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An experimental comparison of negotiation strategies for siting NIMBY facilities

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Abstract. The quality of the urban living environment is strongly related to the provision and planning or design of public facilities, of which NIMBY, not-in-my-back-yard, facilities are often resisted by residents. Therefore, selecting the location for NIMBY facilities has become more and more difficult and time consuming. In Taiwan in particular, when the tenure landholding system is adopted, along with financial difficulties, frequent mass protests take place in relation to environmental issues, and consequently lead to financial development issues for the country. Hence, the interaction between the government and the public becomes critical and urgent. O'Hare believes that NIMBY facilities can be seen as a prisoner's dilemma game in game theory, and Camerer also points out that public issues such as environmental concerns are also a type of prisoner's dilemma game. This research adopts an alternative methodology to that of Axelrod, in which a computer simulation was used to compare interactive strategies in prisoner's dilemma games. On the basis of a deductive analysis comparing different interactive strategies in prisoner's dilemma games, in this research an experiment was conducted to verify empirically the results of that analysis in the context of siting NIMBY facilities. The experiment has once again proven that tit-for-tat is indeed a comparatively more effective strategy than the others, not only for the player under consideration, but also for the society as a whole, with the assumption of symmetric information, and it can be used as a reference when political decisions are to be made from the government regarding NIMBY facilities.

1 Introduction

Game theory has been used recently to a great extent in military applications (Wu and Hsia, 2002), collective negotiations (McDonald and Solow, 1981), transportation (Kermit, 1992), environmental management (Lin, 1994), industrial development (Yan, 2003), finance (Greenwald, 1996), property development (Knaap et al, 1998), and biological evolution (Gonick, 1994). Rasmusen (2002) has provided an example of game theory, in which the model establishers designate the payoff functions and a collection of strategies for players, and then observe the consequence resulting from their chosen strategies to maximize their returns. Following von Neumann and Morgenstern's (1944) zero-sum games, Tucker (1950) responded immediately with non-zero-sum games (cited in Wu and Hsia, 2002), which focus on the interaction of *cooperate* and *defect* strategies between agents. Dixit and Skeath (2002) argue that prisoner's dilemma games are the most promising among all theories for games because of their wide applications.

In *Games of Strategy*, Dixit and Skeath (2004) emphasize that, when players participate in iterated prisoner's dilemma games before they decide whether to defect, they have to weigh up whether the profits of outcomes are larger than the losses resulting from the ensuing encounters. Kagel and Roth (1995) introduce the methodologies

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and applications of both experimental and simulated prisoner's dilemma games in experimental economics. In addition, the iterated games can be divided further into two categories: definite and indefinite numbers of iterations. Axelrod (1984) studied the simulated prisoner's dilemma game using computerized simulations. By analyzing the top-scoring strategies, Axelrod states several conditions necessary for a strategy to be successful—these are, that players be nice, retaliating, forgiving, and nonenvious. Terhune (1968) and Selten and Stoecker (1986) also provided cases which describe the rewards and punishments encountered in iterated prisoner's games. Fan (1996) applied the theories in experimental games to investigate curriculum designs of moral education in primary schools. The findings indicate that students of different ages show different moral cognitive capabilities. Lai and Tsai (2006) used mathematical models, in conjunction with prisoner's dilemma games, to investigate the effects of plans as defined by information gathering.

Axelrod (2000) summarized six advances in cooperation theory by modifying slightly the standard assumptions of the two-person prisoner's dilemma game to study various factors that might affect the likelihood of cooperation, including the timing of choices, the use of a 'hostage', the presence of a social network, whether the players are rational and adaptive, the degree of envy, and the availability of an exit. For example, the timing of choices in the formulation matters, but in the issue of siting NIMBY (not-in-my-back-yard) facilities, most negotiation results arise, at least in Taiwan, when both parties—that is, local government officials and residents—sit down at the table and reveal simultaneously their alternative intents. These variants provide us with a deeper understanding of how cooperation would emerge in general under conditions different from the standard formulation, whereas our purposes here are to look into which negotiation strategies would be most beneficial to the local government and the society as a whole in siting NIMBY facilities, either in cooperative or noncooperative context. Regardless, the two-person prisoner's dilemma game is a fundamental approach to social interactions, and it has generated a wide range of applications in social sciences, including institutional design (eg Ostrom, 1990).

Prisoner's dilemma games pervade our daily lives from personal situations to government negotiations. In this research, on the basis of a mathematical extrapolation (Chiu and Lai, 2008), we compare negotiation strategies by conducting experiments to confirm further that tit-for-tat is the best strategy. The implications of the research may provide insights into how governments should negotiate with residents in planning NIMBY facilities.

Among all possible applications of prisoner's dilemma games, siting NIMBY facilities is worth attending to. Morell (1984) summarizes four major factors which would put the public against NIMBY facilities. These factors are: (1) the psychological fear of possible threats to health and life; (2) a lack of fairness in terms of taxation/compensation; (3) concerns over the environmental pollution, resulting in the depreciation of properties; and (4) government negligence of environmental protection issues. On the other hand, the social cost caused by mass protests is beyond estimation. According to the official statistics by the Environmental Protection Agency of the Executive Yuan of Taiwan in 2006, the cost of incinerator constructions have increased from \$55.2 billion in 1990 to \$63.4 billion in 1997, owing to mass protests.[1] Moreover, the Taiwan Power Company started its first power distribution plan in 1972 with a budget of \$11 billion; the budget for the sixth power distribution plan in 2007 has now reached \$454 billion. The difficulties of siting and constructing the public facilities also explain the delay in pushing the plan forward. The difficulties

[1] All amounts are in New Taiwan dollars (NT\$) throughout.

faced by the Taiwanese government include: (1) an increased financial burden, (2) time pressure because of inefficient management, (3) rising environmental consciousness among the general public, (4) that NIMBY facilities are daily necessities but are disliked by the public, (5) misconception by the general public about NIMBY facilities, and (6) a mismatch between subsidies provided and anticipated. Continual negotiations between local governments and residents are therefore needed.

Lall (1966) argues that negotiation is to understand, improve, and adjust or resolve controversies. As Pruitt (1983) has pointed out, negotiation is the effort or attempt that people make in order for an uncoordinated happening to attain a mutual decision. Hence, using effective strategies becomes the crux of the matter when governments are in the process of communicating, consulting, or negotiating with the public. O'Hare (1977, cited in Weng, 1994) states that the siting of NIMBY facilities, if formulated properly, can be seen as a type of prisoner's dilemma game. Camerer (2003) also points out that public issues such as environmental concerns are also a prisoner's dilemma.

In an earlier paper we gave an extrapolation resulting from mathematical logic using the player strategies applied in the prisoner's dilemma game (Chiu and Lai, 2008), and here we attempt to verify those findings by conducting experiments in the context of siting NIMBY facilities. Our proof is summarized as follows. Two players (player 1 and player 2) participate in the game iteratively and player 1 is the strategy user, with the strategies of tit-for-tat, trigger punishment, faithful, and random. The probabilities of the players' moves (cooperate or defect) in the iterations are noted as p and q. According to the strategy definition, we first enlist all possible outcomes resulting from the game. Once the outcomes are enumerated, the expected payoffs are calculated and compared for the cases of a limited number of iterations and an unlimited number of iterations. Through mathematical deduction, we find that tit-for-tat is the best strategy for both cases.

The present paper attempts to use the prisoner's dilemma game as the basic model to investigate further which strategies the government sectors should apply in negotiating with residents in realistic situations. Axelrod (2000) argues that there are two main approaches to the prisoner's dilemma game—deduction and simulation—and he depicts the advantages and disadvantages of each. We demonstrate here a third approach: a behavioural experiment. With human subjects performing in an experimental setting, their emotions and behavior are authentically presented during the experiment, which neither deduction nor simulation could take into account. In section 2 we will explain the strategies which players may use in the prisoner's dilemma game, and compare the outcomes derived from the experiment with those from mathematical logic. In section 3 we will display and discuss the statistics derived from the experiment. In section 4 we will discuss some related issues. We conclude with section 5.

2 Experimental design

2.1 The hypothetical scenario

A proposed landfill site currently promoted by the government in Taipei, Taiwan, was selected as the hypothetical scenario, on the basis of which an experiment was conducted to compare different negotiation strategies. Taipei City Council has been proposing a third landfill site in Neihu District to solve solid waste problems. The cost of obtaining the land for the landfill site is \$1.54 billion, with the construction cost estimated to be \$1.24 billion. Traditionally, a compensation cost will also be evoked for local residents. Once the landfill site is constructed, the solid waste that the landfill site is capable of handling will be approximately 1 000 000 m^3 with the total area of 30 ha, which includes the landfill site area of 9 ha and the buffering zone area of 21 ha of green fields. The subjects participating in this experiment had a thorough understanding of this hypothetical scenario prior to the commencement of the experiment. Two groups of players are involved. Player 1 will be labeled as the government group and player 2 the residents. Most of the subjects are familiar with the real issues, and we are particularly interested in how they interact in negotiating with each other.

Blake and Mounton (1994, cited in Lin, 1996) classify the conflict negotiation strategies into five strategies—namely, win–loss, win–win, no win–no loss, loss–win, and loss–loss. Pruitt (1983), on the other hand, proposes five different strategies, which are the competing strategy, the cooperating strategy, the negotiation strategy, the compromising strategy, and the escape strategy. In order to verify the deductive results derived from Chiu and Lai (2008), in the experiment we used the same four strategies as summarized in the previous mathematical exploration—namely, the tit-for-tat strategy, the trigger punishment strategy, the faithful strategy, and the random strategy. The definitions of the four strategies are summarized as follows. The faithful strategy means to always cooperate with the opponent player, regardless of the strategies used by the latter. The trigger punishment strategy starts off with a cooperative mode and observes the strategies used by the opponent player; once the opposing player makes a defective move, then the player under consideration will always defect in the ensuing iterations. This strategy is essentially the same as the grim trigger strategy, as termed by Axelrod (2000). The tit-for-tat strategy starts off with a cooperative move, and depending on the opponent's move, the player will respond accordingly with the same move. The random strategy is a strategy to make a cooperative or defective move in a random pattern.

The assumptions of the experiment are described as follows. Firstly, because there are many people involved in the negotiation of the NIMBY facilities, the leaders will represent the residents and be responsible for the negotiation with the government. Secondly, the payoff structure for the government and the residents is generalized in table 1. The government (player 1) will adopt a move of either cooperate or defect, while the residents (player 2) also have the same choices of making a cooperate or defect move. A cooperate move means agreeing with the opponent player, regardless of the strategy or requisition brought into play, whereas the completely opposite response constitutes a defect move. For example, as shown in table 1, the first δ values (in currency value) in the parentheses of the payoff structure table represent the benefits attained by the government when adopting a particular move, while the second δ values represent the benefits attained by the residents. For example, with (δ_3, δ_2), δ_3 represents the benefits attained by the government, while δ_2 represents the benefits attained by the residents, when the two players cooperate and defect, respectively.

In table 1 the payoff for the government stands for the possible economic benefits derived from the NIMBY facilities plan, which are made externally. In other words, the economic benefits of the plan are the gross benefits less the gross costs. To simplify, these benefits are defined as currency—not property rights, as might be argued by economists. The benefits consist of physical benefits such as currency before and after

Table 1. Payoff structure of the government (player 1) and residents (player 2) in the NIMBY facilities siting negotiation.

		Player 2 (residents)	
		cooperate	defect
Player 1 (government)	cooperate	(δ_1, δ_1)	(δ_3, δ_2)
	defect	(δ_2, δ_3)	(δ_4, δ_4)

the construction, as well as nonphysical benefits, such as social welfare. However, the gross costs should include all physical costs, such as money and human resources, as well as nonphysical costs, such as social costs before and after the construction of the facility. The gross benefits to the government include the resolution of the solid waste problem, as well as the physical and nonphysical benefits that are derived from the resolution of the solid waste problem. The gross costs must, however, include all the physical and nonphysical costs involved in implementing this plan. The physical costs may consist of the construction cost, the cost of attaining the land, and the construction costs of related facilities, while the time elapsed and uncertainties caused by protests are accounted for as the nonphysical costs. The residents' payoff structure measures the total nonphysical benefits, such as increased or decreased public space, as well as the compensations received from the government when the NIMBY facilities are to be preceded or abandoned. The logic of the prisoner's dilemma game confines that the payoff structure be constructed such that $\delta_2 > \delta_1 > \delta_4 > \delta_3$.

Cooperate–cooperate is one combination of moves, with the payoff of (δ_1, δ_1). In this fully cooperative mode, the plan has the folowing advantages. Firstly, there are no protests, which can help reduce the cost of preventing the plan from implementation. Secondly, the time spent on implementing the plan will be relatively short because of the lack of protests, which also results in a decrease in interest costs. Thirdly, as the plan is more easily implemented, the benefits gained by both parties also make the plan more effective. In contrast, defect–defect is a different combination of moves, with the payoff being (δ_4, δ_4). This combination indicates that both the government and the residents defect during the negotiation process of siting the NIMBY facilities. Owing to the continuous protests by the residents, the plan cannot be implemented successfully. The following disadvantages reduce the plan effectiveness. Firstly, protests and the costs spent on mitigating them arise. Secondly, the plan is expected to be delayed, owing to the protests, which results in an increase in operation and interest costs. Thirdly, the plan benefits are greatly reduced because of the failure in plan implementation.

In addition, cooperate–defect and defect–cooperate both indicate that one of the players decides to defect, with the other cooperating. When one of the parties decides to make a defect move while the opponent player cooperates, the temporary benefits will rise for the defecting player, whereas the burden of the costs for the cooperate player will be increased, causing reduced benefits. For instance, when the government adopts a cooperative move, it may attempt to match all requisitions made by the residents. This situation may consequently result in higher costs and lower benefits as the goal of the government is simply to construct the NIMBY facilities.

The payoff structure as depicted in the hypothetical scenario coincides with real situations in siting NIMBY facilities and the logic of the prisoner's dilemma game. Table 2 shows the realistic numbers of payoffs used in the experiment. These numbers provide sufficient information derived from the logic of the prisoner's dilemma game. Larger numbers represent better outcomes. Among the combination of moves, cooperate–cooperate means the residents hold no objection and no protests against

Table 2. Payoff structure used in the experiment (units are NT $100 million).

		Player 2 (residents)	
		cooperate	defect
Player 1 (government)	cooperate	(8, 8)	(2, 15)
	defect	(15, 2)	(3, 3)

the siting of the NIMBY facilities. Therefore, the government can save unnecessary expenses, such as the costs of preventing protests. Thus an increase in compensation for the residents and improvements in community facilities can be expected. For the experiment, the hypothetical values of (8, 8) for this combination are given. However, the benefits will increase for the player who decides to defect while the opponent cooperates. To make the experiment more realistic, the payoffs will be represented by currency (in $100 million).

2.2 Experimental design

The mathematical deduction has shown that tit-for-tat is the best strategy among all four strategies in terms of the overall expected payoff for a player (Chiu and Lai, 2008). Therefore, we hypothesize that the government would adopt tit-for-tat as its best strategy, regardless of the cases of limited and unlimited numbers of iterations. In addition, taking the overall benefits across the two players into consideration, tit-for-tat would yield the highest expected payoff as the best strategy among all possible strategies used by the government.

All subjects participating in the experiment were assigned randomly to eight subject groups as shown in table 3, which were further divided into the government and residents groups. Since we are interested in the effectiveness of different negotiation strategies, the government group served as the control group, whose strategies were thus preassigned. The subject groups were divided into subgroups of limited and unlimited number of iterations. To avoid progressive errors and fatigue, which may result in cumulative errors during practicing, twenty iterations were used as the limited time case, whereas the case of an unlimited number of iterations was manifested by control iterations and duration set to thirty iterations and fourteen minutes, respectively.

Table 3. Experimental design.

Time control	Strategy			
	faithful	trigger punishment	tit-for-tat	random
Limited number of iterations	group 1	group 2	group 3	group 4
Unlimited number of iterations	group 5	group 6	group 7	group 8

2.3 Procedure

A pretest was conducted prior to the formal experiment. Suggestions made by the pretest subjects were taken into consideration, including an increase in payoffs to three times their original values and the use of more realistic values of currency units.

2.3.1 *Selection of subjects*

As shown in table 3, the subjects playing the role of the government were further divided into four groups, with five members in each group. The subjects in group 1 played the faithful strategy, while those in group 2 adopted the trigger punishment strategy. The subjects in groups 3 and 4 adopted the tit-for-tat and random strategies, respectively. The subjects playing the role of residents were randomly assigned into these four groups. The selection criteria and rules for participants are described as follows. Firstly, all subjects were required to show willingness and to be motivated to participate. Secondly, to be realistic, the subjects playing the role of the government were required to possess, to some extent, professional knowledge about urban planning, to simulate the negotiation scenario of protests. Twenty students from the Department of Real Estate and Built Environment of National Taipei University and twenty students from the Department of Urban Affairs and Planning of the Chinese Culture

University were selected to participate in this experiment after a survey of willingness was conducted, playing the role of the residents and the government, respectively.

2.3.2 *Implementation*

To avoid progressive errors caused by fatigue, the number of iterations was set to twenty, as a manifestation of a limited number of iterations. In the case of an unlimited number of iterations, the unlimited aspect comes from the unpredictable future that the subjects might face, so the time and number of the iterations were controlled without informing the subjects in advance of when to stop. Once the preset time or number of iterations was reached, the subjects were required to stop. The preset time and number of iterations were fourteen minutes and thirty iterations, respectively.

In the procedure of the formal experiment, the government players were those who were aware of and required to follow the prespecified strategies. The resident players did not know the government players' strategies. The procedural introductions were thus made separately. In addition to strategies, rules of payoffs were also introduced by the instructor to all subjects. The layout of the experiment is shown in figure 1, according to the experimental design as shown in table 3. A thorough introduction of the hypothetical scenario was given to all subjects before the experiment proceeded.

The nine rules described below were followed as the experiment proceeded. (1) Each subject had two move cards, one with '○' and the other with '×', meaning 'cooperate'

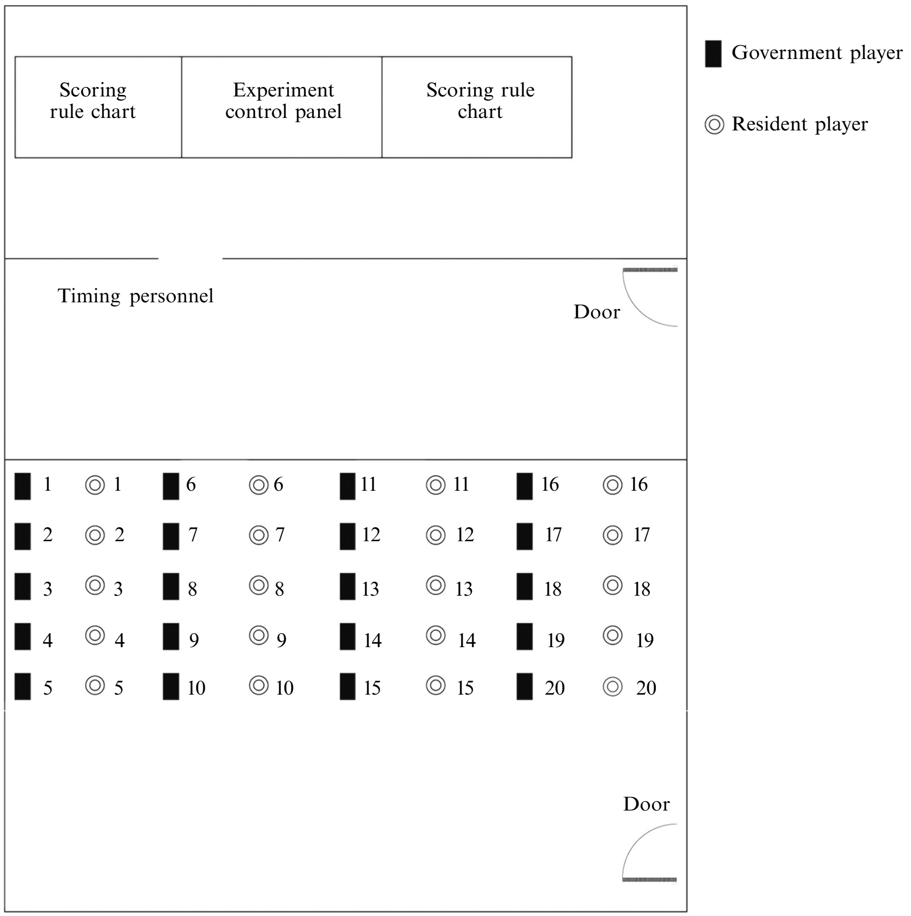

Figure 1. Layout of the experimental setting.

and ‘defect’, respectively. (2) Each subject showed the chosen move card at the same time, as directed by the instructor. (3) Once the card was shown, no changes were allowed to be made. (4) No conversing was allowed throughout the experiment. (5) All subjects were required to have a clear understanding of the roles played without questioning during the experiment. (6) The instructor helped the subjects to understand all the steps prior to the commencement of the experiment. (7) All subjects were randomly divided into eight subject groups. (8) All subjects were required to record all outcomes honestly. Payoffs gained from each game were to be recorded immediately on a record sheet. (9) Each group of subjects were required to participate in a pair of cases of both limited and unlimited numbers of iterations.

Subjects received the payoffs with the scoring rule as shown in table 4. Each subject was to read the information of the experiment and the payoff structure carefully (table 4). Furthermore, to motivate the subjects, the rules for pecuniary bonuses were designed as shown in table 5. The overall average is the average of total payoffs obtained from the cases of both the limited and unlimited numbers of iterations.

Table 4. Scoring rule chart.

Show of move card		Payoff (NT $)	
player 1 (government)	player 2 (residents)	player 1 (government)	player 2 (residents)
○	○	800 million	800 million
×	×	300 million	300 million
○	×	200 million	1.5 billion
×	○	1.5 billion	200 million

Note. ○ represents cooperate move, × represents defect move.

Table 5. Pecuniary bonus chart.

Overall average payoffs (NT $100 million)	Reward (NT $)
⩾ 10.0	300
8.0 – 9.9	150
6.0 – 7.9	50
⩽ 5.9	0

3 Results

In the case of a limited number of iterations just 25% (five subjects) of the residents wished to cooperate initially with the government. This implies that the residents were reluctant to cooperate with the government right from the start. The situation remained the same in the case of an unlimited number of iterations. However, as the game proceeded, there was an apparent increase up to 45% (nine subjects) of residents who chose to cooperate. This finding corresponds with the notion that cooperation emerges, as mentioned in Dixit and Skeath (2004). In a comparison of the four strategies, the results show that, in the case of a limited number of iterations, the tit-for-tat group yielded the highest payoff with a group average of $601 million, followed by the random group with $592 million, the faithful group with $570 million, and finally the trigger punishment group with the lowest payoff of $456 million [see table 6(a)]. Table 6(b) shows the results derived from the case of an unlimited number of iterations.

Table 6. Averaged payoffs by all strategy users in the case of (a) a limited number of iterations and (b) an unlimited number of iterations. All values are in NT $100 million.

Strategy group participant number	Faithful	Trigger and punishment	Tit-for-tat	Random
(a)				
1	6.25	2.6	7	7.25
2	2.85	5.8	5.85	6.05
3	4.15	5	5.8	5.35
4	8	5.9	7.9	5
5	7.25	3.5	3.5	5.95
Average	5.70	4.56	6.01	5.92
(b)				
1	6.2	6.56	6.48	4.64
2	7.4	2.16	7.52	6.28
3	2.96	7.04	3.88	6.88
4	5.8	2.96	8.2	9.04
5	5.56	2.8	7.92	4.88
Average	5.58	4.30	6.79	6.34

Table 7. The one-way analysis of variance for the case of (a) a limited number of iterations, and (b) an unlimited number of iterations, with the sums of payoffs across players.

	Sum of square	df	Mean square	F	p value
(a)					
Intergroup variance	33755.750	3	11251.917	3.34	0.020
Intragroup variance	41451.200	16	2590.700	3	
Total variance	75206.950	19			
(b)					
Intergroup variance	21755.350	3	7251.783	2.953	0.064
Intragroup variance	392997.200	16	2456.075		
Total variance	61052.550	19			

Note. df: degrees of freedom.

Again, the tit-for-tat group scored the highest group average payoff of $679 million, followed by the random group with an average payoff of $634 million, the faithful group with $580 million, and the trigger punishment group, again with the lowest payoff of $580 million. These findings correspond with the comparison derived from the mathematical deduction (Chiu and Lai, 2008); thus the first hypothesis is confirmed.

To investigate whether there is a difference in the application of strategies with respect to the time and number of iterations, a one-way analysis of variance (ANOVA) was conducted. According to the data in table 6, the analysis concludes that tit-for-tat is the best strategy, which also corresponds with the results from the mathematical deduction. It can be further analyzed whether the above results hold if the payoffs are computed as the sums of the two players across iterations. This can also be done for the cases both of limited and of unlimited numbers of iterations.

Under the condition of a limited number of iterations, the highest average of $12.02 billion was yielded by tit-for-tat, with the significance level at $p = 0.02$ on the basis of 0.05 [see table 7(a)]. Under the condition of an unlimited number of iterations, the highest average of $17 billion was yielded again by tit-for-tat, with the significance level at $p = 0.064$ on the basis of 0.05 [see table 7(b)].

We can conclude that, even summing up the payoffs across the players, tit-for-tat is still the best strategy, which confirms the second hypothesis.

4 Discussion

Asymmetry in time and power between the players was also considered in the experiment. For example, the government might face the pressure of time restriction in having the landfill facility constructed within a particular time frame (situation A). Alternatively, the government might have developed an alternative plan, in which time is no longer of concern, and hence they would not have to deal with public opinion (situation B). In both situations the results show that the majority of the residents still demonstrate distrust towards the government, and this accounted for over 65% of the subjects. Therefore, the government would have to acknowledge resident distrust as one of the issues relating to NIMBY facilities.

When time was constrained, the government faced situation A—a shorter or longer time frame, as manifested by limited and unlimited numbers of iterations, respectively. No differences among strategies were observed, as the residents were in a strong position in situation A. The government was limited in the choices of strategies, and so the dominating residents took charge in the negotiation. Owing to the limited strategies available to the government for applications, the differences made in the payoffs were not significant.

When time was not constrained, the government faced situation B—a longer time frame. The results show that the payoff gave the highest average value of $14.12 billion with the strategy of tit-for-tat being used. The ANOVA analysis, with a p-value of 0.031 (at the level of 0.05), demonstrates a significant difference. The experimental results prove that tit-for-tat is a superior strategy, as residents were expecting certain gains in the negotiation. Furthermore, in the case of a longer time frame, under situation B, the government dominated the game, and the faithful strategy enabled the government to obtain the highest average payoff of $14.8 billion, at the significance level of 0.01 on the basis of 0.05. This is because the government sought to maximize social welfare, and even when the residents cooperated, the government did not have to defect to maximize its own benefits. The government was aware of the fact that the defect move might have resulted in the risk of protests. Therefore, the highest social welfare was achieved by the faithful strategy when the residents decided to cooperate, such that the combination of moves remained at cooperate–cooperate.

Coase (1960) argues that, if the trading cost is zero, each agent will trade for his or her own rights until the Pareto efficiency is achieved, regardless of the allocation of rights. Because transaction costs exist, property rights cannot be completely allocated (for example, air pollution rights), just as the parking lots in suburban shopping malls are allocated in the first-come-first-served manner. Lai (2002) investigated the differences in the development permit system and the zoning system of land from the property rights point of view. Barzel (1997), on the other hand, investigated the loss of property rights to the public domain, and property-right-related concepts through the rationing theory and the control and agreement of competing petrol prices. Therefore, much can be said about the payoff measurements in the prisoner's dilemma game. For example, the payoffs in table 1 could be measured in terms of economic property rights, rather than just in terms of the physical compensations. In addition, because the present paper aims to verify experimentally that tit-for-tat is the best strategy using one subject group as the control group, this constraint limits half the subjects to preselected strategies, thus rendering the Nash equilibrium as a rare case.

The experimental findings are relevant to real planning situations. NIMBY facilities, such as landfill sites, incinerators, recycling stations, transformer stations, electricity or power facilities, and airports, are those that are deemed necessary in urban settings, but which are regarded by local residents as unwanted. Usually, the siting of these facilities invokes conflicts between local governments and residents in most democratic societies. Sometimes even medical facilities or fire and rescue stations are unwanted, owing to externalities, such as pollution and noise. The tension between local governments and residents in such situations increases as the society becomes more democratic, in that elected officials usually make policies in order to win votes. Therefore, local governments would try to concede as much to protesters, at least in Taiwan, resulting in more financial difficulty in implementing the construction plans for these facilities. The experimental findings could help local governments to cope wisely with NIMBY issues when faced with prisoner's dilemmas, without losing their negotiation ground. For example, the tit-for-tat strategy proves to be more beneficial than other strategies, not only to the local government, but also to the society as a whole. In similar real planning situations that are reminiscent of prisoner's dilemmas—including a local government as regulator versus a private land user as developer; a private land user versus another private land user, both as developers; a private land user as developer versus a community group as landowners; and a local government versus a higher tier or neighboring local government, both as regulators—planners can also gain useful insights from the experimental findings into how to deal with the issues of land and community development. For example, holdouts could be minimized by mechanism designs which are based on effective social interactions found in the experiment to enhance just land and urban development.

5 Conclusions

This research is motivated by a mathematical generalization to verify experimentally that tit-for-tat is the best interactive strategy. It was carried out through an experiment on the siting of NIMBY facilities. Both hypotheses were confirmed; that is, the experimental results show that, not only can the tit-for-tat strategy create better payoffs for the player who adopts the strategy, but it can also provide a better outcome when payoffs are summed across players. The confirmation of the former corresponds with the mathematical deduction, whereas the mathematical proof of the latter prompts future work. Useful insight can be gained for both cases as to what strategies to adopt in a prisoner's dilemma situation in general, and in siting NIMBY facilities in particular.

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