The Effect of Indifference and Compassion on the Emergence of Cooperation in a Demographic Donor-Recipient Game[1]

Tsuneyuki Namekata and Yoko Namekata

Abstract A player in a game sometimes does not fully understand the situation of the game. We regard him in this state as being indifferent to the game. He needs to experience the games some times in order to escape being indifferent to the game and to fully understand the situation of the game. It is also an important factor in his experience how other players deal with him when he is indifferent to the game. We model this situation into a Demographic Donor-Recipient game. We investigate their effect on the emergence of cooperation by Agent-Based Simulation.

We observe the following main results under some reasonable assumptions by Agent-Based Simulation: (1) If indifferent players are supposed not to escape from being indifferent to the game, then the cooperation does not emerge. (2) If indifferent players are supposed to escape from being indifferent to the game by experiencing some number of games as a recipient and imitating their experience in a certain inner way, then the cooperation emerges more often. (3) Further, if compassionate recipients, faced with an indifferent donor, pay the cost of Cooperative move in order for the indifferent player to experience the Cooperative outcome, then the cooperation emerges more often. Thus, we observe that the indifferent player's imitation of his experience in games and the compassionate player's self-sacrificing move promote the cooperation.

Keywords: Emergence of Cooperation, Donor-Recipient Game, Demographic Model, Agent-Based Simulation, Indifference, Compassion

1 Introduction

We introduce two states of a player, indifferent and compassionate. A player in the indifferent state in a game does not fully understand the situation of the game and therefore he is indifferent

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to the game. A player in the compassionate state is compassionate toward the indifferent player to the game. We investigate their effect on the emergence of cooperation in a Demographic Donor-Recipient (DR) game.

Epstein [1] introduces his demographic model. He shows the emergence of cooperation where AllC and AllD are initially randomly distributed in a square lattice of cells. In each period, players move locally (that is, to a random cell within the neighboring 4 cells, that is, the north, west, south, and east cells; or von Neumann neighbors, if unoccupied) and play the Prisoner's Dilemma (PD) game against local (neighboring) player(s). Here AllC always Cooperates and AllD always Defects. If wealth (accumulated payoff) of a player becomes negative or his age becomes greater than his lifetime, he dies. If his wealth becomes greater than some amount and there is an unoccupied cell in a von Neumann neighbor, he has offspring and gives the offspring some amount from his wealth. Thus, the local interaction in the spatial structure is an important element in the emergence of cooperation.

Namekata and Namekata [2, 3] extend Epstein's original model discussed above by introducing a global move, a global play, and a Reluctant player into a demographic PD or DR game. Reluctant players delay replying to changes and use extended forms of tit-for-tat (TFT). Here, TFT Cooperates in the first game and in later games uses the same move as his opponent did in the previous game. They show cases where the reluctance to respond the opponent's change promotes the emergence of cooperation. Thus, this reluctance, which is a personal character of players, is an important element to promote cooperation. They also show that cooperative strategies evolutionarily tend to move and play locally, defective do not.

Szabó and Szolnoki [7] deal with two-strategy (C or D) games including a PD game in a spatial structure (a square lattice) and introduce a Fraternal player. A player on the lattice plays the games against his nearest neighbors and calculates his utility that depends on his and co-players' payoff. A player chosen at random changes from his current move to an opposite move, that is, from C to D, or from D to C, in order to maximize stochastically his utility. The Fraternal player calculates his utility by averaging his own and a coplayers' payoff. They show that the stationary pattern of C or D does not fall into a state of the "tragedy of the commons" and gives the maximum total payoff if the system starts initially with the fraternal players. Zagorsky, Reiter, Chatterjee, and Nowak [8] consider all strategies that can be implemented by one and two-state automata in a strictly alternating DR game and observe a convergence to some equilibria, one of which represents a cooperative alliance of several strategies, dominated by a Forgiver. In each period, two strategies in the population play strictly alternating DR games some fixed number of times. Frequencies of strategies in the population over continuous periods are determined by a usual replicator dynamics. The Forgiver cooperates whenever the opponent has cooperated; it defects once when the opponent has defected, but subsequently the Forgiver attempts to reestablish cooperation even if the opponent has defected again. The Fraternal player and the Forgiver represent human behavioral features that relate to cooperation.

Namekata and Namekata [4] introduce a set of human personal characters, Optimist, Pessimist, and Average in a Demographic Multi-Attribute DR game and investigate the role of the Optimist against the Pessimist on the emergence of cooperation. The Optimists focus on the best attribute of the outcomes and adjust their next actions accordingly, whereas the Pessimists focus on the worst attribute. They show that the Optimists are crucial for a high emergence of cooperation if the initial distribution consists of more than one character and includes the Pessimists.

In general, interaction structures for the evolution of cooperation in dilemma situations are classified into five mechanisms, some of which are (reduced to) spatial structure, direct reciprocity, and indirect reciprocity (Nowak [5]; Nowak and Sigmund [6]). Here an interaction structure specifies how players interact to accumulate payoff and to compete for reproduction. Spatial structure means that players are embedded on a square lattice of cells, they stay at their original position or may dynamically move around the lattice, and they basically play games against their nearest neighbors. Direct reciprocity assumes that a player plays games with the same opponent repeatedly and he determines his move depending on the moves of the same opponent. If a player plays games repeatedly and the opponents may not be the same, indirect (downstream) reciprocity assumes that the player determines his move against the current opponent depending on the previous moves of this current opponent, or indirect upstream reciprocity, or generalized reciprocity, assumes that the player determines his move against the current opponent depending on the previous experience of his own. Epstein [1] uses spatial structure. Namekata and Namekata [2-4] use spatial structure and generalized reciprocity. Szabó and Szolnoki [7] and Zagorsky, Reiter, Chatterjee, and Nowak [8] use direct reciprocity.

We are interested in human behavioral features that relate to cooperation. Let us imagine that a player in a game do not fully understand the situation of the game. We interpret this state of the player as indifferent. An indifferent player cannot take a suitable action for the game. He needs to experience the games some times in order to fully understand the situation of the game and his experience in his indifferent state adjusts his future actions in the game. There is also a compassionate player who is compassionate toward the indifferent player to the game. The compassionate player takes self-sacrificing actions to the indifferent player and the latter thanks the former for the former's self-sacrificing actions on a certain condition. We investigate the effect of indifference and compassion on the emergence of cooperation in a Demographic DR game.

2 Model

A DR game in the original form is a two-person game between a donor and a recipient. The donor has two moves, Cooperate and Defect. Cooperate means the donor pays a cost *c* for the recipient to receive a benefit *b* (*b*>*c*>0), whereas Defect means the donor does nothing. The recipient has no move. We introduce three states (personal characters) of a player, indifferent, compassionate, and thankful. A player in the indifferent state does not fully understand the situation of the game and therefore he is indifferent to the DR game, and a player in the compassionate state is compassionate toward the indifferent player to the game. We add a third move, Indifference (I) to the original DR game. Indifferent move of the donor means both of the donor and the recipient receive a small positive payoff *d*. We assume that each player plays 6 games against (possibly different) players at each period. Since it is common in demographic dilemma games that the sum of payoffs of a player, in two successive games - once as a Donor and once as a Recipient, to be positive if the opponent uses C and negative if D; and the worst sum of a player is equal to the best sum in absolute value, we therefore transform the original payoffs to new ones by subtracting the constant *x*. Constant *x* is given by (*b*–*c*)/4. We set *b*=6, *c*=1, and *d*=0.5 in this paper. Table 1 shows the transformed payoff matrix of the DR game with Indifference.

Table 1. Payoff Matrix of the DR game with Indifference

		Recipient
Donor	C	$-c-x, b-x$
	I	$d-x, d-x$
	D	$-x, -x$

If an indifferent donor makes his indifferent move to a compassionate recipient, then the compassionate recipient in a cooperative state (explained later) pays the cost *c* of Cooperative move in order for the indifferent player to experience the Cooperative outcome, that is, to receive the benefit *b*. This compassionate C of the recipient is not included in the original DR game.

We extend the TFT as follows in order to introduce a reluctant strategy: Let $m+1$ represent the number of states, $t \in \{0,\ldots,m+1\}$, and $s \in \{0,\ldots,m\}$. The inner states of a strategy $(m,t;s)$ are numbered $0,1,\ldots,m$. The state i is labeled D_i if $i<t$ or C_i if not. If the current state is labeled C or D, then the strategy prescribes using C or D, respectively. In other words, the strategy prescribes using D if the current state $i<t$ but using C if not; thus the value t is the threshold which determines the move of the player. A state labeled D or C is called defective or cooperative, respectively. The initial state is state s; its label is D_s if $s<t$ or C_s if not. If the current state is i, then the next state is $\min\{i+1,m\}$ or $\max\{i-1,0\}$ given that the opponent uses C or D, respectively, in this game. If $m>1$, then the strategy may delay replying to its opponent's change. Note that TFT is expressed as (1,1;1) in this notation. Thus, a strategy $(m,t;s)$ is an extended form of TFT. To sum up, our strategies are expressed as $(m,t;s)$; m is the largest state number, t is the threshold, and s is the initial state number. The initial state is denoted as $(m,t;*)$ if it is determined randomly. We also omit the initial state like (m,t) if we have no need to specify it. We also call the current value of the inner state, "Cooperation Indicator" (CI). Note that a reluctant strategy $(m,t;s)$ by itself decides its move against the current opponent depending on its own previous experience, meaning indirect upstream reciprocity, that is, generalized reciprocity. We set $m = 2$ in this paper. AllC is denoted by $(2,0)$ and AllD by (2.3).

We explain how the indifference and the compassion relate to each other in detail: A player has his properties, indifferent (true or false), compassionate (true or false), strategy, lengthOfImitation, onlyForLocalPlay (true or false), and thankful (true or false). Every player can be indifferent (his indifferent property is true). The indifferent property is inborn as well as inheriting. A player at age 0 is set to be indifferent with a probability of rateOfIndifferent (=0.2) even if his parent is not indifferent. An indifferent player makes only Indifferent move as a Donor in the DR game. Both (2,1) and (2,2) player can be compassionate (his compassionate property is true but his indifferent property is false). If the compassionate player as a Recipient is faced with the Indifferent move of the indifferent Donor in the DR game, then the compassionate player feels compassion for the indifference of the indifferent player. And if the compassionate player is in a cooperative state, he pays the cost c in order for the indifferent player to receive the benefit b, that is, makes a Cooperative move to the indifferent player, as an example of good move and result of the DR game. If the onlyForLocalPlay of the compassionate player is true, then the compassionate C is restricted only to a local play (explained later). If the indifferent player experiences C or D moves lengthOfImitation times, where these experiences modify CI of his strategy as described in the last paragraph (i.e. the indifferent player imitates in a certain inner way), then the indifferent player escapes from being indifferent to the game and starts to use his strategy (AllC, (2,1), (2,2), or AllD). If the times of C experienced from the compassionate players during his indifferent periods is larger than or equal to timesOfCompassionateCToChangeThreshold (=2) and the indifferent player is thankful (his thankful property is true), then AllC or AllD changes to (2,1) or (2,2), respectively, because indifferent players thank compassionate players for their sacrificing actions.

A player has the following properties that are inherited from parents to offspring; indifferent, compassionate, onlyForLocalPlay, lengthOfImitation, thankful, strategy, rateOfGlobalMove (*rGM*), and rateOfGlobalPlay (*rGP*); whose initial distributions are summarized in Table 2.

In period 0, N (=100) players (agents) are randomly located in a 30-by-30 lattice of cells. The left and right borders of the lattice are connected. If a player moves outside, for example, from the right border, then he comes inside from the left border. The upper and lower borders are connected similarly. Players have their own properties such as indifferent, compassionate, thankful, strategy, and so on. The initial distributions of inherited properties are given in Table 2. The initial wealth of every player is 6. Their initial (integer valued) age is randomly distributed between 0 and lifetime (=50).

Table 2. Initial Distributions of Inheriting Properties

property	initial distribution
indifferent	With a probability of rateOfIndifferent (=0.2), indifferent is true. Indifferent is also inborn, meaning that indifferent property of a child is set to be true even if his parent is not indifferent.
compassionate	With a probability of Co, compassionate is true. We assume Co is one of 0.0, 0.5, and 0.8.
onlyForLocalPlay	With a probability Of L, onlyForLocalPaly is true. We assume L is one of 0.0, 0.5, 0.8, 0.99, and 1.0.
lengthOfImitation	We deal with 2 distributions, {5,10} and {5,15}. {*lower*,*upper*} (*lower*<*upper*) means length of Imitation is selected randomly between *lower* ((L)ower value) and *upper* ((U)pper value). We vary U(pper) value of length of imitation in these 2 distributions. We also deal with the case of lengthOfImitation = ∞, which means that an indifferent player never escapes from being indifferent, as a reference point.
thankful	With a probability of rateOfThankful (=0.5), thankful is true.
strategy	We deal with the population, Rlct-2:={(1/4)(2,0), (1/4)(2,1;*), (1/4)(2,2;*), (1/4)(2,3)}. Rlct-2 means Reluctant strategies with *m*=2. Rlct-2 implies that with a probability of 1/4 strategy (2,0) (AllC) is selected, with a probability of 1/4 strategy (2,1;*) is selected, and so on, where * indicates that initial state is selected randomly. Note that initially 50% of players use C on the average since both AllC and AllD are included with the same probability and so are both (*m*,*t*;*) and (*m*,*m*−*t*+1;*).
(*rGM*,*rGP*)	We deal with the distribution, {(1/4)*ll*, (1/4)*lg*, (1/4)*gl*, (1/4)*gg*}. For example, *gl* means *rGM* is distributed in interval *g* and *rGP* in interval *l*, where *l*:=(0.05,0.2) and *g*:=(0.8,0.95), indicating to move globally and play locally. {(1/4)*ll*, (1/4)*lg*, (1/4)*gl*, (1/4)*gg*} means *rGM* and *rGP* are selected randomly among *ll*, *lg*, *gl*, and *gg*.

In each period, each player (1^{st}) moves and (2^{nd}) plays DR games against other players. Positive payoff needs opponent's C. (The detailed description of (1^{st}) move and (2^{nd}) play is given in Table 3.) The payoff of the game is added to his wealth. If the resultant wealth is greater than fissionWealth (=10) and there is an unoccupied cell in von Neumann neighbors, the player has offspring and gives the offspring 6 units from his wealth. The indifferent property of the offspring is set to be true with a probability of rateOfIndifferent (=0.2) if his parent is not indifferent. His age is increased by one. If the resultant wealth becomes negative or his age is greater than lifetime (=50), then he dies. Then the next period starts.

In our simulation we use synchronous updating, that is, in each period, all players move, then all players play, then all players have offspring if possible. We remark that the initial state of the offspring's strategy is set to the current state of the parent's strategy. There is a small mutationRate (=0.05) with which inheriting properties are not inherited. The initial distributions of inheriting properties given in Table 2 are also used when the mutation occurs. We assume that with errorRate (=0.05) a player makes mistake when he makes his move (C or D). Thus, AllC may defect sometimes.

Table 3. Detailed Description of (1) Move and (2) Play

(1)	With a probability of *rGM*, a player moves to a random unoccupied cell in the whole lattice. If there is no such cell, he stays in the current cell. Or with a probability of 1−*rGM*, a player moves to a random cell in von Neumann neighbors if it is unoccupied. If there is no such cell, he stays in the current cell.
(2)	With a probability of *rGP*, the opponent against whom a player plays the DR game is selected at random from all players (except himself) in the whole lattice. Or with a probability of 1−*rGP*, the opponent is selected at random from von Neumann neighbors (no interaction if there are no neighbors). This process is repeated 6 times. (Opponents are possibly different.)

Note that the initial distribution of a strategy is Rlct-2 (including AllC, (2,1), (2,2), and AllD). Also note that a player moves and plays locally or globally with high probability, thus there are 4 move-play patterns such as *ll*, *lg*, *gl*, and *gg*

Especially note the following:

1. An indifferent property of a player is inborn as well as inheriting, meaning that it is set to be true if his parent is indifferent or with a probability of rateOfIndifferent (=0.2) if not.
2. An indifferent Donor makes only an Indifferent move in the DR game.
3. Faced with the indifferent move of an indifferent Donor, a compassionate Recipient in a cooperative state makes a Cooperative move to the indifferent player in order for the indifferent player to experience an example of good move and result of the DR game. If the onlyForLocalPlay of the compassionate player is true, the Cooperative move is restricted to a local play.
4. After the indifferent player experiences C or D and modifies CI of his strategy accordingly, that is, imitates lengthOfImitation times, he escapes from being indifferent and starts to use his strategy (one of AllC, (2,1), (2,2), or AllD). If he experiences compassionate C more than or equal to timesOfCompassionateCToChangeThreshold (=2) and he is thankful, then his strategy (AllC or AllD) changes to (2,1) or (2,2), respectively.

3 Simulation and Results

Our purpose to simulate our model is to examine the effect of indifference and compassion on the emergence of cooperation and the distribution of strategies. We use Repast Simphony 2.7 to simulate our model.

We execute 300 runs of simulations in each different setting. We judge that cooperation emerges in a run if there are more than 100 players and the average C rate is greater than 0.2 at period 500, where the average C rate at a period is the average of the player's average C rate at that period, and the player's average C rate at the period is defined as the number of C moves used by the player, divided by the number of games played as a Donor at that period. (We interpret 0/0 as 0.) This average C rate is the rate at which we see cooperative move C as an outside observer. We call a run in which the cooperation emerges as a *successful* run. Since the negative wealth of a player means his death in our model and he has a lifetime, it is necessary for many players to use C so that the population does not become extinct. We are interested in the emergence rate of cooperation (Ce), that is, the rate at which the cooperation emerges.

3.1 Emergence Rate of Cooperation, Ce

What is the effect of introducing human personal characters, indifference and compassion, on the emergence of cooperation? We first consider two reference points, (1) NoIndifferent (rateOfIndifferent = 0.0) case and (2) Indiff-∞ (rateOfIndifferent = 0.2 and lengthOfImitation = ∞) case. (1) NoIndifferent is the case where there are no indifferent players, whereas (2) Indiff-∞ is the case where there exist some indifferent players and they cannot escape from being indifferent. We see that the emergence rates of cooperation, Ce's for NoIndifferent and Indiff-∞ are 79.0% and 0.0%, respectively. Thus, we observe that Indifference reduces the cooperation quite a lot. What is the effect of lengthOfImitation and introducing compassionate player on the emergence of cooperation if rateOfIndifferent = 0.2 and lengthOfImitation < ∞? We summarize the emergence rates of cooperation, Ce's, for the distributions of lengthOfImitation, {5,10}and {5,15} in Table 4 and Table 5, respectively. The first column indicates the value of Co and the first row L. The rest entities are Ce's for corresponding Co and L. Their corresponding graphs are depicted in Figure 1 and Figure 2, respectively.

Table 4. Ce for {5,10}

Ce {5,10}	L=0.0	L=0.5	L=0.8	L=0.99	L=1.0
Co=0.0	59.7%	59.7%	59.7%	59.7%	59.7%
Co=0.5	66.7%	66.0%	69.0%	69.0%	70.3%
Co=0.8	68.7%	69.0%	69.0%	70.3%	72.0%

Table 5. Ce for {5,15}

Ce {5,15}	L=0.0	L=0.5	L=0.8	L=0.99	L=1.0
Co=0.0	44.3%	44.3%	44.3%	44.3%	44.3%
Co=0.5	28.0%	41.0%	51.3%	51.3%	53.3%
Co=0.8	22.7%	35.7%	43.6%	57.0%	56.0%

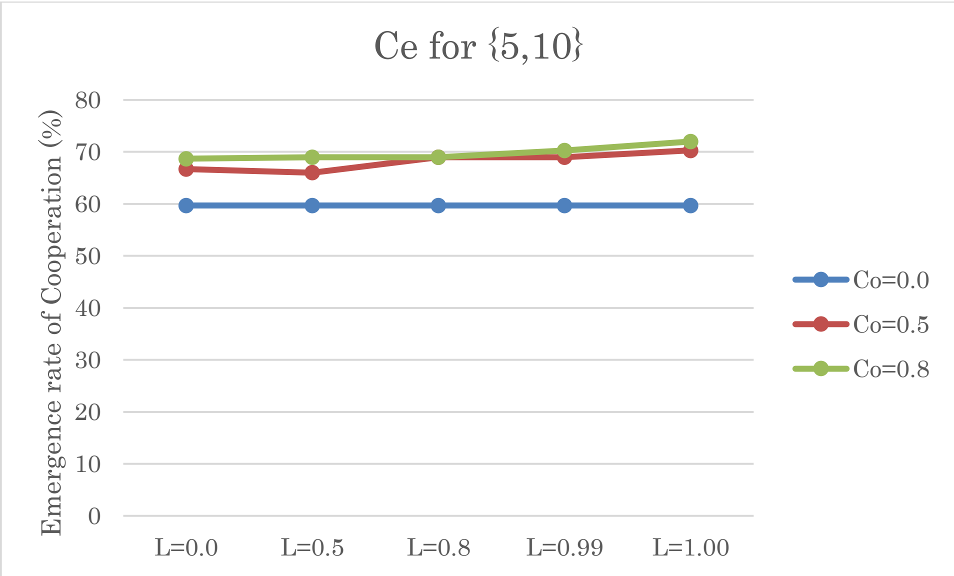

Figure 1. Ce for {5,10}

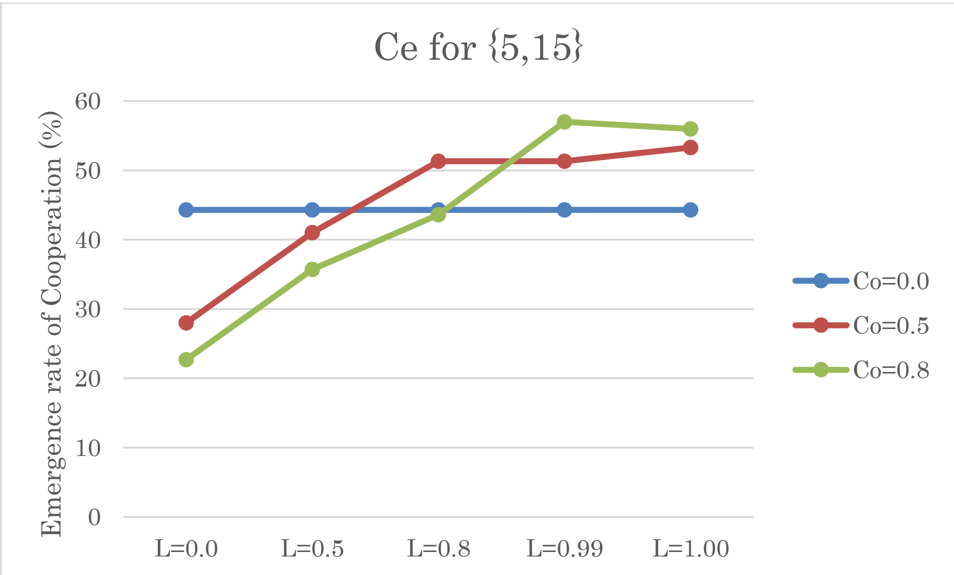

Figure 2. Ce for {5,15}

First let us focus only on the effect of imitation of an indifferent player. Since Ce's for Co=0.0 in Table 4 and Table 5 (see also corresponding Figure 1 and Figure 2) are larger than 0.0% but smaller than 79.0%, we observe that the imitation of an indifferent player promotes the cooperation to some degree.

In Table 4 (see also Figure 1), Ce's for Co=0.5 and 0.8 are larger than that for Co=0.0 and almost do not vary so widely with values of L. Co=0.5 or 0.8 is almost sufficient for large Ce. Ce does not depend on the value of L, that is, whether compassionate players restrict their compassionate C to local plays or not. We observe that compassionate players further promote the cooperation if U(pper) value of lengthOfImitation is 10.

The situation in Figure 2 is quite different from that in Figure 1 (see also Table 4 and Table 5). Ce's for Co>0.0 is smaller than that for Co=0.0 if L<0.8. L=0.5 is not enough for a high Ce. L=0.8 is also not enough for a high Ce if Co=0.8. Thus, if U(pper) value of lengthOfImitation is 15, then it is necessary for almost all compassionate players to restrict their compassionate C to local plays in order to promote the cooperation.

3.2 Average Distribution of Strategies, Indifferent, Compassionate, and Thankful Player

Let us pick up two typical cases. Case 1 is {5,10}, Co=0.8, and L=0.99. The other, Case 2, is {5,15}, Co=0.8, and L=0.99. We concentrate on them and investigate average distribution of strategies, indifferent, compassionate, and thankful player over the successful runs at period 500.

Average distribution of strategies over the successful runs at period 500 for NoIndifferent case is shown in Figure 3 as a reference point. AllD and AllC have large share, whereas (2,1) and (2,2) are very small.

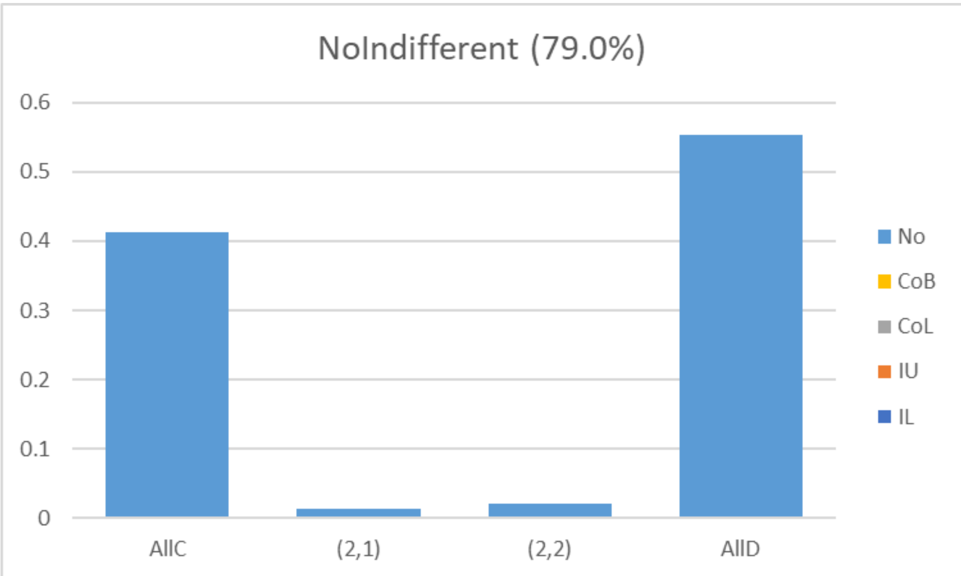

Figure 3. Distribution of strategies for NoIndifferent

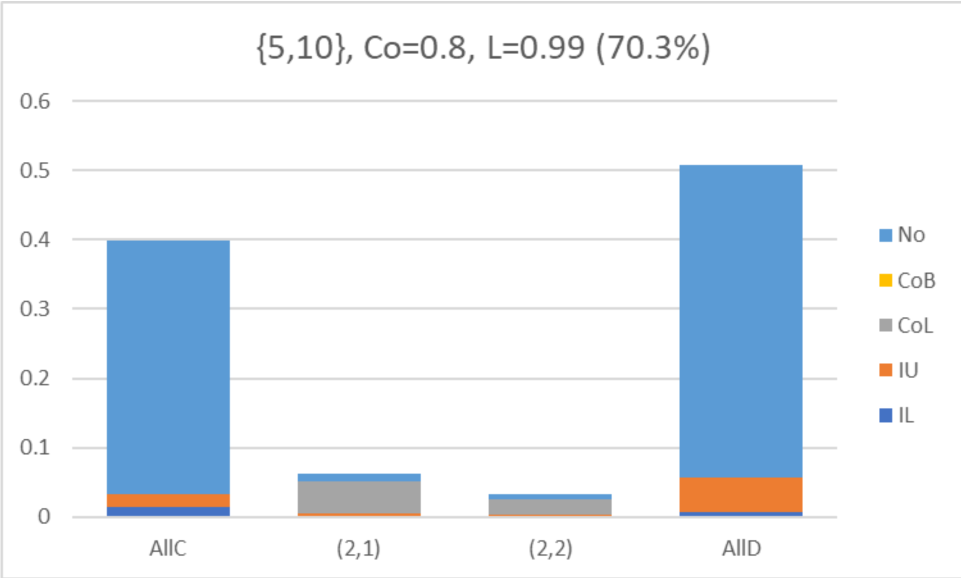

Figure 4. Distribution of strategies for {5,10}

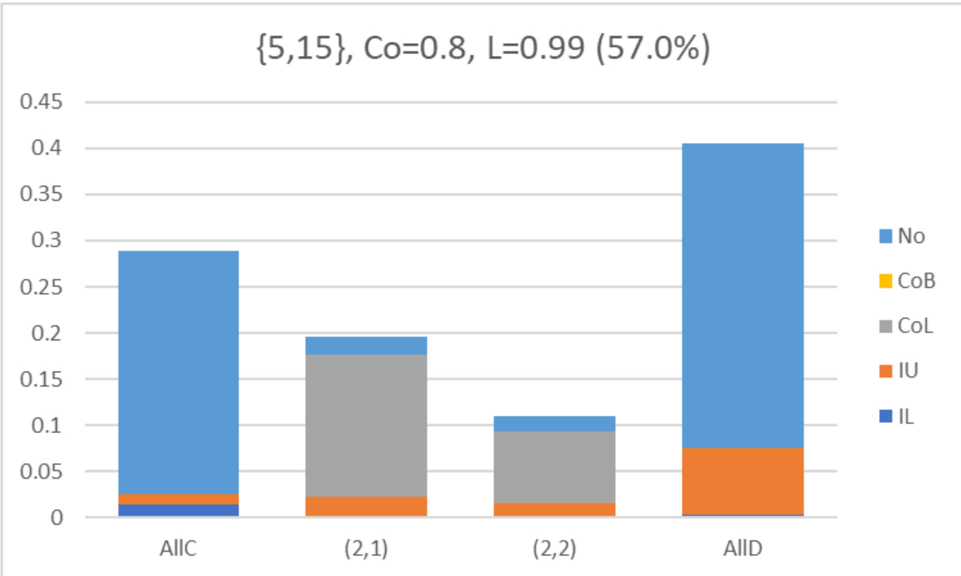

Figure 5. Distribution of strategies for {5,15}

Average distribution of strategies over the successful runs at period 500 for Case 1 is shown in Figure 4 and that for Case 2 in Figure 5. Share of (2,1) and (2,2) are not so small in Case 1 and increases to some amount as U(pper) value of lengthOfImitation increases from 10 in Case 1 to 15 in Case 2.

Table 6 shows the average rate of indifferent player and the average rates of player with the lower value or the upper value of lengthOfImitation over the successful runs at period 500. The average rates of indifferent player for Case 1 and 2 are 9.7% and 13.9%, respectively. The average rates of player with the upper value 10 and 15 of lengthOfImitation for Case 1 and 2 are 76.5% and 85.7%, respectively. They are much larger than the initial value 50%.

Table 6. Average rateOfIndifferent, Average rate of lower and upper value of lengthOfImitation

case	rateOfIndifferent	lengthOfImitation	rate
Case 1: {5,10}, Co=0.8, L=0.99	0.097	5	0.235
		10	0.765
Case 2: {5,15}, Co=0.8, L=0.99	0.139	5	0.143
		15	0.857

Table 7. Average Co and L

case	Co or L	(2,1)	(2,2)
Case 1: {5,10}, Co=0.8, L=0.99	Co	0.736	0.716
	L	0.990	0.990
Case 2: {5,15}, Co=0.8, L=0.99	Co	0.787	0.702
	L	0.999	0.995

Table 8. Average rate of thankful

case	AllC	AllD
Case 1: {5,10}, Co=0.8, L=0.99	0.986	0.992
Case 2: {5,15}, Co=0.8, L=0.99	0.979	0.994

Table 7 shows the average value of Co, that is, the average rate of a compassionate player (2,1) or (2,2), and the average value of L, that is, the average rate of a compassionate player (2,1) or (2,2) with onlyForLocalPlay=true over the successful runs at period 500. We observe that the average Co's of (2,1) are 73.6% and 78.7% for Case 1 and 2, respectively. They are a bit smaller than the initial value 80.0%. Thus, the average rate of compassionate (2,1) does not decrease so much from the its initial value. The average L of (2,1) is 99.0% and 99.9% for Case 1 and 2, respectively, which are almost the same as the initial value 99.0%.

Table 8 shows the average rate of a thankful player in AllC and AllD over the successful runs at period 500. They are much larger than the initial value 50%.

4 Conclusion

We investigate the effect of Indifference and Compassion on the emergence of cooperation in a Demographic Donor-Recipient game. We show, by Agent-Based Simulation, that Indifference reduces the cooperation, imitation of indifferent players promotes the cooperation, and compassionate C’s to the indifferent players further promote the cooperation, although the compassionate C’s need to be restricted to a local play if U(pper) value of lenghtOfImitation is large.

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