner's dilemma. If you know your opponent is going to vote Foe, then your choice does not affect your winnings. In a certain sense, *Friend or Foe* has a payoff model between prisoner's dilemma and the game of Chicken.

The payoff matrix is

	Cooperate	**Defect**
Cooperate	1, 1	0, 2
Defect	2, 0	0, 0

This payoff matrix has also been used on the British television programmes *Trust Me*, *Shafted*, *The Bank Job* and *Golden Balls*, and on the American shows *Bachelor Pad* and *Take It All*. Game data from the *Golden Balls* series has been analyzed by a team of economists, who found that cooperation was "surprisingly high" for amounts of money that would seem consequential in the real world, but were comparatively low in the context of the game.[20]

Iterated Snowdrift

Researchers from the University of Lausanne and the University of Edinburgh have suggested that the "Iterated Snowdrift Game" may more closely reflect real-world social situations. In this model, the risk of being exploited through defection is lower, and individuals always gain from taking the cooperative choice. The Snowdrift game imagines two drivers who are stuck on opposite sides of a snowdrift, each of whom is given the option of shovelling snow to clear a path, or remaining in their car. A player's highest payoff comes from leaving the opponent to clear all the snow by themselves, but the opponent is still nominally rewarded for their work.

This may better reflect real world scenarios, the researchers giving the example of two scientists collaborating on a report, both of whom would benefit if the other worked harder. "But when your collaborator doesn’t do any work, it’s probably better for you to do all the work yourself. You’ll still end up with a completed project."[21]

Example Snowdrift Payouts (A, B)

	A cooperates	**A defects**
B cooperates	200, 200	300, 100
B defects	100, 300	0, 0

Example PD Payouts (A, B)

	A cooperates	**A defects**
B cooperates	200, 200	300, −100
B defects	−100, 300	0, 0

See also

- Centipede game
- Christmas truce
- Cooperation
- Diner's dilemma
- Ethical dilemma
- Evolutionarily stable strategy
- Folk theorem (game theory)
- Innocent prisoner's dilemma
- Nash equilibrium
- Prisoner's dilemma and cooperation an experimental study
- Platonia dilemma
- Public choice theory
- Public goods game
- Reciprocal altruism
- Rendezvous problem
- Simultaneous action selection
- Social trap
- Superrationality: an attempt to improve on the traditional game theory approach.
- Tit for tat
- Tragedy of the commons
- Traveler's dilemma
- War of attrition (game)
- Zero-sum

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6. ^ For example see the 2003 study "Bayesian Nash equilibrium; a statistical test of the hypothesis" (http://econ.hevra.haifa.ac.il/~mbengad/seminars/whole1.pdf) for discussion of the concept and whether it can apply in real economic or strategic situations (from Tel Aviv University).
7. ^ http://www.southampton.ac.uk/mediacentre/news/2004/oct/04_151.shtml
8. ^ The 2004 Prisoners' Dilemma Tournament Results (http://www.prisoners'-dilemma.com/results/cec04/ipd_cec04_full_run.html) show University of Southampton's strategies in the first three places, despite having fewer wins and many more losses than the GRIM strategy. (Note that in a PD tournament, the aim of the game is not to "win" matches – that can easily be achieved by frequent defection). It should also be pointed out that even without implicit collusion between software strategies (exploited by the Southampton team) tit for tat is not always the absolute winner of any given tournament; it would be more precise to say that its long run results over a series of tournaments outperform its rivals. (In any one event a given strategy can be slightly better adjusted to the competition than tit for tat, but tit for tat is more robust). The same applies for the tit for tat with forgiveness variant, and other optimal strategies: on any given day they might not 'win' against a specific mix of counter-strategies. An alternative way of putting it is using the Darwinian ESS simulation. In such a simulation, tit for tat will almost always come to dominate, though nasty strategies will drift in and out of the population because a tit for tat population is penetrable by non-retaliating nice strategies, which in turn are easy prey for the nasty strategies. Richard Dawkins showed that here, no static mix of strategies form a stable equilibrium and the system will always oscillate between bounds.
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14. ^ This argument for the development of cooperation through trust is given in *The Wisdom of Crowds* , where it is argued that long-distance capitalism was able to form around a nucleus of Quakers, who always dealt honourably with their business partners. (Rather than defecting and reneging on promises – a phenomenon that had discouraged earlier long-term unenforceable overseas contracts). It is argued that dealings with reliable merchants allowed the meme for cooperation to spread to other traders, who spread it further until a high degree of cooperation became a profitable strategy in general commerce

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External links

- Prisoner's Dilemma (*Stanford Encyclopedia of Philosophy*) (http://plato.stanford.edu/entries/prisoner-dilemma/)
- Is there a "dilemma" in Prisoner's Dilemma? (http://www.egwald.ca/operationsresearch/prisonersdilemma.php) by Elmer G. Wiens
- "Games Prisoners Play" (http://webfiles.uci.edu/mkaminsk/www/book.html) – game-theoretic analysis of interactions among actual prisoners, including PD.
- Iterated prisoner's dilemma game (http://www.iterated-prisoners-dilemma.net/)
- Another version of the Iterated prisoner's dilemma game (http://kane.me.uk/ipd/)
- Another version of the Iterated prisoner's dilemma game (http://www.gametheory.net/Web/PDilemma/)
- Iterated prisoner's dilemma game (http://www.paulspages.co.uk/hmd/) applied to *Big Brother* TV show situation.
- The Bowerbird's Dilemma (http://www.msri.org/ext/larryg/pages/15.htm) The Prisoner's Dilemma in ornithology – mathematical cartoon by Larry Gonick.
- Examples of Prisoners' dilemma (http://www.economics.li/downloads/egefdile.pdf)
- Multiplayer game based on prisoner dilemma (http://www.gohfgl.com/) Play prisoner's dilemma over IRC – by Axiologic Research.
- Prisoner's Dilemma Party Game (http://fortwain.com/pddg.html) A party game based on the prisoner's dilemma
- The Edge cites Robert Axelrod's book and discusses the success of U2 following the principles of IPD. (http://www.rte.ie/tv/theview/archive/20080331.html)
- "Radiolab: "The Good Show"" (http://www.radiolab.org/2010/dec/14/). Season 9. Episode 1. December 14, 2011. WNYC. http://www.radiolab.org/2010/dec/14/.

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