The Role of Subsidies in a Social Network with Interconnected Risk

Min Gong
Columbia University
mg3030@columbia.edu

Geoffrey Heal
Columbia University

David H. Krantz
Columbia University

Howard Kunreuther
Wharton School
University of Pennsylvania

Elke U. Weber
Columbia University

Working Paper # 2011-12

Risk Management and Decision Processes Center
The Wharton School, University of Pennsylvania
3730 Walnut Street, Jon Huntsman Hall, Suite 500
Philadelphia, PA, 19104
USA
Phone: 215-898-4589
Fax: 215-573-2130
http://opim.wharton.upenn.edu/risk/

THE WHARTON RISK MANAGEMENT AND DECISION PROCESSES CENTER

Established in 1984, the Wharton Risk Management and Decision Processes Center develops and promotes effective corporate and public policies for low-probability events with potentially catastrophic consequences through the integration of risk assessment, and risk perception with risk management strategies. Natural disasters, technological hazards, and national and international security issues (e.g., terrorism risk insurance markets, protection of critical infrastructure, global security) are among the extreme events that are the focus of the Center's research.

The Risk Center's neutrality allows it to undertake large-scale projects in conjunction with other researchers and organizations in the public and private sectors. Building on the disciplines of economics, decision sciences, finance, insurance, marketing and psychology, the Center supports and undertakes field and experimental studies of risk and uncertainty to better understand how individuals and organizations make choices under conditions of risk and uncertainty. Risk Center research also investigates the effectiveness of strategies such as risk communication, information sharing, incentive systems, insurance, regulation and public-private collaborations at a national and international scale. From these findings, the Wharton Risk Center's research team – over 50 faculty, fellows and doctoral students – is able to design new approaches to enable individuals and organizations to make better decisions regarding risk under various regulatory and market conditions.

The Center is also concerned with training leading decision makers. It actively engages multiple viewpoints, including top-level representatives from industry, government, international organizations, interest groups and academics through its research and policy publications, and through sponsored seminars, roundtables and forums.

More information is available at http://opim.wharton.upenn.edu/risk.

The Role of Subsidies in a Social Network with Interconnected Risk

Ming Gong, Geoffrey Heal, David H. Krantz, Howard Kunreuther and Elke U. Weber

Abstract

Can subsidies promote Pareto-optimum coordination? We found that partially subsidizing the cooperative actions for 2 out of 6 players in a laboratory coordination game usually produced better coordination and higher total payoffs both with deterministic and stochastic payoffs. Not only were the subsidized players more likely to cooperate (choose the Pareto-optimum action), but the unsubsidized players increased their expectations on how likely others would cooperate and they cooperated more frequently themselves. After removing the subsidy, high coordination rates continued in most groups with stochastic payoffs, but declined for groups with deterministic payoffs. A post-game survey indicated that with stochastic payoffs, players focused on risk reduction. Temporary subsidies promoted lasting coordination because even after the subsidy was removed, players still assumed that others players would prefer reduced risks from cooperation. With deterministic payoffs, however, the subsidy might crowd out other rationales for coordination, with many players indicating that subsidy was the only reason for anyone to cooperate. Hence the coordination level dropped when the subsidy was removed.

1. Introduction

In many situations, including interactive games or social networks, people often influence each others' decisions. Examples in economics include Schelling's (1978) tipping points on racial composition in a neighborhood, and Leibenstein's (1950) "bandwagon effects" in which one agent's demand for a good increases with others' demand level. In sociology Granovetter (1978) and Watts (2002) have studied similar phenomena using network models of social interactions.

The existence of mutual influence has been captured by coordination games with multiple Pareto-ranked Nash Equilibria (NE). Interdependency among airlines with respect to baggage security (Kunreuther and Heal 2003) is an example of such coordination. Airline companies have to choose whether to invest in baggage security screening equipment. Such an investment reduces the risk of bombs in bags checked on their own airline, but each company still faces indirect risks of unsafe bags transferred from other airlines that did not invest in the screening equipment. The Pareto-optimal NE is that all airlines invest in security systems. An inferior NE is that no airline invests, because each believes that the indirect risk from unsafe airlines is so high that the benefits from investing in protection is less than the costs. Other instances of interdependent security (IDS) include wildfire protection decisions (Shafran, 2008), computer network security updates (Kearns 2004), and the failure of divisions in financial organizations to control risk (Kunreuther and Heal 2005; Kunreuther 2009).

Another illustrative example with multiple NEs arises in the garbage disposal decisions faced daily by households in some communities in China. Often 20-30 households share a garbage bin near their apartment building. However, some households leave their garbage outside the bin. This behavior may affect others in at least three ways. First, as garbage left outside accumulates, others must wade through it in order to dump their own garbage inside the bin; this imposes an extra cost. Second, the behavior signals that littering is acceptable in this community, thus reducing the psychological influence of a social norm for public cleanliness. Third, the goal of public cleanliness, even if still valued by some, may seem unattainable so that it is not worth exerting effort to try and meet it. The resulting NE is where everyone leaves their garbage outside. Whereas most people prefer the NE where everyone places their garbage inside the bin, with a cleaner environment at slightly additional cost, the inferior NE of littering outside the bin is so common in China that during the 2008 Beijing Olympic season, one of the public slogans the government circulated was "Learn to be Civilized and Dump your Garbage in the Bin".

Note the difference between the garbage bin and the airline security examples. Airline security investment is a coordination game in a stochastic setting: outcomes depend not only on the degree of cooperation (how many airlines invest in protection) but also on low-probability high-impact moves by "nature" (terrorist attacks). The garbage disposal coordination involves deterministic outcomes, which depend only on the degree of coordination, i.e. the number of households who leave garbage outside the bin. Other deterministic examples with Pareto-ranked equilibria include hiring private tutors for one's children for them to achieve better grades than others in their class, or using commercial software instead of open source software.

The above examples illustrate social reinforcement mechanisms in which positive decisions by a few individuals are likely to lead others to follow suit. Recently, Heal and Kunreuther (2010) modeled this behavior in a game-theoretical framework by showing that changes in the decisions by a subset of players (a "tipping set") can theoretically shift the system from one equilibrium to another. External incentives given to an appropriate set of players can lead to cascading or tipping so the system reaches the socially optimal equilibrium.

One obvious external intervention is to subsidize the members of a tipping set so they choose the strategies corresponding to an efficient outcome. Zhuang et al. (2007) present a dynamic theoretical model of interdependent security where the probability of losses evolves over time and the agents have heterogeneous discounting rates. Zhuang et al. conclude that a subsidy is more efficient if allocated to those agents least likely to improve security on their own. Shafran and Lepore (2011) and Shafran (2010) confirm that an asymmetric subsidy paying different amounts to different agents can eliminate the inferior equilibrium at less expense than the same subsidy for all players.

2. Role of Incentives in Coordination Games

This paper investigates how people respond to positive incentives in an interdependent coordination game. Rational choice theories, such as traditional economic models, predict that subsidies promote the Pareto optimum because non-subsidized players believe that this optimum is more likely to be attained, given that subsidized players will choose the Pareto preferable option (Heal and Kunreuther, 2010). On the other hand, human motivation typically is more complex than suggested by rational choice theories that focus only on outcomes. In contrast, decades of behavioral decision decision research has demonstrated that inference and decision processes and motivations play an important role in shaping people's preferences and choices (Weber and Johnson, 2009).

As an example, research in psychology reported that expecting material rewards reduced intrinsic incentives for previously enjoyable activities (Lepper et al, 1973; Greene et al., 1976). This motivation damage brought by the positive external rewards has been referred as the overjustification effect. Another example is the relationship of altruism and monetary compensation in blood donation (Titmuss 1971). Titmuss suggests that more blood was wasted in the U.S. than in Britain. In the U.S. recipients paid for blood and some donors were paid for their donation; in Britain blood was received by altruistic donors and given to recipients free of charge. He also argued that blood purchased in America was less safe and hospitals experienced shortages of blood more frequently.

More recently, behavioral economists have begun to test the relationship between financial reward and motivation. Motivation crowding theory (Frey and Jegen, 2001) suggests that external monetary interventions, such as a subsidy or a financial punishment, may undermine intrinsic motivations, by changing either the decision maker's preference, or changing her perception of the task.

In a field study, Meier (2007) investigated the effect of subsidies in encouraging the provision of one type of public good, charitable giving. He found that people were more willing to contribute when a donation-matching mechanism was applied, but the contribution rate declined after the matching mechanism ceased. Furthermore, the post-subsidy reduction was large enough for the matching mechanism to post a negative effect on average donations. Meier proposed several possible underlying reasons for this crowding-out effect including the possibility that economic incentives undermine pro-social motivations, such as a sense of responsibility or trust between donors and receivers being reduced by the subsidy. Conditional cooperation can be compromised if incentives lead individuals to conclude that nobody will contribute in the absence of the material incentive, and hence they themselves do not contribute.

More generally in coordination games, players' strategies depend not only on their own preferences and motivations, but also on their perceptions of those of other players. Subsidies could potentially "crowd out" other reasons for a given choice of strategy, which may cause players to be even less willing to choose the Pareto preferable option. In other words, a subsidy in the interdependent coordination game may undermine the naturally occurring optimal equilibrium.

Coordination in stochastic settings may differ from coordination with deterministic payoffs as illustrated above when comparing investment in airline security and disposal of garbage. Berger and Hershey (1994) find participants less likely to contribute to a public good when returns are stochastic rather than deterministic. Bereby-Meyer and Roth (2006) report that people's learning to cooperate in a prisoner's dilemma game is reduced when the payoffs are noisy. Kunreuther et al (2009) shows that individuals are much more likely to be cooperative in prisoner's dilemma games when payoffs are deterministic than when the outcomes are probabilistic with approximately the same expected value. Gong et al. (2009) report that individuals are less cooperative than groups in deterministic prisoner's dilemma games, but more cooperative than groups when the outcomes are stochastic.

We next briefly describe work on coordination games in both deterministic and stochastic settings. Experimental studies on coordination games in deterministic settings have attracted much attention over the past two decades. The existence of multiple equilibria in coordination games makes it difficult to predict which equilibrium a system will reach. The problem is thus an empirical one. Following Van Hayck et. al (1990, 1991), we refer to failing to reach the Pareto optimum equilibrium in a coordination game as *coordination failure*. Previous experimental research has found that coordination failure is common in the lab, but that coordination can be improved by a variety of methods (for a review, see Camerer, 2003).

Camerer (2003) divides coordination games into three categories: matching games, e.g. beauty contest game; games with asymmetric payoffs, e.g. battle of sexes; and games with asymmetric equilibria, e.g. the stag hunt game. The game type most related to our work is the order-statistic game with multiple Pareto-ranked Nash equilibria (Van Hayck et. al, 1990, 1991) of which the stag-hunt game is a special case. In a typical order-statistic game, N players each choose among a fixed set of ordered actions, (X_1, X_2, ..., X_n). A player's payoff is increasing in an order-statistic of all players, usually the median or minimum of the chosen actions, and decreasing in the deviation of the player's choice from the order-statistics.

This game mimics a real-world decision faced by team members in joint production. The higher the median effort, the higher is the production level, and the better off everyone in the production team is. But the effort involves a cost for the individual member. Thus one's best strategy is to choose an effort level that is as close as possible to the median level, not to work too hard or too little. Multiple Pareto-ranked Nash equilibria exist in an order statistic game: all players choosing X_1, or X_2, ... , or X_n. Depending on the nature of the order statistic, usually there is a payoff-dominant or efficient equilibrium in which all players choose the highest action to maximize the payoffs, and a secure equilibrium in which all players choose the action that maximize the lowest possible payoff.

Previous research finds that people often fail to reach the payoff-dominant equilibrium and fall into the security equilibrium that yields lower payoffs in order-statistic games. Different studies have tested different ways to encourage coordination, such as lowering the attractiveness of the secure action (Brandts and Cooper, 2004), reducing deviation cost from the order statistic (Goeree and Holt, 2005), smaller group size (Van Huyck et al., 2007), and communication and information sharing (Van Huyck et al., 1993; Chaudhuri et al., 2009).

One method that is particularly relevant to our research on subsidy is charging an entry fee to encourage coordination in an order-statistic game. The fee can be viewed as a negative monetary incentive. Subjects in Cachon and Camerer (1996) coordinate to an equilibrium with higher payoffs when they have to pay an entry fee than when there is no fee, because players use "avoid losses" as a selection principle, which implies that only the actions that yield at least the entry fee will be selected. Using projection, they also expect others to try to avoid losses, and choose an equilibrium with a positive payoff after the entry fee is subtracted. In a sense, the entry fee functions as a negative subsidy that changes both the players' preferences and their expectation of other players' preferences. A more complete review on the order statistic game, including the stag-hunt game, has been provided by Devetag and Ortmann (2007).

The games characterizing the experiments in this paper also belong to the category of critical mass games. In a critical mass game, players usually make binary decisions (X or Y), and once a threshold of players choose X (Y), all other players can be expected to follow suit. Urban segregation and weekly seminars participation are typical examples of a critical mass game (see Schelling (1978) for more details) as are the threshold public good games in which the good is provided once the total contribution meets or exceeds a threshold value (Van de Kragt et al., 1983; Isaac et al., 1989). In a critical mass game, information about other player's historical decisions and increasing returns above the critical mass encourage players to reach the efficient equilibrium (Devetag 2003).

An additional complication arises in situations characterized by the presence of uncertainty, such as the IDS game. In a stochastic coordination game, the decisions of the agents depend on both their expectation of others' actions and their own risk preferences. For example, Hess et al. (2007) find that coordination failure is common in an IDS game in which players simultaneously make decisions to coordinate investment to reduce the probability of losses, but coordination is improved when the degree of interdependency is small relative to the overall risk, or when decisions are made sequentially, because the leader decides to cooperate with the expectation that others will follow suit. Shafran (2010) shows that the coordination level improves when two players are removed from a 7-person IDS game and the payoff structure is modified so that it becomes a 5-person game with two extra players (other players being unaware of the two extra players) implicitly choosing the preferable option.

To determine potential reasons for previously observed differences between successful and unsuccessful coordination in stochastic and deterministic settings, we empirically studied subsidy effects in both types of coordination game. In light of the disparity between the positive short-term effect and negative long-term impact of subsidies reported by Meier (2007), we also tested whether the consequences of a subsidy carried over to subsequent non-subsidized periods. We found that partially subsidizing 2 out of 6 players in a laboratory coordination game usually produced greater coordination and higher total payoffs than when subsidies were not provided. This was especially noticeable in a stochastic setting where a subsidy had a significant effect in tipping some groups into the Pareto-optimum equilibrium. After removal of the subsidy, high levels of coordination continued in most groups with stochastic payoffs, but declined with deterministic ones.

A post-game survey indicated that with stochastic payoffs, players focused on risk reduction. Temporary subsidies promoted lasting coordination because, even after subsidy was removed, players still assumed that others players would prefer reduced risks from cooperation. With deterministic payoffs, however, the subsidy might crowd out other rationales for coordination, with many players indicating that subsidy was the only reason for anyone to cooperate. Hence the coordination level dropped when subsidy was removed.

Section 3 describes the study design, Section 4 describes our results. Implications are discussed in Section 5.

3. Experimental Design

3.1 General Setup

We conducted two games: a stochastic coordination game and a deterministic one. The stochastic game is based on the IDS game by Kunreuther and Heal (2003), in which n players each need to make a discrete decision, strategy A or B. All players face the possibility of a local security breach with probability p of losing L. Strategy A can eliminate the risk of a local breach at a cost of C. A player also faces possible interdependent security breaches, i.e., cross breaches from other players. If any player suffers a loss, all other players have a probability q of being contaminated and losing

L. Players can only suffer the loss once, either from the local breach or the cross breach. Each player's initial wealth is *Y*.

Let $\pi(i, m)$ denote the payoff of a player who chooses strategy *i* when *m* out of *n-1* other players choose strategy *A*, and $i \in \{A, B\}$. The player's expected payoff for choosing *A* or *B* when no other players choose A are given respectively by

$$\pi(A,0) = Y - C - \{q \prod_{t=0}^{n-2} (1-q)^t\} L \qquad (1)$$

and

$$\pi(B,0) = Y - \{p + (1-p) q \prod_{t=0}^{n-2} (1-q)^t\} L \qquad (2)$$

On the other hand, if all other players choose *A*, then

$$\pi(A, n-1) = Y - C \qquad (3)$$

and

$$\pi(B, n-1) = Y - pL \qquad (4)$$

In a coordination game, $\pi(A,0) < \pi(B,0)$, and $\pi(A,\text{n-1}) > \pi(B,\text{n-1})$. That is, a rational and risk neutral agent will choose *A (B)* if all other players choose *A (B).* Thus there are two Pareto-ranked NEs, all-*A* and all-*B*. All-*A* is the preferable equilibrium. Depending on the values of the parameters, there is a tipping point *s* at which $\pi(A,s) \geq \pi(B,s)$ and $\pi(A,s-1) < \pi(B,s-1)$.

3.2 The Coordination Games

There were 6 players in our game. The parameters were chosen so that the tipping point was 4. That is, if 4 or more players chose *A*, a player had a higher expected payoff by also choosing *A* rather than *B*. Otherwise, the player should choose *B*. A fictitious currency (Talers) was used with 50 Talers equal to \$1. The parameters in our game were *p*=0.4, *q*=0.2, *Y*=2000 Talers (exchangeable for \$40), *C*=32 Talers, *L*=100 Talers, *n*=6, and *s*=4. Table 1 shows a player's probabilities of suffering a loss when she chose *A* or *B* as a function of other players' decisions.

Table 1: Probabilities of Losing 100 Talers in the Stochastic Game

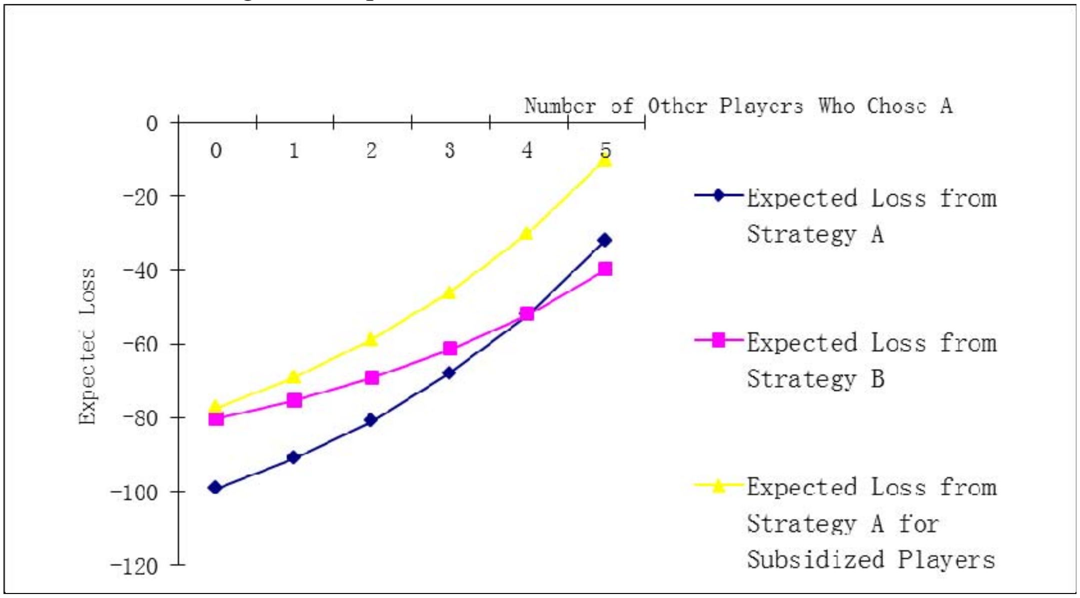
		Number of Other Players Who Choose Option A					
		0	1	2	3	4	5
Your Choice	**Option A** (cost= 32)	67%	59%	49%	36%	20%	0%
	Option B (cost= 0)	80%	75%	69%	61%	52%	40%

As shown in Figure 1, the expected loss by choosing Option *B* is less than the expected loss (including the cost of choosing *A*) of Option A until at least 4 players choose *A*. Theoretically if less than 4 players choose *A*, the system tips to the Pareto-inferior equilibrium, all-*B*. Otherwise, the system converges to the

Pareto-superior equilibrium, all-*A*. Both equilibria were observed in our study[1].

Note that in Figure 1, there is a third line that represents the expected loss from Strategy A for subsidized players. The subsidy was set to 22 Talers. That is, those who are subsidized pay 10 Talers to play Strategy A instead of 32 Talers. For a risk neutral subsidized player, the expected loss of strategy A (the yellow line) is always less than that of strategy B (the purple line).

Figure 1: Expected Loss in the Coordination Game



To create a corresponding deterministic game, we removed the uncertainty of payoffs in the stochastic game and provided players with the expected value of each cell in the stochastic game, as described in Table 2.

Table 2: Possible Losses in the Deterministic Game

		Number of Other Players Who Choose Option A					
		0	1	2	3	4	5
Your Choice	**Option A** (cost= 32)	-67	-59	-49	-36	-20	0
	Option B (cost= 0)	-80	-75	-69	-61	-52	-40

3.3 Four Conditions

A 2X2 between-subject design: (Subsidy vs. Baseline) X (Stochastic Game vs. Deterministic Game), allowed us to test the effect of a subsidy in promoting the Pareto-optimum equilibrium in coordination games, and to look for an interaction between providing a subsidy and behavior in either the stochastic and/or deterministic setting.

As in most coordination studies, we ran repeated games to allow for learning

[1] Some groups never reached either equilibrium and stabilized with some choosing A and others choosing B.

and convergence to the equilibria. The same 6 players played 20 periods of the same game in a session. Each player was given 2000 Talers at the beginning of the session. As shown in Table 1, in each period a player's probability of suffering a 100-Taler loss, *X*%, depended on both their own and other players' decisions. The server computer then generated a random number between 0 and 100. If the random number was smaller than or equal to the value of *X,* the player lost 100 Talers. The losses over the 20 periods were accumulated and deducted from players' initial wealth. Participants were told that there was a 20% chance that their final payoff would depend on their number of Talers at the end of the study. Before making their decision between Option *A* and *B* in each period, players also indicated how many other players they expected to choose *A*. After each period *t*, players were given information on their loss, their accumulated losses, wealth level, and the number of players choosing *A* in all past periods, including period *t.*

We tested whether there was a carry-over effect of a subsidy by running a second session in each condition. At the beginning of Session 2, players' wealth level was restored to 2000 Talers. The same 6 subjects played the same type of game (stochastic or deterministic) for another 20 rounds, with the subsidy removed for those who were given a subsidy in Session 1, and the subsidy added for those who were in the baseline conditions in Session 1. Players were not aware of the existence of Session 2 until they finished Session 1.

3.4 Participants and Procedure

294 people (49 6-person groups) participated in the study. 82% of participants were between 18 and 25 years old, and 62% were females. All were paid a $10 show-up fee. 20% of the players were randomly chosen to be paid the dollar values of Talers they earned at the end of the study. The data collection for Group 8 could not be completed because of a mechanical failure. All data analyzed in this paper were from the remaining 48 groups.

The study was conducted in the behavioral labs of two Northeastern universities using Z-tree, a software package for developing economic experiments (Fischbacher, 2007). Each player was provided with a personal computer to make his/her decisions, with the computers of the six group members in the same room, but in separate cubicles to provide anonymity. Participants were not allowed to talk to each other. Instructions were read aloud to insure that the rules and payoff structure of the game were common knowledge, an important consideration in examining how players formed their expectation of other players' decisions.

After reading the instruction and before playing the game, all participants were required to complete a quiz that contained questions regarding the game, the procedure, decision method, and payment information. At the end of the experiment, participants answered questions on demographics, their reasons for choosing A or B, and the Holt and Laury survey that measured their risk preference (Holt & Laury (2002).

4. Hypotheses and Results

4.1 Hypotheses

We tested the following hypotheses:

The General Subsidy Effect Hypothesis.

H1: Players are more likely to choose Strategy A with subsidy than without subsidy in both the stochastic and deterministic game. H1 was tested using the between-subject data from 48 groups in Session 1 only.

The Subsidy Carry-over Effect Hypothesis.

H2: The higher cooperation rate in Session 1 due to a subsidy is sustained after the subsidy is removed. H2 was tested using data from Sessions 1 and 2.

4.2 Results for Session 1

Average cooperation rates (percentage choosing A) across periods in the 4 conditions are reported in Table 3. We first focus on the data from Session 1. Random effect logit regressions confirmed H1, i.e., players were more likely to choose Strategy A with a subsidy than without a subsidy ($p<0.01$) after controlling for period and individual subject differences. The complete regression results are reported in Table 4. Social welfare, computed as summed payoff minus subsidy cost, was 7% higher in the subsidy conditions than in the baseline conditions, in both the deterministic and stochastic settings. Note that the coefficient for Period is negative and marginally significant ($p=0.09$), indicating that the coordination level decreased over time. This is consistent with previous findings in coordination games (Camerer 2003).

Table 3: Percentage of Choosing A in the Four Conditions

Name	DB1-DS2		DS1-DB2		SB1-SS2		SS1-SB2	
# of 6-Person Groups	13		13		10		12	
	Description	Percentage	Description	Percentage	Description	Percentage	Description	Percentage
Session 1	Deterministic-Baseline	0. 64	Deterministic –Subsidy	0. 76	Stochastic-Baseline	0. 71	Stochastic-Subsidy	0. 79
Session 2	Deterministic-Subsidy	0. 79	Deterministic-Baseline-	0. 67	Stochastic-Subsidy	0. 76	Stochastic-Baseline	0. 79

Table 4. Random Individual Logit Model for Choosing Strategy A in Session 1

Variable	Coefficient	Standard Error	z value	Pr(>|z|)
Dependent Variable				
Choosing A				
Independent Variables				
Constant	1.25	0.26	4.72	0.00
Stochastic Game	0.48	0.31	1.55	0.11

Subsidy	1.08	0.31	3.51	0.00
Fixed Effects				
Period	-0.01	0.006	-1.68	0.09
Rho	5.78	2.40		
Log likelihood		-2385		
Sample size		5760		

Figure 2 provides more details on the average cooperation rate in each period. The unit numbers on the y-axis correspond to the number of players choosing A. For example, the cooperation rate on the y-axis is 0.17 if only 1 out of 6 players in that group chose A. At first sight, it appears that the subsidy effect in encouraging players to choose A are similar in the stochastic and deterministic game, except that players were somewhat more likely to choose Option A in the stochastic game than in the deterministic game, although the differences are not statistically significant (p=0.11). The average cooperation rates, however, mask important group differences and decision dynamics in different periods, as shown in Table 5

Figure 2: Cooperation Rates in Session 1

Table 5 reports all 48 groups' cooperation rates in the 20 periods of Session 1 grouped into Period 1-5, 6-15, and 16-20. Again, group averages in each period category confirm H1, namely that subsidy encouraged players to choose Option A. The subsidy-induced coordination improvement occurred at the beginning periods (Period 1-5) and was sustained through the game. This suggests that the subsidy changed participants' expectations of the number of other players who might choose Option A, and that the options chosen by others over time confirmed these expectations.

Table 5: Average Cooperation Rates in each Group by Periods in Session 1

	Stochastic – Baseline
	Group Number

	6	7	9	10	22	23	30	31	32	33				Average
Period 1-5	1.00	0.47	0.73	0.57	0.67	0.80	0.93	0.83	0.43	0.93				0.74
Period 6-15	1.00	0.62	0.43	0.33	0.77	0.80	0.90	0.80	0.57	0.80				0.70
Period 16-20	1.00	0.67	0.27	0.67	0.77	0.67	0.83	0.80	0.40	0.77				0.68
All Periods	1.00	0.59	0.47	0.48	0.74	0.77	0.89	0.81	0.49	0.83				0.70
	Stochastic – Subsidy													
	Group Number													
	5	11	12	13	18	19	20	21	35	37	38	39		Average
Period 1-5	0.77	0.80	0.80	0.63	0.80	0.80	1.00	1.00	0.83	0.93	0.53	0.83		0.81
Period 6-15	0.77	0.80	0.58	0.83	0.73	0.80	0.98	0.98	0.87	0.98	0.50	0.67		0.79
Period 16-20	0.87	0.83	0.57	0.90	0.73	0.70	0.87	1.00	0.77	1.00	0.37	0.63		0.77
All Periods	0.79	0.81	0.63	0.80	0.75	0.78	0.96	0.99	0.83	0.98	0.48	0.70		0.79
	Deterministic – Baseline													
	Group Number													
	1	2	15	24	28	29	34	36	45	46	47	48	49	Average
Period 1-5	0.57	0.90	0.77	0.80	0.20	0.27	0.50	0.53	0.60	0.53	1.00	0.63	0.67	0.61
Period 6-15	0.37	1.00	0.98	0.90	0.70	0.07	0.35	1.00	0.28	0.43	1.00	0.52	0.92	0.66
Period 16-20	0.37	1.00	1.00	0.97	0.63	0.07	0.20	0.97	0.13	0.20	0.97	0.83	1.00	0.64
All Periods	0.42	0.98	0.93	0.89	0.56	0.12	0.35	0.88	0.33	0.40	0.99	0.63	0.88	0.64
	Deterministic – Subsidy													
	Group Number													
	3	4	14	16	17	25	26	27	40	41	42	43	44	Average
Period 1-5	0.73	0.70	1.00	0.97	0.43	0.70	0.83	0.97	0.53	0.53	0.93	0.40	1.00	0.74
Period 6-15	0.73	0.85	1.00	0.82	0.75	0.55	0.98	0.98	0.57	0.50	0.95	0.45	1.00	0.78
Period 16-20	0.60	0.80	1.00	0.93	0.47	0.57	1.00	0.97	0.53	0.40	0.97	0.47	0.97	0.74
All Periods	0.70	0.80	1.00	0.88	0.60	0.59	0.95	0.98	0.55	0.48	0.95	0.44	0.99	0.76

It is instructive to ask whether the expectations regarding the cooperation rate differed between subsidized and unsubsidized players. The rational theory discussed in the beginning of the paper predicts that the unsubsidized players would increase their expectation of the coordination rate when realizing that the two subsidized players would probably choose Option A. The subsidized players would also predict a higher coordination rate for the same reason. Bounded rationality with its acknowledgement of finite attention and limited information processing capacity (e.g., Simon, 1957) predicts that the effect of a subsidy would be more salient to the subsidized players than to the unsubsidized players, because the subsidized players were personally experiencing it. In contrast the unsubsidized players were told that others were able to incur a lower cost of investing in A than they were; they thus would be expected to see the subsidy as a changed set of game rules (Hertwig et al., 2007).

The random effect (individual subjects) regression results in Table 6 confirm both predictions. Compared with the expectations of the players in the Baseline conditions, unsubsidized players in the Subsidy condition had higher expectations as to how many others players would choose A ($p<0.01$), confirming the rational theory.

The unsubsidized players' expectations, however, were lower than the expectations of the subsidized players (p=0.01), consistent with the bounded rationality predictions. The increase in expectations affected the behavior: the unsubsidized players in the Subsidy condition were more likely to choose A than players in the Baseline condition (p<0.01). Similar results are found when using data from the 1st period or from the first five periods only.

Table 6. Subsidy Effects on Expectations

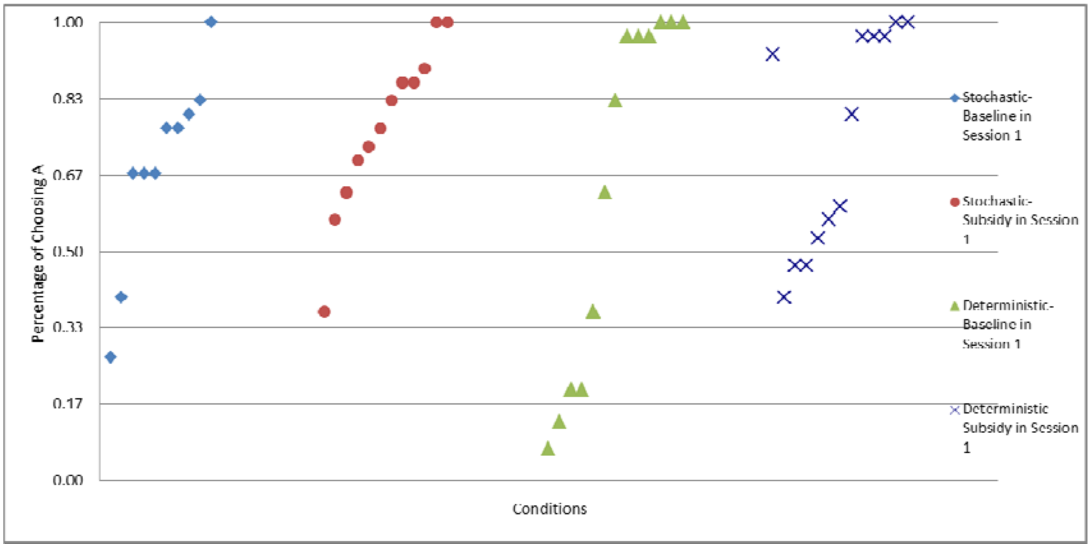
Variable	Coefficient	Standard Error	t value	Pr(>|z|)
Dependent Variable				
Expectation on the number of others choosing A				
Independent Variables				
Constant	3.66	0.11	34.49	0.00
Players in Baseline Condition	-0.37	0.12	-3.00	0.00
Subsidized Players in Subsidy Condition	0.06	0.04	2.16	0.01
Stochastic Game	0.0	0.12	0.76	0.76
Period	0.01	0.002	6.63	0.00
Log likelihood		-8228		
Sample size		5760		

We now turn to differences in reaching successful coordination in the last five periods between the four conditions. Figure 3, showing average cooperation rates in Period 16-20 of Session 1, reveals interesting and important similarities and differences between the stochastic and deterministic games. First, there is a clear pattern that subsidy did improve the cooperation rates. Recall that the tipping point for choosing A based on the rational theory prediction is the expectation that 4 other players will choose A. Hence we define an efficient equilibrium as 5 or more players choosing A (i.e., cooperation rate equal to or greater than 0.83) in the last 5 periods, and an inefficient equilibrium as 2 or fewer players choosing A (i.e., cooperation rate equal to or smaller than 0.33) in the last 5 periods. With subsidy, more groups reached the efficient equilibrium and less groups stabilized at the inefficient equilibrium than in the baseline. This was true for both the deterministic and stochastic game.

Second, both Nash equilibria, all-A and all-B, were observed in the study, although a large number of groups never reached the theoretically predicted equilibria. No groups were trapped in the inefficient equilibrium in games with a subsidy, because, as the payoff graphs shows in Figure 1, choosing A is always preferable than B for the two subsidized players, unless they are extremely risk seeking, even when no other players choose A. The data confirm that subsidized players chose option *A* 91% of the time.

Third, as predicted, subsidy tipped some groups toward the Pareto-superior equilibrium. The tipping effect of the subsidy is clearly illustrated in the stochastic game. As shown in Figure 3, in the Stochastic-Baseline condition, only 2 out of 10 groups (20%) had a cooperation rate over 0.83, only one group converged on the inefficient equilibrium, and the majority of the groups were stuck between the two NEs. In the Stochastic-Subsidy condition, 6 out of 12 groups (50%) successfully reached the efficient equilibrium.

Figure 3: Cooperation Rate in Groups in Period 16-20 in Session 1



Fourth, there is a noticeable difference in the patterns of how subsidy affected the deterministic game vs. the stochastic game. 11 of the 13 groups in the Deterministic-Baseline condition reached the predicted NEs, consistent with previous research (Van Huyck et al., 1997). In particular, 7 groups reached the efficient equilibrium, and 4 groups clustered at the inefficient equilibrium, and only 2 groups settled between the two NEs. In the Deterministic-Subsidy condition, the majority of the groups had 2-4 players choosing A, i.e., no group converged at the inefficient equilibrium; similar number of groups reached the efficient equilibrium as in the baseline condition.

To summarize, subsidy improved coordination in the stochastic game by tipping half of the groups towards the efficient equilibrium, and by diverting one third of the groups away from the inefficient equilibrium in the deterministic game. However, several questions remain unanswered by the data. For instance, why do players show a dichotomous pattern in the Deterministic-Baseline condition, but cluster in the middle in the Stochastic-Baseline game (shown in Figure 3)? Why does subsidy help the divided groups in the stochastic game to reach the efficient equilibrium, but not those in the deterministic game? The post-game survey provides some tentative answers to these questions.

An answer to the first question on why most groups in the Stochastic-Baseline condition chose a mixture of Options A and B appears to be related to the risk control strategy of the players. Players' decision in the stochastic game depends not only on their expectation of what others will do, but also their own risk preferences. The risk preference data collected in our post-game survey confirmed that the more risk-averse a player was, the more likely she would choose Strategy A to reduce her chance of suffering a 100-Taler loss ($p<0.01$) whether or not she was subsidized. 78% of the players in the stochastic game considered A to be a safer option than B. Players with a high degree of risk aversion may thus always prefer A to B, even when they expect others to choose B. This would explain why we rarely observed the All-B equilibrium in the Stochastic-Baseline condition. Risk-seeking players may decide not to pay the cost of choosing A, even though they expect others to do so, which explains why we observed only two groups reaching the All-A equilibrium.

How does a subsidy affect the deterministic and stochastic game differently? To answer that question, we first analyze how a subsidy might have encouraged those groups that settled in the middle to reach the efficient equilibrium in the stochastic game. On the one hand, subsidy encourages subsidized players to choose A. At an unsubsidized cost of 32 Talers players who are not very risk averse would be willing to take their chances of a loss and choose B; with a subsidized cost level of 10 Talers, they will then want to switch to A. On the other hand, the unsubsidized players are also more likely to choose A by perceiving that the subsidized players will want to switch from B to A.

For example, as shown in Table 1, a moderately risk averse player may expect only one other player to choose A, and decide that it is not worth 32 Talers to reduce the risk of losing 100 Talers from 75% to 59%. Assume that this player is not subsidized but increases her expectation of the number of players choosing A from 1 to 3 when she believes that 2 subsidized players will choose A. She is now willing to pay 32 Talers to reduce her risk from 61% to 36%. Note that in this example, the new expectation is still below the tipping point of a risk- neutral agent, 4, but a risk averse player may be tipped towards A anyway. This is not likely to be the case in the deterministic game. In other words, although in theory both games have a tipping point at 4, the stochastic game may have a lower tipping point depending on the risk preferences of the players in specific groups.[2]

We speculate that the differences in the actual tipping point is a possible reason why subsidy encourages some divided groups to reach the efficient equilibrium in the stochastic game, but has little effect on those in the deterministic game. The expectation question data indicate that the average expectation of the efficient groups in the stochastic game is significantly lower than that in the deterministic game (4.5 vs. 4.1, $p<0.01$). This implies that a lower tipping point is probably required to change players' strategy from B to A in the stochastic than in the deterministic game.

Note that in the above example an unsubsidized player increases her expectation of the number of others choosing A from one player to three players by adding two subsidized players. That is, we assume that the unsubsidized player is a naïve decision maker and does not take into account the subsidized players' initial tendency to choose A without subsidy or believes that the subsidized players will not choose A without subsidy. In the lab or real world, the expectation formation process is probably much more complicated than simply adding the number of the subsidized players (2 in this case) to ones prior expectation as to how many players would choose Option A in the baseline condition. People may add a fraction of two, or adjust

[2] The opposite is possible when an expectation greater than 4 is not enough to tip a risk seeking player. But in the current study, most players were risk averse according to the Holt and Laury risk preference scale.

it only when their initial expectation is below 2. They may even decrease their expectation if their initial expectation is above 2 and they suspect the existence of a crowding-out effect, as mentioned in the literature review. The fact that fewer groups reached the efficient equilibrium in the Deterministic-Subsidy condition than in the Deterministic-Baseline condition is an indication that there might be a crowding-out effect for some groups. We will revisit the crowding-out effect later in the data analysis for Session 2.

4.3 Results in Session 2

Combined data from Sessions 1 and 2 were used to test H2, the *Subsidy Carry-over Effect Hypothesis*, with 78 participants (13 groups) in the DS1-DB2 condition, and 72 participants (12 groups) in the SS1-SB2 condition. A random effect logit model tested whether the subsidy effect carried over from the first session to a second session in which the subsidy was removed. The regression results, reported in Table 7 show that there was a significant interaction between game type (stochastic vs. deterministic) and the subsidy carry-over effect ($p<0.01$). Participants in the deterministic game were significantly less likely to choose A after the subsidy was removed than with a subsidy ($p<0.01$), but those in the stochastic game sustained the same level of coordination without subsidy as with the subsidy ($p>0.10$)[3].

Table 7. Random Individual Logit model for Choosing Strategy A

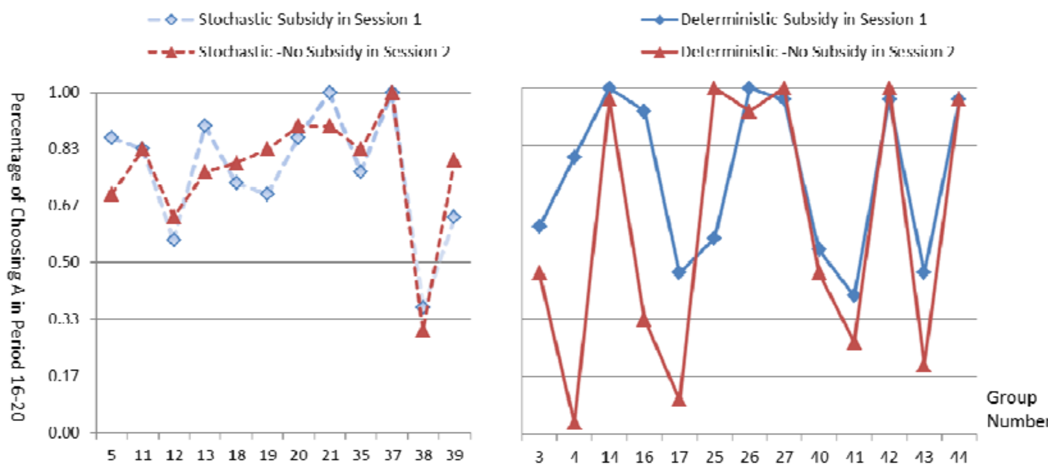
Variable	Coefficient	Standard Error	z value	Pr(>|z|)
Dependent Variable				
Choosing A				
Independent Variables				
Constant	2.72	0.33	8.08	0.00
Stochastic Game	0.42	0.47	0.88	0.38
Subsidy Removed	-0.87	0.10	-8.34	0.00
Fixed Effects				
Period	-0.02	0.007	-4.28	0.00
Interaction				
Stochastic Game X Subsidy Removed	0.85	0.16	5.36	0.00
Rho	7.36	2.72		
Log likelihood		-2203		
Sample size		5988		

The interaction between game type and subsidy carry-over effect can be shown more clearly when we look at cooperation rates in greater detail, as in Figure 4. The blue lines represent groups in the Subsidy condition in Session 1, while the red lines represent the same groups in Session 2 when the subsidy was removed. Figure 4 shows that most groups in the stochastic game maintained the coordination levels they

[3] The results of a second regression, similar to the one reported in Table 7, to test the subsidy carry-over effect in the stochastic game are reported in Table 9 in Appendix B.

had achieved with the subsidy in Session 1, after the subsidy was removed in Session 2. In the deterministic game, however, after the subsidy was removed, groups manifested similar dichotomous pattern observed in the Deterministic-Baseline condition (the green dots in Figure 3), as if they had never been exposed to the subsidy. That is, the subsidy effect of Session 1 did not carry over to an unsubsidized Session 2 for the deterministic game.

Figure 4: Cooperation Rates in Period 16-20 with Subsidy and without Subsidy in Subsequent Session as a Function of Game Type.



Why does the subsidy carry-over effect differ in the deterministic from the stochastic game? Our post-game survey showed that in the deterministic game, 43% of players believed that paying a lower cost was the only reason to choose A, and that others would choose A only when subsidized. This behavior is consistent with the motivation crowding-out theory (Frey and Jegen, 2001). Once the subsidy was removed, those players probably expected fewer players to choose A, and decided to choose B. Hence, some divided groups tipped toward the inefficient equilibrium all-B. In the stochastic game, only 22% of players viewed paying a lower cost as the only reason for choosing A. 78% of the players simply regarded A as a safer option, and assumed that others also preferred reduced risk, once the subsidy helped the group reach a higher number of players choosing A. In summary, subsidy seems to crowd out other possible reasons for cooperation in the deterministic setting, but safety is the principal reason for coordination on A in the stochastic setting. As a result, the subsidy effect carries over in the stochastic setting, but not in the deterministic one.

5. Conclusions

Prior research shows that people often have difficulty reaching the efficient equilibrium in coordination games with multiple Pareto-ranked Nash Equilibria. The current study investigates the effect of subsidy in a coordination game, both in a deterministic and stochastic setting. We find that partially subsidizing one third of the players not only encourages the subsidized players to cooperate, but also changes the unsubsidized players' expectation and behavior, so that some groups are tipped towards the efficient equilibrium. Social welfare is increased with subsidy in both the deterministic and stochastic settings. Furthermore, the subsidy-induced coordination improvement is sustained after the subsidy is removed in the stochastic game, but not in the deterministic game. A post-game survey indicated that with stochastic payoffs, players focused on risk reduction. Temporary subsidies promoted lasting coordination because even after subsidy was removed, players still assumed that others players would prefer reduced risks from cooperation. With deterministic payoffs, however, the subsidy might crowd out other rationales for coordination, with many players indicating that subsidy was the only reason for anyone to cooperate. Hence the coordination level dropped when subsidy was removed.

The experimental results in this paper have important public policy implications. If the laboratory results hold in community settings, then a limited budget might best be used to support temporary subsidies in stochastic settings, spread among many groups, because the coordination on Pareto optimum will often persist after the subsidy ends. In deterministic settings subsidies might have to be maintained indefinitely and might crowd out cooperation based on other rationales, such as social expectation to cooperate.

Another implication is that instead of playing down the uncertainty aspects in a coordination scenario, as public policy makers often do, we may be able to utilize people's natural tendency to be risk averse to encourage efficient and lasting risk reduction cooperation by emphasizing the uncertainty existing in the problem.

We encourage future work that will test the subsidy effect and the subsidy carry-over effect under conditions more similar to a natural environment, such as allowing player to communicate, or with the introduction of a social norm for coordination.

References

Bereby-Meyer, Y., Roth, A.E. 2006. “The speed of learning in noisy games: partial reinforcement and the sustainability of cooperation”. *American Economic Review* 96: 1029-1042.

Berger, L A. and Hershey, J.C. 1994. "Moral Hazard, Risk Seeking, and Free Riding," *Journal of Risk and Uncertainty* 9: 173– 186.

Brandts, J. and Cooper, D.J. 2004. “A Change Would Do You Good … An Experimental Study on How to Overcome Coordination Failure in Organizations.”*American Economic Review*, 96: 669-693.

Camerer, C. 2003. *Behavioral Game Theory: experiments in strategic interaction*. The Roundtable Series in Behavioral Economics. Princeton, NJ: Princeton

Chaudhri , A., Schotter, A., Sopher, B. 2009.‘“Coordination in Inter-generational Minimum Effort Games with Private, Almost‘*, Economic Journal* 119: 91-122.

Cachon, Gérard P. and Camerer, Colin F. 1996. Loss-Avoidance and Forward Induction in Experimental Coordination Games. *Quarterly Journal of Economics* 111(1):165-194.

Devetag, G. 2003. “Coordination and information in critical mass games: An experimental study” *Experimental Economics* 6: 53–73.

Fischbacher, U. (2007). z-Tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics*, 10(2), 171–178.

Frey, Bruno S & Jegen, Reto. 2001. " Motivation Crowding Theory." *Journal of Economic Surveys*, Blackwell Publishing 15(5): 589-611.

Devetag G. & A. Ortmann, 2007. "When and why? A critical survey on coordination failure in the laboratory." *Experimental Economics* ,10(3): 331-344.

Goeree, J.K. and Holt, C.A. 2005. “An Experimental Study of Costly Coordination.” *Games and Economic Behavior*, 51:349–364.

Gong, M., Baron, J. and H. Kunreuther. 2009. “Group Cooperation Under Uncertainty”. *Journal of Risk and Uncertainty,* 39(3): 251-270.

Granovetter, M. 1978. “Threshold Models of Collective Behavior.” *The American Journal of Sociology*(6): 1420-1443.

Greene, D., Sternberg, B., & Lepper, M.R. (1976). Overjustification in a token economy. *Journal of Personality and Social Psychology*, 34: 1219-1234.

Heal, G., Kunreuther, H., 2010. Social reinforcement: cascades, entrapment, and tipping. *American Economic Journal: Microeconomics* 2, 86–99.

Hess, R. O., C. A. Holt, and A. M. Smith. 2007. “Coordination of strategic responses to security threats: Laboratory evidence.” *Experimental Economics* 10: 235–50.

Holt, C. A., and S. K. Laury. 2002. "Risk Aversion and Incentive Effects ." *American Economic Review*, 92(5): 1644–1655.

Isaac, M., Schmidtz, D., and Walker, J. 1989. “The Assurance Problem in a Laboratory Market.” *Public Choice*. 62, 217–236.

Kearns, Michael. 2005 "Economics, Computer Science, and Policy." *Issues in Science and Technology*, Winter 2005.

Kunreuther, H., Heal, G., 2003. Interdependent security. *Journal of Risk and Uncertainty* 26, 231–249.

Kunreuther, H, and G. Heal, (2005). "Interdependencies in Organizations," in B. Hutter and M. Powers (eds.) *Organizational Encounters with Risk*, Cambridge: Cambridge University Press.

Kunreuther, H. (2009) "The Weakest Link: Risk Management Strategies for Dealing with Interdependencies" in *The Network Challenge: New Competencies and Strategies for an Interlinked World,* Paul R. Kleindorfer and Yoram Wind (eds.), Wharton School Publishing, Upper Saddle River, NJ:.

Leibenstein, H. 1950. "Bandwagon, Snob, and Veblen Effects in the Theory of Consumers' Demand," *The Quarterly Journal of Economics*, 64(2): 183-207.

Lepper, M. R., Greene, D., & Nisbett, R. E. 1973. Undermining children's intrinsic interest with extrinsic rewards: A test of the "overjustification" hypothesis. *Journal of Personality and Social Psychology,* 28, 129–137.

Meier, S. 2007. Do Subsidies Increase Charitable Giving in the Long Run? Matching Donations in a Field Experiment. *Journal of the European Economic Association*, 5(6) 1203-1222

2005; Kunreuther 2009) ??

Schelling, T., 1978. *Micromotives and macrobehaviors*. Norton, New York.

Shafran, Aric P., "Risk Externalities and the Problem of Wildfire Risk," *Journal of Urban Economics*, 2008, 64: pp. 488-95.

Shafran, A.P. "Interdependent Security Experiments," *Economics Bulletin*, 2010, 30, 1950-62.

Shafran, A.P. and J.J. Lepore. "Subsidization to Induce Tipping," *Economics Letters*, 2011, 110(1), 32-35.

Titmuss, R. M., 1971. *The Gift Relationship: From Human Blood to Social Policy*. Pantheon Books, New York

van de Kragt, A., Orbell, J., and Dawes, R. 1983. "The Minimal Contributing Set as a Solution to Public Goods Problems." *American Political Science Review*. 77, 112–122.

Van Huyck, J. B., R. C. Battalio, and R. O. Beil. 1990. "Tacit coordination games, strategic uncertainty, and coordination failure." *American Economic Review* 80, 234–48.

Van Huyck, J. B., R. C. Battalio, and R. O. Beil. 1991. "Strategic uncertainty, equilibrium selection, and coordination failure in average opinion games" *Quarterly Journal of Economics* 106, 885–910.

Van Huyck, J. B., Battalio, R.C., and Beil, R.O. 1993. "Asset Markets as an Equilibrium Selection Mechanism: Coordination Failure, Game Form Auctions, and Tacit Communication." *Games and Economic Behavior*, 5, 485-504.

Van Huyck, J., R. Battalio and F. Rankin (2007) „Evidence on learning in coordination games‟, *Experimental Economics* 10: 205-220.

Watts, Duncan. J. 2002. A simple model of global cascades on random networks, *Proceedings of the National Academy of Sciences*, 99(9): 5766-5771.

Weber, E. U. & Johnson, E. J. (2009). Mindful judgment and decision making.

Annual Review of Psychology, 60: 53-86.

Zhuang, J., V.M. Bier and A. Gupta. "Subsidies in Interdependent Security with Heterogeneous Discount Rates," *The Engineering Economist* 52(1):1-19, 2007.

Appendix A: Average Rate of Choosing A in each Group in Session 2

Table 8: Average Rate of Choosing A in each Group in Session 2

	Stochastic - Subsidy										
	Group Number										
	6	7	9	10	22	23	30	31	32	33	Average
Period 1-5	0.97	0.63	0.47	0.70	0.87	0.87	0.93	0.93	0.63	0.83	0.78
Period 6-15	0.93	0.77	0.53	0.57	0.80	0.90	0.87	0.90	0.73	0.83	0.78
Period 16-20	0.87	0.77	0.43	0.50	0.83	0.83	0.73	0.80	0.73	0.83	0.73
All Periods	0.93	0.73	0.49	0.58	0.83	0.88	0.85	0.88	0.71	0.83	0.77

	Stochastic - Baseline												
	Group Number												
	5	11	12	13	18	19	20	21	35	37	38	39	Average
Period 1-5	0.80	0.83	0.70	0.73	0.57	0.60	0.97	0.87	0.80	1.00	0.53	0.93	0.78
Period 6-15	0.77	0.83	0.77	0.85	0.73	0.68	1.00	0.93	0.85	1.00	0.43	0.82	0.81
Period 16-20	0.70	0.83	0.63	0.77	0.79	0.83	0.90	0.90	0.83	1.00	0.30	0.80	0.77
All Periods	0.76	0.83	0.72	0.80	0.70	0.69	0.97	0.91	0.83	1.00	0.43	0.84	0.79

	Deterministic - Subsidy													
	Group Number													
	1	2	15	24	28	29	34	36	45	46	47	48	49	Average
Period 1-5	0.67	1.00	1.00	0.93	0.77	0.70	0.50	0.97	0.63	0.60	1.00	0.83	0.97	0.81
Period 6-15	0.55	1.00	1.00	0.95	0.87	0.48	0.37	1.00	0.63	0.45	1.00	0.95	0.97	0.79
Period 16-20	0.37	1.00	1.00	0.93	1.00	0.53	0.40	1.00	0.40	0.40	0.97	1.00	1.00	0.77
All Periods	0.53	1.00	1.00	0.94	0.88	0.55	0.41	0.99	0.58	0.48	0.99	0.93	0.98	0.79

	Deterministic - Baseline													
	Group Number													
	3	4	14	16	17	25	26	27	40	41	42	43	44	Average
Period 1-5	0.80	0.37	1.00	0.53	0.30	0.93	0.93	0.97	0.73	0.33	0.90	0.67	1.00	0.73
Period 6-15	0.55	0.22	1.00	0.77	0.17	1.00	0.95	1.00	0.55	0.18	0.77	0.32	1.00	0.65
Period 16-20	0.47	0.03	0.97	0.33	0.10	1.00	0.93	1.00	0.47	0.27	1.00	0.20	0.97	0.60
All Periods	0.59	0.21	0.99	0.60	0.18	0.98	0.94	0.99	0.58	0.24	0.86	0.38	0.99	0.67

Appendix B: the Subsidy Carry-over Effect in the Stochastic Game

Table 9. Random Individual Logit model for Choosing Strategy A

Variable	Coefficient	Standard Error	z value	Pr(>|z|)
Dependent Variable				
Choosing A				
Independent Variables				
Constant	3.14	0.36	8.78	0.00
Deterministic Game	-0.42	0.47	-0.88	0.38
Subsidy Removed	-0.01	0.12	-0.10	0.92
Fixed Effects				
Period	-0.02	0.007	-4.28	0.00
Interaction				
Stochastic Game X Subsidy Removed	-0.85	0.16	-5.36	0.00
Rho	7.36	2.72		
Log likelihood		-2203		
Sample size		5988		

Appendix C: Instruction Sample in the Stochastic- Subsidy Condition

Instructions

In this study, you will be randomly matched with 5 persons to play 6-person games in which the outcomes of your decisions depend not only on what you do, but also on what others do.

You will be given 2000 Talers at the beginning of the study (2000 Talers = $40 or 1 Taler = 2 cents). The amount of Talers you keep may determines your final payoff. Two persons will be **chosen at random** to receive the dollar equivalent of the Talers they have at the end of the study, plus a $10 show-up fee.

To illustrate, suppose that Participant 3 and 5 are randomly chosen to be paid for their Talers. Suppose at the end of the game, Participant 3 has 900 Talers and Participant 5 has 800 Talers. Participant 3 will be paid $18 (900 Talers) + $10 showup fee = $28. Participant 5 will be paid $16 (800 Talers) + $10 showup fee = $26. Other people will be paid $10 for showing up.

The Game

There are 20 rounds in the game. You will be playing with the **SAME** 5 other people in all 20 rounds. In each round, all players will independently make a decision about whether to choose Option A or Option B. Your outcome depends on how many of the other 5 players choose **Option A** and how many of the other 5 players choose **Option B** .

There are two kinds of players, Player X or Player Y. In each round, the computer randomly assigns 4 players to be X, and 2 players to be Y. The assignment lasts for one round only. Assignments in each round are independent. That is, in each round, you have 2/3 chance of being X, and 1/3 chance of being Y.

The following illustrates possible outcomes of Player X and Y respectively. You should be familiar with both, because you probably will play both as X and Y during the 20-round game.

For Player **X**:

Table 1 illustrates possible outcomes in each round for Player X. For example, if you choose Option A, it costs 32 Talers. If no players out of the other 5 players choose **Option A**, you have a 67% probability of losing 100 Talers, in addition to paying 32 Talers (the cost of A). If one out of the other 5 players choose **Option A**, you have a 59% probability of losing 100 Talers, in addition to paying 32 Talers. All other possible outcomes are presented in Table 1 in the Option A row.

If you choose Option B, it costs zero Talers. If no players out of the other 5 players choose **Option A**, you have an 80% probability of losing 100 Talers. If one out of the other 5 players choose **Option A**, you have 75% probability of losing 100 Talers. All other possible outcomes are presented in Table 1 in the Option B row.

Table 1: Probabilities of Losing 100 Talers for Player *X*

		Number of Other Players Who Choose Option A					
		0	1	2	3	4	5
Your Choice	**Option A** (cost= 32)	67%	59%	49%	36%	20%	0%
	Option B (cost= 0)	80%	75%	69%	61%	52%	40%

For Player **Y**:

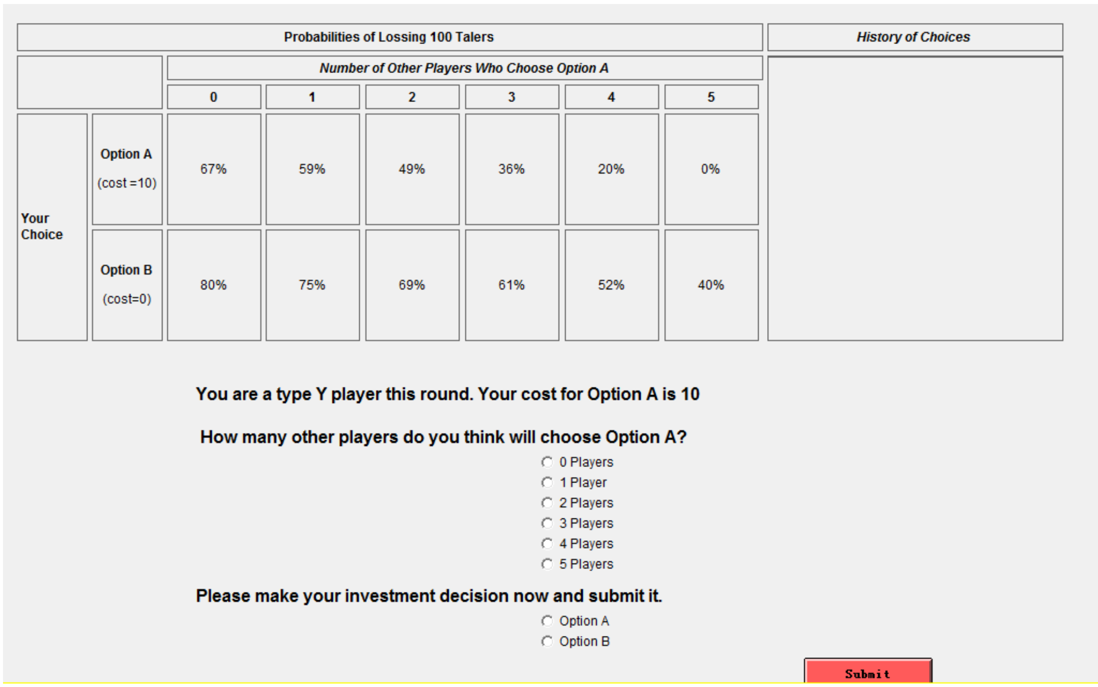
The major difference between Player X and Y is that the cost of Option A for Player Y is 10 Talers instead of 32 Talers. Table 2 illustrates possible outcomes in each round for Player Y

Table 2: Probabilities of Losing 100 Talers for Player *Y*

		Number of Other Players Who Choose Option A					
		0	1	2	3	4	5
Your Choice	**Option A** (cost= 10)	67%	59%	49%	36%	20%	0%
	Option B (cost= 0)	80%	75%	69%	61%	52%	40%

Procedure

You will not know the decision of other players until the end of the round.
Here is an example of the decision page for **the first round** for a Player Y:



After all players have made a decision, the computer will randomly generate a number between 1 and 100 to decide whether you have suffered a loss.

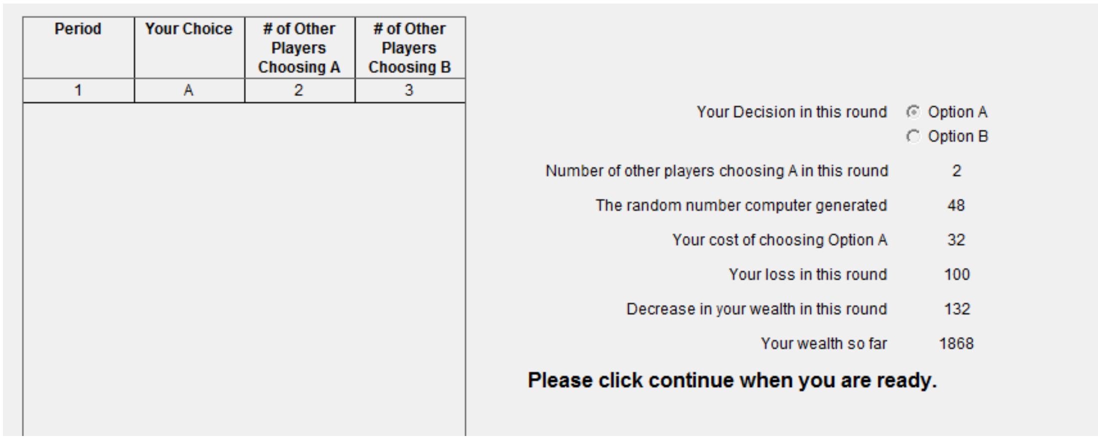
For example, suppose that in one round, you choose Option A, and 3 out of the other 5 players have chosen A as well. According to Table 1, you have 36% chance of losing 100, plus paying 32 for the cost of Option A. If the random number is less than or equal to 36, you suffer the 100 Talers loss. That is, you will have to pay 100+32=132 Talers in that round. If the random number is greater than 36, however, you will pay the cost of Option A only (32 Talers).

The general rule is that if the random number is less than or equal to your chance of losing 100 Talers (in percentage), you will suffer a loss of 100 Talers, plus paying whatever cost your choice incurs (32 for A or 0 for B). Note that in each round, the computer generates only one random number. That is, the same random number is compared to all players' respective probabilities to determine who suffer a loss.

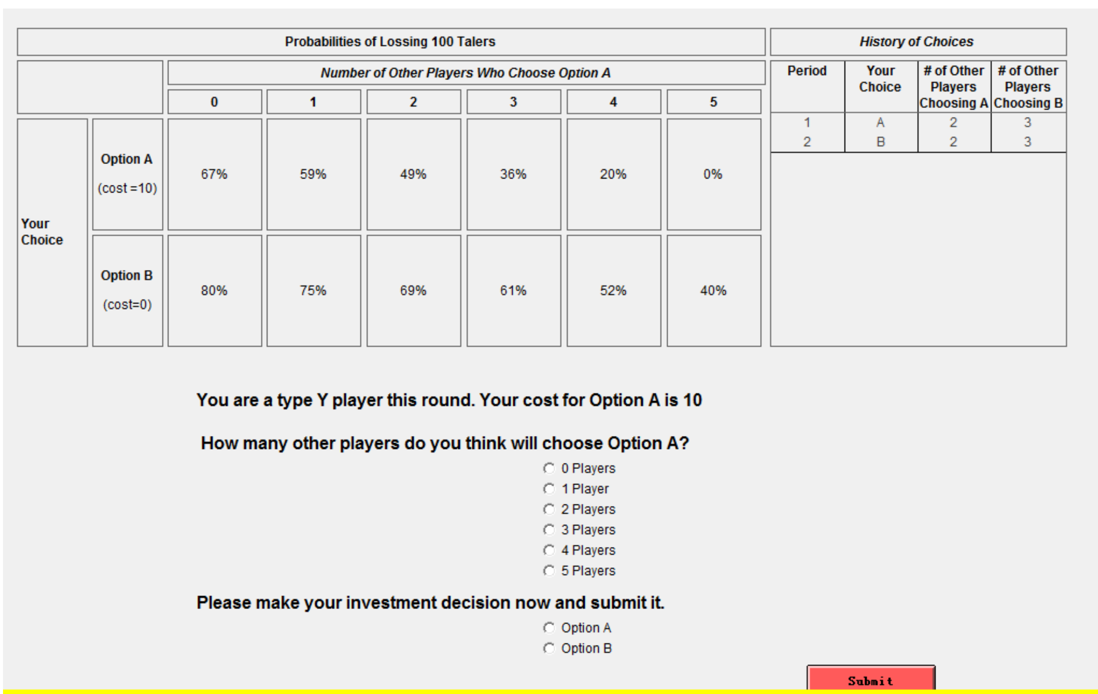
There is no strict time limit on how long you can spend on making a decision. But please keep in mind that **everyone** in this room will have to wait for you if it takes too long for you to make a decision. A reminder will appear on the top right of the screen if fail to make your decision within 60 seconds.

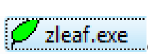
Before starting the next round, you will be given feedback on your loss in the current round, your total wealth so far, and how many players (including you) have chosen A and how many have chosen B.

Here is an example of the feedback page for a Player X:



Starting the 2nd round, you will be given information on how many players have chosen A and B respectively in each of previous rounds. Here is an example of the decision page for the 3rd round for a Player Y:



Please **raise your hand** if you have any question. Otherwise, please **open Zleaf** 

on your desktop to start quiz.