Modeling Reputation Management System on Online C2C Market

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Abstract: This paper discusses the effectiveness of sharing information concerning the reputations of buyers and sellers making online transactions in a consumer-to-consumer (C2C) market. We developed a computer simulation model that describes online transactions with a reputation management system that shares information concerning the reputations of consumers. The model takes an agent-based approach in which agents' actions are based on the iterated prisoner's dilemma. No model exists to analyze C2C markets even though there are many case studies concerning the effectiveness of sharing reputation information among participants in a market. The simulation results revealed that a positive reputation system can be more effective than a negative reputation system for an online transaction, even though the negative one can work for a traditional transaction. The result should be an important consideration when designing practical reputation management systems for online transactions.

Keywords: Reputation Management System, C2C market, e-commerce, online market, Agent-Based Approach, Iterated Prisoner's Dilemma.

1. Introduction

The e-commerce market is growing rapidly, thanks in part to the ease at which participants can enter and exit, it's anonymity and ease of registration. However, these attractive features have led to a new problem, which is increasing risk of cheating in online trading, e.g., receiving goods without payment or receiving payment without sending goods, as there are incentives to get goods or payments without being forced to make corresponding the contribution.

In particular, we need a new type of management system that can prevent non-cooperative behavior on the part of the buyers or sellers of online trading. In traditional markets, we can exchange goods and make payments because there are safety mechanisms such as membership in the market, laws, and trusted third parties.

In online markets, however, we can't rely on these mechanisms because of the ease (and low cost) that one has in entering and exiting from the market and ease in which participant's can change their identity. The distance and time between buyer and seller is also a problem. We will discuss whether it is possible to establish trust between buyers and sellers without a trusted third party.

An auction on the Internet is an example of a C2C online transaction. The risk of cheating in such a transaction seems to be higher than that in a face-to-face transaction, because it is easy to cheat in a virtual environment. However, several online auctions, e.g., eBay and Yahoo auction, have effectively supported C2C transactions. Based on these successful examples, we hypothesize that sharing information concerning one's reputation is important to managing the risk of cheating in C2C online transactions. To explore the effectiveness of reputation information in a virtual world, we developed a model that defines a reputation management system as a mechanism to promote and maintain cooperative behavior among participants

Concerning the function of reputation in a market, Kollock (1999) distinguished the differences between negative and positive reputation systems, and pointed out that it could be possible to promote cooperation without a trusted third party. We have embedded such a reputation system in our model and have found the conditions to make a good transaction policy that can be incorporated into the design of an online market. We introduced the basic reputation model in a previous paper (Yamamoto et al., 2003); in the present paper, we describe a detailed model and analyze the characteristics of a reputation management system.

2. Emergence of trust in C2C transactions

Let us review the types of online transaction on the Internet in order to discuss the emergence of trust in C2C transactions. Based on this review, we will discuss the requirements of a reputation management system for online transactions.

There are two types of trust management system: the top-down type, e.g., one with a trusted third party, and the bottom-up type, e.g., one where participants share reputation information. We will discuss these systems in 2.2 and 2.3 and show that the bottom-up type is more effective than the top-down type for online transactions.

2.1 Online transactions

In an online transaction, business organizations (B) and consumers (C) are the main participants. The most successful kind of online transaction is the business organization to business organization (B2B) one, e.g., a supply chain management (SCM) system. B2B transactions on the Internet are similar to transactions made in other markets, except for the cost; B2B transactions tended to use on-line systems before the era of the Internet.

Another type of transaction is business organization to consumer (B2C). Bank transactions and online ticket sales are popular examples because they are exchanges of information instead of physical goods. Standardized goods, e.g., a book and a music compact disk (CD), are also popular goods exchanged in online transactions. Amazon.com is one of the successful examples and it shows us that B2C transactions have evolved because of the Internet. A new type of Internet-powered retailer has appeared, called the “Click & Mortar” retailer.

Distributors also have undergone large changes in the way they do business. For example, Dell assembles a computer on demand from a consumer. It is an example of a direct transaction between a maker and a consumer, and it is also an example of a intermediated transaction between suppliers of computer parts and consumers. The new type of intermediary is named the infomediary, which stands for an internet powered intermediary (Hagel and Singer, 1999).

Consumer and consumer (C2C) is another type of online transaction that has only just begun to be seen. The Internet has helped C2C transactions to grow, because the network has removed the constraints in terms of distance and time and has provided opportunities for individuals to make deals with lots of others. Examples of the new market include eBay and Yahoo auction.

We will discuss C2C online transactions because of the big impact of the Internet on this kind of transaction. In online transactions, especially C2C, there is a larger risk of cheating, because it is easy for people to enter and exit the market and it’s anonymous. The characteristics of an online transaction lead to incentives to get services, goods or money without making any corresponding contribution. This risky situation is a kind of Prisoner’s Dilemma and is the reason our model based on this dilemma. We explain the dilemma in section 3.

2.2 Top-down trust management system

The trusted third party, e.g., a grading service or escrow, is a popular kind of top-down trust management system. However, a grading service is not effective in C2C transactions, even though it is effective in B2B transactions. Escrow is effective, because it can remove any possibility of cheating others. Figure 1 shows how escrow can complete transactions by intermediating between buyer and seller to prevent any cheating.

Even though escrow is effective in C2C online transactions, there are three problems to its use. The first problem is its high cost. The second problem is its complex procedure, which impairs the convenience of use of the Internet. The third problem is its low availability, which constrains the areas available to make transactions.

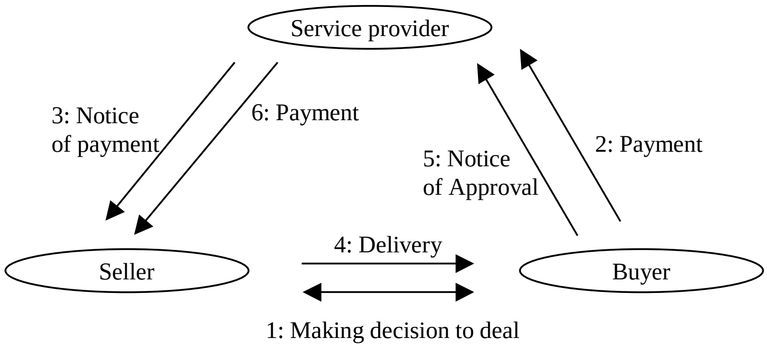

Figure 1: Overview of Escrow

2.3 Bottom-up trust management system

In from the bottom up management system, participants circulate and share reputation information among themselves to promote cooperative behavior. Many researchers pay much attention to reputation information that constructs trust among participants. Resnick et. al. (2000) discusses that reputation promotes trust formation among participants in an online market and community. From the bottom up management system can also provide a safety mechanism, in that participants can distinguish good offers from bad ones with respect to trust. For example, the feedback mechanism in eBay of Yahoo auction, which is one of the famous and successful online auction services, is from the bottom up management system with respect to trust. To model reputation operationally, we define it based on the study of Wilson (1985) as “A person’s characteristic described by others based on his or her behavioral history.”

Kollock (1999) provided a classification of negative and positive aspects of information with which reputation management systems deal. A negative reputation system is to prohibit bad behavior by distributing the histories of badly behaving participants to all participants. It is possible to exclude a member from a community because of his or her bad behavior. The negative reputation system is a sort of black list system whose mechanism is one of exclusion. It is effective in real transactions; however, it seems to be not effective in online transactions, because of its anonymity and the ease by which people can enter and exit from an online market. Moreover, there is the possibility to distribute incorrect information to downgrade another’s reputation.

What is a suitable reputation system for an online transaction? A positive reputation system seems to be a proper system to make participants cooperative. A person of positive reputation means that he/she must be trustworthy. We can evaluate trustworthiness of a partner by the number of cooperative transaction in his/her previous transactions. It is the system that distributes information concerning trustworthiness of participants. In the positive reputation system, a participant cannot accumulate good reputation if he/she changes his/her ID frequently. Therefore, the system can provide participants for the incentive to be cooperative and to transact continuously with their same ID. It also provides an incentive to stay in a market for a long time, because the system promotes one’s good reputation, distributing his or her history concerning good behavior. However, there are two problems with the positive reputation system in an online transaction. The first problem is that it is hard to distinguish the difference between cooperative and non-cooperative participants. The second problem is the difficulty to establish a good reputation when participants frequently enter and exit from an online market. We will analyze which system is suitable for what type of market with our agent-based model and describe the advantages and disadvantages of negative and positive reputation management systems.

3. Modeling C2C online transactions

To analyze and design a C2C online market, we developed our model based on an agent-based approach, because the analysis and design require detailed and dynamic explanations at the individual participants' level to exhibit social phenomena. Axelrod (1997) concluded that the agent-based approach would be effective for analyzing mechanisms that can promote global phenomena from local interactions between agents. By employing this approach, we describe C2C online transactions within the framework of the Prisoner's Dilemma, to find the requisite conditions and market mechanism for promoting the emergence of cooperative behavior.

3.1 Prisoner's Dilemma in C2C online transactions

A player who participates in a C2C online transaction always has an incentive to cheat on others (non-cooperation), because of the anonymity and ease of entry and exit from the transaction. On the one hand, a buyer may take goods from a seller without paying for them. On the other hand, a seller may get a payment from a buyer without sending the goods to him or her.

The situation in C2C online transactions is representative of the Prisoner's Dilemma. In its simplest incarnation, there are two players, i.e. player-1 and player-2, and they cannot communicate with each other directly because they are in solitary confinement in a prison. Each player has two strategies, i.e. cooperation (C) and defection (D). We can consider a payoff matrix, as shown in Table 1.

Table 1: Payoff matrix for prisoner's dilemma

		Action of player-2	
		C	D
Action of player-1	C	S_1, S_2	W_1, B_2
	D	B_1, W_2	T_1, T_2

The necessary conditions for prisoner's dilemma are the following three inequalities (1).

$$\begin{cases} B_i > S_i > T_i > W_i \quad , i = 1,2 \\ 2S_1 > B_1 + W_1 \\ 2S_2 > B_2 + W_2 \end{cases} \qquad (1)$$

In the prisoner's dilemma of a C2C online transaction, a seller can have two actions, i.e. cooperation with a buyer to give goods for his or her payments and defection with him or her to get payments without sending goods. A buyer also can cooperate or defect, i.e. paying for goods or getting goods without paying for them.

Under these circumstances, if there is no system to promote cooperation, a participant who does not always cooperate could exploit a participant who always cooperates with everyone. To promote cooperation, one can embed a reputation information management system into the C2C online transaction.

3.2 Formulation of Reputation Management System

Our market model is for sellers and buyers dealing in goods through bids and awards. Transactions are performed by the following procedure.

1. The seller puts the "goods" which he has on the market.
2. The buyer chooses "goods" based on his or her preference (which is identical to “demand,” here).
3. The buyer performs matching of "supply" and "demand."
4. The buyer chooses a transaction partner by checking the seller's reputation.
5. The seller chooses a transaction partner by checking the buyer's reputation.
6. If a transaction partner is chosen, they will trade.
7. The profits of the seller and the buyer are found by consulting the prisoner's dilemma pay-off matrix.
8. A new participant enters the market every term.
9. The new participant copies the strategy of the participant who has the highest current profit.

By repeating such transactions, those participants who have a suitable strategy survive in the market as time progresses. We varied the parameters of the environment and reputation management system in the simulation. The simulation experiment explored the structure of the reputation management system for which cooperative actions would be stable. We then formulized the actions of participants and the reputation management system. An agent is to be a seller or a buyer who has strategic choices and trades autonomously.

In our model, the agent comprises the strategies of transaction, goods to sell, goods to buy, range of allowable difference in goods between buyer and seller, focus on reputation, and length of history taken into account by the agent. The strategies of transaction are cooperative, non-cooperative, tit for tat, and random (Table 2).

Table 2: Agent elements

Properties of an agent	Types or meaning
Strategy of agent	Each agent has a choice of strategy: i.e., “cooperative strategy”, “non-cooperative strategy”, “tit for tat strategy” or “random strategy”
Goods to sell	Property of goods to sell is described by a string of bits
Goods to buy	Preference of agent (in case of a buyer) concerning goods to buy is described by a string of bits
Allowable difference in goods	Range of allowable difference for an agent between the posted goods (the goods to sell) and the goods to buy
A weight of choice between negative and positive	A weight of choice between negative reputation and positive one when an agent evaluate a partner
Length of history observed by agent	The length of history in transaction which an agent takes into account when the agent evaluates a partner

An action of agent-i during a time period t (A_t^i) can be either cooperation (C) or defection (D)

$$A_t^i = \{C, D\} \quad (2)$$

A consistently cooperative agent always chooses C, whereas a non-cooperative agent always chooses D. An agent with a tit for tat strategy selects his or her action based on the previous actions of the agent it is dealing with. A random agent cooperates or defects with others randomly.

A transaction history (T_t^i) is recorded by the online transaction system.

$$T_t^i = \{A_k^i | k \in \{0,1,\cdots,t\}\} \qquad (3)$$

To make a deal, agents who want to buy bid on goods offered by other agents; the agent who has received bids awards the goods to one of them. A bid or an award is decided by each agent based on the reputation it calculates by using the historical records of the actions of others. Based on the historical record, an agent can calculate the number of cooperative and non-cooperative actions in a certain time span, i.e., $T_{C,t}^i, T_{D,t}^i$ respectively.

$$T_{C,t}^i = \{k | A_k^i = C, k \in \{t - Scope + 1, t - Scope + 2, \cdots, t\}\} \quad (4)$$

$$T_{D,t}^i = \{k | A_k^i = D, k \in \{t - Scope + 1, t - Scope + 2, \cdots, t\}\} \quad (5)$$

The reputation of agent(i) is calculated based on focus of reputation (α) as described in equation (6).

$$R_t^i = \alpha \left|T_{C,t}^i\right| - (1-\alpha)\left|T_{D,t}^i\right| \qquad (6)$$

Positive or negative reputation systems can be described with α equaling 1 or 0, respectively. Based on the value calculated by (6), each agent makes his or her bid or award. We can describe a choice of agent between positive reputation and negative one with alpha ($0 \le \alpha \le 1$). The pure negative reputation system, on the one extreme, can be described by alpha=0. On the other extreme, the pure positive reputation system can be described by alpha=1. In an actual on-line market, a participant seems to employ a mixed choice between positive and negative reputation, therefore the system may be described as an intermediate system ($0 \le \alpha \le 1$).

We can change the initial number of agents with cooperative, non-cooperative, tit for tat, and random strategies. We also change a number of characteristics of goods, varieties of each characteristic, number of agents who enter and exit during each time period. Randomly chosen agents leave the market. The number of exit agents is described by a parameter "turnover rate". New entry agents employ the strategy of participant who achieved the highest current profit in the market. The number of entry agents is equal to the number of exit agents. In many cases the new participant enters a market after asking an acquaintance who has already participated in a market about what the market is like. If the acquaintance has high profits from that market, the new agent begins to carry out actions in the market. In contrast, if the acquaintance has low profits, the newcomer avoids the market. Byrne (1965) showed that a person gets acquainted with other persons who have similar attitudes and characters. In our model, therefore, a new participant selects the best current strategy in the market.

4. Simulation Experiment

Market flexibility is one of the important factors distinguishing an online transaction from a transaction in the real world. In our model, it is described as the number of agents entering and exiting within a certain time period. The markets of online transaction and real world can be described by low and high values of the parameter, respectively. The parameters concerning focus on reputation and length of history are the characteristics of the reputation management system. Table 3 shows the parameters and their values.

Table 3: Experimental parameters

Initial number of agents for each strategy group	25
Duration	100 periods
Number of characteristics of goods	5 bits
Varieties of each characteristic	5 bits
Allowable difference in goods' characteristics	10 bits
Focus on reputation	Operational parameter [0,1]
Length of history	Operational parameter {0, 5, 10, 20}
Number of entrances and exits (turnover rate)	Operational parameter {10, 20, 30}

To find an effective strategy for each condition, we observed the populations of each strategy. A large population indicated the effectiveness of the strategy for the given condition.

First, we simulated the situation where a reputation management system does not exist. From the definition of the prisoner's dilemma, the non-cooperative strategy was expected to become dominant.

Figure 2 shows the trajectories of population for four groups when the entry and exit number is low and reputation management system does not exist. This figure illustrates that non-cooperative strategy becomes dominant. A market collapses in the environment where no reputation management system exists. Next, we introduced the reputation management system described in section 3.2 and performed the simulation over again.

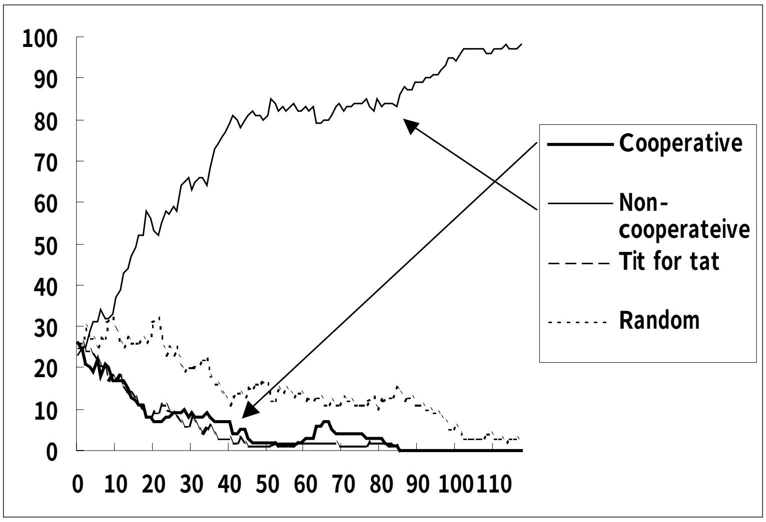

Figure 2: Trajectories of population for a slow turnover rate and no reputation system. The vertical axis shows the population of agents. The horizontal axis shows simulation time.

Figure 3 shows the trajectories of population for four groups when the entry and exit number is low (=10) and the focus on reputation is negative (α =0). This figure illustrates the effectiveness of the cooperative strategy in the negative reputation system.

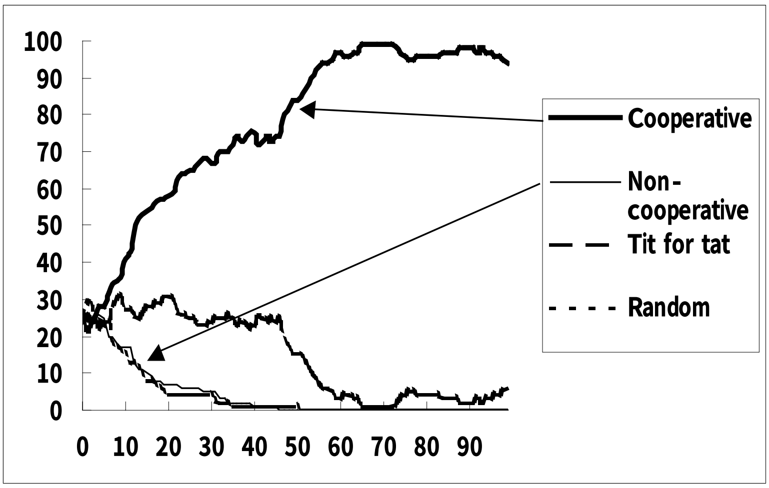

Figure 3: Trajectories of population for a slow turnover rate and negative reputation system. The axes are the same as in Figure 2.

Figure 4 shows the trajectories of population when the entry and exit number is high (=30) and the focus on reputation is negative (α =0). This figure illustrates the effectiveness of the non-cooperative strategy. A high entry and exit number is indicative of an environment of an on-line market. In such a situation, the negative reputation system could not eliminate non-cooperative participants. That is, negative reputation systems like the black list of a traditional market do not function effectively in an on-line market. Next, we checked if a positive reputation system functioned effectively in an on-line market. We determined whether a cooperative strategy is stable in a positive reputation system.

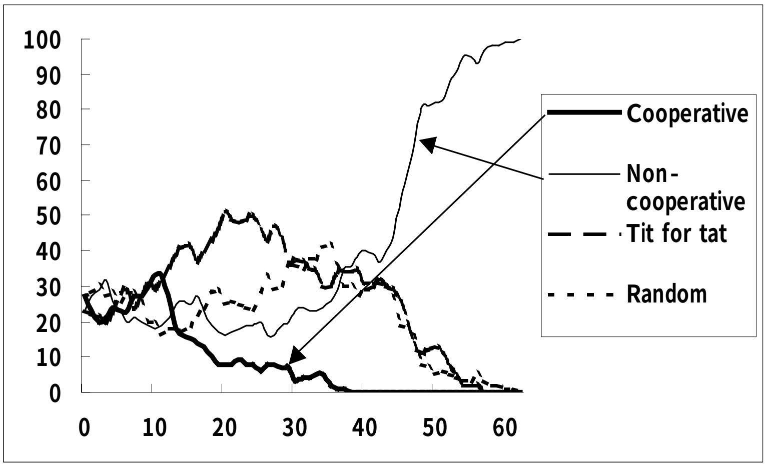

Figure 4: Trajectories of population for a high turnover rate and negative reputation system. The axes are the same as in Fig. 2.

Figure 5 shows the trajectories when the entry and exit number is high (=30) and the focus on reputation is both positive and negative (α =0.5). In this environment, a participant can clearly distinguish cooperative participants from non-cooperative ones. Furthermore, a participant who accumulates a high reputation is frequently selected as a transaction partner. He/She can get increasingly high profits. This system not only distinguishes and eliminates non-cooperative participants, but can evaluate a cooperative participant's positive reputation. This environment thus expresses a real C2C market.

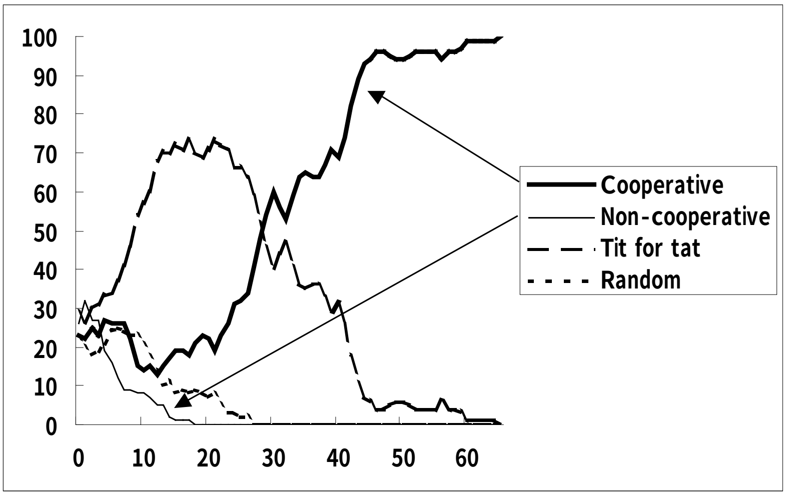

Figure 5: Trajectories of population for a high turnover rate and positive/negative reputation system. The axes are the same as in Fig. 2.

Figure 6 shows the trajectories when the entry and exit number is high (=30) and the focus on reputation is only positive (α =1). In this environment, a participant can behave non-cooperatively and change his or her ID. Nonetheless, the cooperative strategy becomes dominant. This indicates the effectiveness of a positive reputation system in an on-line market.

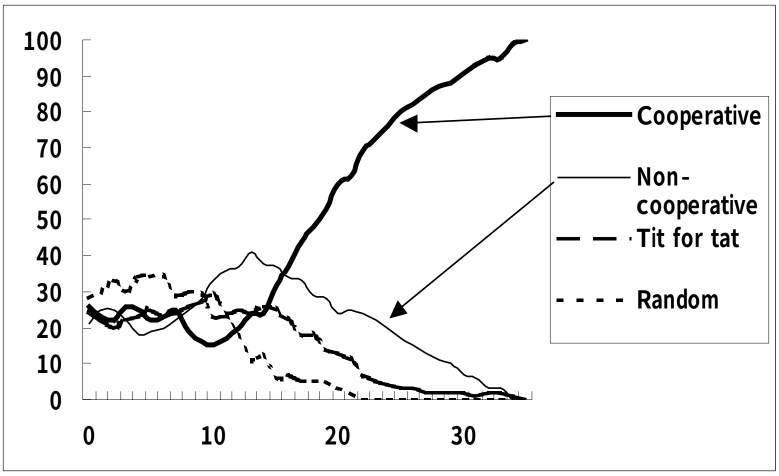

Figure 6: Trajectories of population for a high turnover rate and positive reputation system. The axes are the same as in Fig. 2.

Table 4 summarizes the results of the most effective strategies after 100 time periods in each situation.

Table 4: Effective strategy depending on market situation

Number of entrances and exits	Focus on reputation	Strategy	Frequency
Low	No reputation information	Non-cooperation	Anytime
	Negative	Cooperation	Anytime
	Positive and Negative	Cooperation	Anytime
	Positive	Cooperation	Anytime
High	No reputation information	Non-cooperation	Anytime
	Negative	Non-cooperation	Anytime
	Positive and Negative	Cooperation	Often
	Positive	Cooperation	Often

Finally we show in Figure 7 the rate at which the non-cooperative strategy becomes dominant when the entry and exit number is high (=30). The vertical axis shows the rate at which the non-cooperative strategy becomes dominant when the simulation finished. The horizontal axis shows α . By using positive evaluations, the system can eliminate non-cooperative participants.

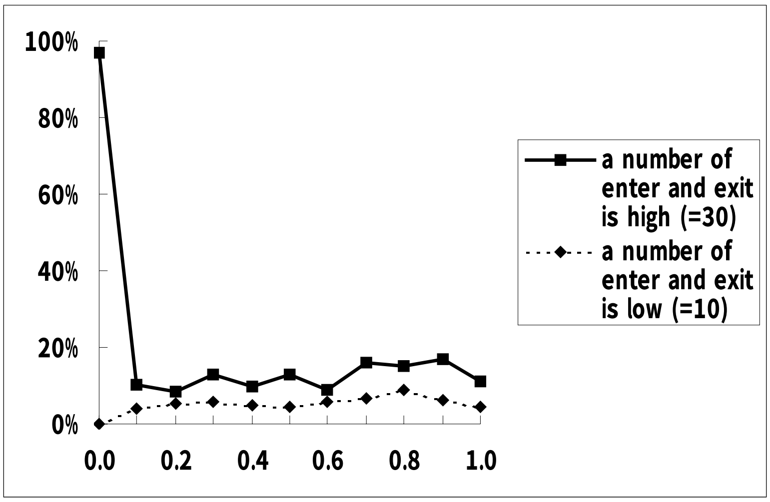

Figure 7: Rate at which non-cooperative strategy becomes dominant.

The horizontal axis shows $\alpha \ (0 \le \alpha \le 1)$.

5. Discussion

In a negative reputation system, the cooperative strategy is effective when the turnover rate is low, as shown in Figures 2, 3, 4, 5 and 6 and Table 4. This reflects the effectiveness of the law punishing non-cooperative participants in the real world. In a society with a low turnover rate, non-cooperative actions lead to low reputations for which an affected participant would face difficulty in making transactions. Hence, a negative reputation system in the real world makes non-cooperative participants leave a market and lets cooperative ones enter.

However, a negative reputation system does not work when the turnover rate is high, because non-cooperative participants frequently come and go from a market. If a participant has a low reputation, he or she could re-enter as a new participant. Hence, cooperative participants can be exploited and they will disappear from a high turnover rate market with a negative reputation system.

A positive reputation system can overcome this problem, because it counts cooperative actions. This means that it is beneficial for a participant to cooperate with others and to stay in the market for a long time. Furthermore, the system makes non-cooperative participants get out of it. According to a study by McDonald (2002), a buyer who has a high reputation can sell his or her goods at a higher price compared with others who have the same goods. From Figure 7, we see that if a market can evaluate positive behavior, it can make a cooperative strategy dominant. In other words, it is effective in promoting cooperation in addition to penalizing non-cooperative behavior.

In on-line transactions, a positive reputation management system activates cooperative transactions as our simulation and example show. However, groups of malicious participants can give high reputations to each other. In a Peer-to-Peer System (P2P), this problem is serious because of the lack of security. Milojicic et al. (2002) demonstrated that there was a security problem by contrasting P2P with a client and server system (Milojicic et al., 2002). Various researches have used simulations to study how to overcome this problem (Kamvar et. al, 2003) (Stoica et. al., 2001). Kambar et al. (2003) studied a distributed hash table (DHT) can prevent malicious groups in a peer-to-peer environment. The security of the on-line transactions market of the present web base is relatively high because the market employs a client and server system instead of a P2P system. In this case, the markets' structure and the reputation information are managed intensively, and the participants can directly refer to the reputations of all participants. For these reasons, few malicious groups will exist in an actual on-line market as compared with a P2P system.

Our model is premised on the Prisoner's Dilemma in order to analyze the mechanism of evolution of cooperation in on-line C2C transactions. For example, treating the properties of reputation as asymmetric information (Shapiro, 1982) is not within the range of the present model. In the present work, we performed a simulation only on a negative or positive reputation management system. We simply described the characteristics of the reputation management system as α in equation (6). Positive or negative reputation systems can be described with α =1 and α =0, respectively. However, in an actual on-line market, a participant uses both positive and negative reputation, so an intermediate system (0< α <1) that evaluates both cooperative action and non-cooperative action will be one of our future works. The results concerning alpha is shown in Fig. 7. We will investigate how a participant should consider negative reputations within a positive reputation system.

In a real-world online C2C market, which should be adopted: a positive or a negative reputation management system? Let us briefly look at an actual online C2C market and the structure of an actual reputation management system. eBay is a large-scale market which deals with various goods, from cheap goods, such as toys, to very expensive goods, such as cars.

An eBay participant's reputation is calculated using the following procedure. A buyer and a seller evaluate each other by assigning the values of (-1), (0), or (+1) after a transaction. The reputation management system holds these values. The reputation of a participant is the sum the negative evaluations (each evaluation is -1) and the positive evaluations (each +1). Our model can express this case as α =0.5. On eBay, participants can refer to the transaction histories of other participants. Participants who are evaluated negatively will not be selected as partners for transactions. As a result, a more positive participant will be favorably treated in the market. We can thus say that at least one positive reputation system is functioning well in a real online C2C market.

We have made a number of contributions to the understanding and design of reputation management systems of C2C markets. First we described a reputation management system from an operational perspective. Next, we used simulation experiments to model several scenarios that show the effectiveness of negative and positive reputation systems. Both positive and negative reputation systems function effectively in markets where participants tend to stay. The negative reputation system is more advantageous in such a market because it is easy to construct. A positive reputation system is advantageous in online markets where participants come and go.

6. Conclusion

We showed the effectiveness of sharing information concerning reputation to ensure cooperative actions among participants in C2C online transactions by using an agent-based model in an experimental simulation. In a high turnover market that is typical of C2C online transactions, a positive reputation system can be more effective than a negative reputation system. This means that we need a new framework for the institutions of an online market; the traditional framework of punishing criminals is ineffective. Moreover, it also means that branding strategies will become more important in an online market than in a traditional market.

However, a positive reputation system has a problem in that new participants cannot make deals with others because they have little reputation information on a market. Because of this problem, we observed that the positive reputation system would be ineffective for promoting cooperative participants in a few cases. We will develop a new method to avoid this problem in our future research.

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