ESSAYS ON APPLIED ECONOMICS WITH EXPERIMENTAL EVIDENCE

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ESSAYS ON APPLIED ECONOMICS WITH EXPERIMENTAL EVIDENCE

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My dissertation consists of three chapters, each of which experimentally investigates the reasonings of an individual's suboptimal decisions from the perspective of self-interested rational agents. In the first chapter, I examine how the voluntary contribution of public goods is affected by uncertainty in the size of the relevant population. I show that when the number of players is random and each player knows only the population distribution, the voluntary contribution level in Nash equilibrium is higher than when the number of players is fixed at the mean of the population distribution if the marginal production of public goods is convex and the agents are self-interested. I also show that the voluntary contribution level decreases as the expected number of players increases, but such a decreasing tendency is weaker than predicted by the model for the case where there is no uncertainty in the size of the population. On the contrary, by modeling the agents' social preferences in the form of an increasing concave warm-glow utility in the population size, I show that the voluntary contribution level is smaller under population uncertainty when the production function is linear. The linear voluntary contributions mechanism (VCM) can capture the relationships between warm glow and population uncertainty, and the nonlinear VCM with population uncertainty can provide a structural way to additionally examine theoretical predictions. The results of the lab experiments support many aspects of the theoretical predictions. As the mean population size increased, the changes in contribution level were smaller under population

uncertainty, and the subjects' decisions were determined mainly by the lower bound of the population distribution. When the population distribution was more volatile, subjects contributed more. It is a new and interesting observation that the salience of population uncertainty partly drove out warm glow.

In the second chapter, I show that winner-take-all competitions can lead to the person in the second (middle-tier) environment having the worst expected payoff when players exclusively choose their environment and exert effort before their random, heterogeneous environmental supports are realized. The tiers are defined by the ranks in pairwise competitions. The second-tier trap (STT) is a situation in which a player from the second-tier environment has the worst expected payoff even though his expected environmental support is strictly greater than that of the third-tier player. A sufficient condition for the STT is that the ex-ante advantages, the winning probabilities when all the players exert the same amount of effort regardless of their environment, be the same for those two environments. I claim that this sufficient condition for the STT is so weak that players can easily be tempted to choose the second-tier environment, which is the wrong decision. Lab experiments verify this claim. In two-stage all-pay auction games whose structure leads to the STT, subjects chose an environment and then an effort level. In four rounds (called the unrestricted rounds) they chose one of three environments, and in six rounds (the restricted rounds) they were not allowed to choose the first-tier environment. No subject chose the optimal environment in all the restricted rounds, while 52.27% of subjects did so in all the unrestricted rounds. On average, subjects chose the optimal environment in 28.67% of all the restricted rounds and in 75.57% of all the unrestricted rounds. Those who chose the optimal environment in all the unrestricted rounds were more likely to fall into the STT.

In the last chapter, I report the results from a natural field experiment about charitable giving. I asked a cooperative charity whose headquarters is located in Seoul, South Korea, to send 16,000 solicitation letters of four different types, with each having a different attachment, in order to better understand the philanthropy initiatives and individuals' social preferences by collecting responses and comparing them by letter type. They received only one donation and 381 'active' returns in eight weeks. The real coin attachment, though some charities including UNICEF have used this 'coin strategy,' did not bring a significantly positive effect. A sense of involuntarily indebtedness by itself does not seem to be one of the major driving forces behind reciprocity. The coin attachment confirms that potential donors have inequity aversion: A significantly larger proportion of mail recipients returned the letter with 100 Korean won than those with no attachment. I also claim that the results from the previous studies should be extrapolated to a general situation with extra care due to the sample selection bias.

BIOGRAPHICAL SKETCH

Duk Gyoo Kim was born in Seoul, Republic of Korea in 1982. He received his B.A. in Business Administration and M.A. in Economics from Yonsei University in Seoul. He was granted the Fulbright Graduate Study Award when he began his doctoral work in Economics at Cornell University. He earned his Ph.D. in Economics in 2015. Following graduation, he accepted to continue his research as a Dan Searle Postdoctoral Fellow in Economics at the California Institute of Technology in Pasadena, CA.

To my wife, Yuri Choi.

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I am deeply indebted to Professor Stephen Coate, another co-advisor. He taught me in every academic aspect. He was the best advisor that I could have imagined. He was upfront in evaluating my research questions and academic strength so that I could think about research questions in new and better ways, and minimize unnecessary time and energy spent to less promising projects. He commented on my written work in a very detailed manner with extra care. He has provided me with a great role model in the classroom. I took his graduate-level courses and worked as a grader for his undergraduate-level course, and I learned from him a large extent about how a good teacher leads and manages courses.

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CHAPTER 1

POPULATION UNCERTAINTY IN VOLUNTARY CONTRIBUTIONS OF PUBLIC GOODS

1.1 Introduction

I examine how individuals contribute to the production of public goods when they do not know the exact number of participants in the contributor pool. Previous research has used lab experiments to determine what factors encourage individuals to contribute to the provision of public goods.[1] The voluntary contributions mechanism (VCM), including variations thereof, has been repeatedly revisited by verifying observations,[2] extending ideas,[3] or extrapolating results[4] from the existing literature. One common result found in the vast majority of the previous studies is that some subjects seem to feel a "warm

[1]Experimental studies of private provision of public goods include, but are not limited to, Marwell and Ames (1979), Isaac et al. (1994), Smith et al. (1995), Palfrey and Prisbrey (1997), Isaac and Walker (1988), Bagnoli and Mckee (1991), Fehr and Gächter (2000), and Croson (2007).

[2]Andreoni (1995a) found that, on average, about half of all cooperation comes from subjects who understand that non-cooperation maximizes their payoffs but choose to cooperate out of some form of kindness. Brandts and Schram (2001) found that subjects' behavior cannot be explained exclusively as the result of errors. Fischbacher et al. (2001) found in a one-shot public goods game that half of the subjects were conditional cooperators. Harbaugh and Krause (2000) conducted a public goods game with children and found that older children's behavior was similar to that of adults.

[3]Andreoni (1995b) found asymmetries in subjects' behavior between provision of public goods and provision of public "bads." Messer et al. (2007) studied how contextual factors can produce sustained efficiencies in a voluntary contribution game. Morgan (2000) considered a way to increase contributions by introducing a certain feature of lotteries, and Morgan and Sefton (2000) tested the idea experimentally. Zhang and Zhu (2011) investigated the effect of group size in a natural field experiment via the Chinese Wikipedia site.

[4]Andreoni (1993) and Andreoni and Payne (2003) tested the proposition that government contributions via lump-sum taxation will completely crowd out voluntary contributions to the production of public goods, and found that such crowding-out was incomplete. Fehr and Gächter (2000) and Masclet et al. (2003) added some forms of punishment for people who did not contribute voluntarily. Duffy et al. (2007) and **?** investigated how the dynamics of public goods games affected subjects' behavior. Keser and Van Winden (2000) and Andreoni and Croson (2008) studied whether subjects' behavior changes when they play with partners instead of with strangers (or vice versa).

glow," which can be modeled by additional utility derived from the activity of giving itself (Cornes and Sandler (1984), and Andreoni (1989, 1990)). In terms of experimental designs, another noticeable similarity of the previous research is that all experiment participants knew exactly how many other individuals were making their decisions simultaneously, and accordingly knew exactly how influential their contributions were. However, in many real-world situations, a potential contributor does not know how many other contributors there are: A voter does not know how many people with voting rights will consider turning out for an election, a charitable giver does not know how many others will consider making donations of aid to needy children in developing countries, a voluntary participant in a Neighborhood Watch group does not know how many neighbors would consider filling in—on short notice—for members who are out of town during the summer vacation period, and potluck party organizers do not know how many others will contribute since they do not know how many will consider coming.[5] Does this uncertainty change the behavior of individuals? If so, how does it change?

To answer these questions, I modeled a voluntary contribution game with population uncertainty. A player in this game knows the population distribution of the players but not the exact number of players. This randomness is referred to as population uncertainty. Though population uncertainty has been adopted in many other fields in applied microeconomics,[6] to the best of my knowledge it has not been emphasized in the literature on voluntary contribu-

[5] I distinguish the uncertainty in the number of players from the uncertainty about how a known number of other players would act. I will discuss further the distinction between population uncertainty and changes in population size.

[6] Since Myerson (1998b) introduced the notion of population uncertainty in games, studies in political economy have actively used the idea of population uncertainty to understand voter turnout (Myerson (1998a), Piketty (2000), Dhillon and Peralta (2002), **?**, Spenkuch (2013)). In the context of contests, population uncertainty has also played an important role (Myerson and Wärneryd (2006), Münster (2006), Lim and Matros (2009)).

tion of public goods.

This study also extends previous studies that addressed the relationship between population size and pro-social behavior.[7] However, the difference between population uncertainty and changes in population size should be clarified, because each economic agent's outcome is uncertain even when the population size is fixed. In the context of this paper, the unknown strategic behavior of other agents, which can be refined by many strategic equilibrium concepts, is not regarded as population uncertainty. By population uncertainty, I mean only the randomness in the population size.

One issue on which consensus has not been reached is whether voluntary contributions increase or decrease with group size. Andreoni (2007) points out that voluntary contribution constitutes a congestive public good because an increase in the group size decreases the price of providing a unit of social value and at the same time reduces individuals' incentives to contribute. His finding was that for the average subject, a gift that results in one person receiving g is equivalent to n people receiving $g/n^{0.68}$ each, that is, for most subjects altruism ($gn^{0.32}$) is increasing and convex in the population size. I take this finding as an initial point, because it provides some predictions of how the voluntary contribution level is affected by population uncertainty.

With a model that includes a constant marginal warm-glow utility in terms of population size, I show that when the number of players is random, the vol-

[7] Many studies following Isaac et al. (1984) and Isaac and Walker (1988) have considered relationships between free-riding behaviors and group size. Isaac et al. (1994) found that groups of size 40 or 100 provided a public good more efficiently than groups of size 4 or 10, while standard theory predicts the opposite. Goeree et al. (2002) also found that contributions are generally increasing in the group size. Carpenter (2007) found that people will punish free riders even at considerable cost and that such punishment does not fall appreciably in large groups. Nosenzo et al. (2013) found that such patterns of increased contributions with group size are observed only when the marginal per capita return is low.

untary contribution level in a symmetric Nash equilibrium is higher than when the number of players is fixed at the mean number of players if the marginal production of public goods is convex. The equilibrium voluntary contribution level decreases when the population size increases (Andreoni (2006)) or when population uncertainty exists. I also show that when population uncertainty increases with mean population size, the tendency of the equilibrium voluntary contribution level to decrease is weaker than when the population size is certain. With these two findings, my model can distinguish between voluntary contributions driven primarily by warm glow and those that are significantly affected by population uncertainty, so it provides a structural form for estimation of the warm-glow utility separately from the effect of population uncertainty. The model incorporates the standard public goods provision model (Bergstrom et al. (1986)) as a special case. Population uncertainty is described in a manner similar to that of Poisson games (Myerson (1998b), Myerson and Wärneryd (2006)), but my model does not require having unbounded support.

While theoretical predictions of the effect of population uncertainty on voluntary contribution of public goods are evident, it is unclear how people actually respond to population uncertainty, as the self-interested agent models of voluntary contribution have been unsuccessful at predicting warm-glow behavior. Another model that focuses on the warm-glow utility (Cornes and Sandler (1984), Andreoni (1989, 1990)) is also considered here. If the warm-glow utility can be described by an increasing concave function of the group size and the marginal utility of public goods is constant in the group size, then population uncertainty may serve to decrease the individual contribution level. Also, if some players regard the uncertain population size as a cognitive barrier that hampers them from calculating a strategically optimal contribution, they might want to increase their allocation to the consumption of private goods so that their utility will come from a more certain source. On the other hand, if risk-averse subjects worry more about the worst-case scenario, where the population size turns out to be small, or their risk aversion drives them to put more weight on the possibility that the contributor pool is small, they may want to contribute more in order not to give up the higher marginal utility of public goods. Another possibility is that the salience of population uncertainty may change a subject's decision process, by implicitly encouraging them to recognize the strategic aspects of the game. This open question about how population uncertainty affects warm glow can be answered with a linear public goods production function. Under the null hypothesis of self-interested rational agents, changes in their responses under population uncertainty depend only on the convexity of marginal production, so population uncertainty plays no role in the case of self-interested agents with a linear production function.

I conducted a series of experiments designed to test hypotheses about how population uncertainty affects voluntary contributions of public goods. The nonlinear-with-no-uncertainty (NN) experiment investigated the effects of group size by using a decreasing convex marginal production function. The nonlinear-with-uncertainty (NU) experiment added population uncertainty to the setup for the NN experiment. Subjects in the NU experiment chose their contribution level given only the population distribution (two different group sizes with equal probability), and their earnings were determined later, after the population size was revealed. The nonlinear-within-subjects (NWS) experiment combined both NN and NU experiments for within-group comparisons. The linear-within-subjects (LWS) experiment investigated whether and how people respond to population uncertainty in the linear VCM, where production of public goods is linear in total contributions. The experiments were conducted at the Cornell Lab for Experimental Economics & Decision Research (LEEDR) and employed undergraduate students at Cornell University. Except for including the randomness of the group size and the nonlinearity of the production function, the basic structure of the experiment resembled that of Palfrey and Prisbrey (1997). To minimize the effects of dynamic strategies, I adopted random rematching (Andreoni and Croson (2008)).[8] For the same reason, I did not tell subjects when the experiments would end.[9]

The experimental results can be summarized as follows: (1) Population uncertainty confirmed that the warm glow is congestive: In the linear VCM, where the contributions could be explained only by warm glow, the contribution levels were halved under population uncertainty. I call this a drive-out effect. (2) The subjects' decisions were determined mainly by the lower bound of the population distribution. (3) The more volatile population distributions yielded more contributions. (4) After controlling for the drive-out effect, subjects responded to population uncertainty to a greater extent than predicted by theory. These are new observations that could not have been captured by the previous experiments.

The rest of this paper is organized in the following way. Section 2 describes a simple model, and Section 3 presents theoretical findings that will shed light on the experimentally testable hypotheses. Section 4 describes the design and procedure of the experiments, and Section 5 highlights the experimental results.

[8]When subjects are matched with the same group members for multiple periods, they have an incentive to behave strategically: If they can send credible signals in some rounds that they are cooperative, then they can leverage their earnings by betraying the other members of their group and behaving non-cooperatively in the final round.

[9]In the consent form, subjects were informed that "the whole experiment consists of several (but not more than 30) rounds of simple games whose overall procedure is the same." The actual experiment consisted of 20 rounds.

Section 6 concludes.

1.2 The Model

As a benchmark, consider a case where there are a fixed number of players. Let $N = \{1, 2, \ldots, n\}$, $n \geq 2$, denote a set of homogeneous potential contributors. Each contributor has endowment $y > 0$. There are one public good and one private good. Each contributor $i \in N$ voluntarily contributes $g_i \geq 0$ to the provision of the public good and consumes the remainder, $x_i = y - g_i$. The supply function for the amount of the public good which is produced as a result of the voluntary contributions, $f : \mathbb{R}_+ \to \mathbb{R}_+$, is an increasing, strictly concave function of the sum of the individual contributions, $G = \sum_{i=1}^{n} g_i$. The utility function for contributor i is $U(x_i, g_i, G) = x_i + \psi(g_i, n) + f(G)$. This additively separable quasi-linear form is assumed for simplicity, and relaxation of this assumption does not change the direction of the main theoretical findings. $\psi(\cdot, \cdot)$ is concave and increasing on $\mathbb{R}^2_+$, and differentiable on $\mathbb{R}^2_{++}$. Note that $\psi(\cdot, \cdot)$ captures the warm-glow utility (Cornes and Sandler (1984), Andreoni (1989, 1990)), which may depend on the population size.

In a game with population uncertainty, the number of individual players is random. Formally, let $N_{1+} = \{2, 3, \ldots\}$ be the set of integers greater than 1, and let $\pi : N_{1+} \to [0, 1]$ such that $\sum_{n=2}^{\infty} \pi(n) = 1$ be the commonly known probability density function for the number of players. Let $\mu := \sum_{n=2}^{\infty} \pi(n)n$ denote the expected number of players. When π is a degenerate function at n, it reduces to the benchmark setup. I assume risk neutrality with respect to private consumption, because in the context of a voluntary contribution game, x simply refers to the risk-neutral monetary value.

Now I consider this voluntary contribution game from the perspective of a single player.[10] He is told that the actual population size will be from a distribution whose density function is $\pi(n)$.[11] This player's objective is to choose the contribution level g that maximizes his expected utility given the contribution of any other player (which is presumed to be symmetric in the players), denoted by $\tilde{g}$.

Definition 1. *A contribution level g^* is a symmetric equilibrium if the following hold:*

(i) $g^* = \arg\max_{g\in[0,y]} \sum_{n=2}^{\infty} \pi(n)\{y - g + \psi(g, n) + f(g + (n-1)\tilde{g})\}$

(ii) $g^* = \tilde{g}$.

To exclude the trivial equilibrium where everyone contributes nothing, assume that some positive amount of the public good is desirable.

Assumption 1. $\lim_{g\to 0} \psi_1(g, n) + f'(g) > 1$,

where $\psi_1(g, n) = \partial\psi(g, n)/\partial g$. Assumption 1 states that even when no other players contribute, it is desirable to contribute a nonzero amount of one's endowment to the production of public goods. Note that the right-hand side of

[10] Since the population size is always greater than or equal to 2 in this model, we can assume there always exists a player and his/her match participating in this game. For slightly different setups in studies that involve population uncertainty, see Myerson (1998b) and Myerson and Wärneryd (2006).

[11] Some studies, especially in auction theories, deal with population uncertainty by introducing a pre-stage into the game. In the pre-stage, some players are selected from the whole population pool and then they play the game. In such a setup a single player should update his belief conditional on the fact that he is being selected, because that fact implies that the population is more likely to be large. $\pi(n)$ in this paper can be understood as a posterior belief that has already been updated. Also, in this context the players' participation within the realized population is not their choice variable, unlike in other studies regarding voluntary participation, including Dixit and Olson (2000) and Saijo and Yamato (2010).

the inequality is the marginal cost of increasing the contribution in the case of a quasi-linear utility function, so this assumption could be generalized to $\lim_{g\to 0} U_2 + f' > \lim_{g\to 0} U_1$, where U_i is the partial derivative of U with respect to the ith argument.

Assume further that y is large enough that no two players should contribute their entire endowments.

Assumption 2. $\lim_{g\to y} \psi_1(g, n) + f'(y + g) < 1$

Assumption 2 states that contributing all of one's endowment is not desirable when another player contributes his/her entire endowment to the production of the public good.

1.3 Analysis

1.3.1 When $\psi(g, n) = \psi(g)$

This section studies the simplest model, where the marginal utility of warm glow is unaffected by population size, that is, $\psi(g, n) = \psi(g)$. This restriction will be relaxed in the following section. The player's maximization problem simplifies to

$$\max_{g_i \in [0,y]} \sum_{n=2}^{\infty} \pi(n)(y - g_i + \psi(g_i) + f(g + (n-1)\tilde{g})$$

By Assumptions 1 and 2, corner solutions can be excluded, so the first-order condition is

$$\sum_{n=2}^{\infty} \pi(n) \left[\psi'(g^*) + f'(g^* + (n-1)\tilde{g}\right] = 1. \tag{1.1}$$

In the symmetric equilibrium, where $g^* = \tilde{g}$, the first-order condition becomes

$$\sum_{n=2}^{\infty} \pi(n) f'(ng^*) + \psi'(g^*) = 1. \tag{1.2}$$

Without population uncertainty, the first-order condition is

$$f'(\mu g^*) + \psi'(g^*) = 1, \tag{1.3}$$

which is the same as the standard voluntary contribution model's optimality condition shown by, for example, Bergstrom et al. (1986) if the warm-glow utility is constant or $\psi'(\cdot) = 0$. The existence and the uniqueness of the symmetric voluntary contribution equilibrium are well established in Cornes (2009). Since $\sum_{n=2}^{\infty} \pi(n) = 1$ and $\sum_{n=2}^{\infty} \pi(n) n g^* = \mu g^*$, we can read equation (1.3) as $f'(\sum_{n=2}^{\infty} \pi(n) n g^*) + \psi'(g^*) = 1$. Then by Jensen's inequality it immediately follows that the equilibrium contribution level with population uncertainty is greater than the level with certainty if the marginal production function is convex. Figure 1.1 illustrates Proposition 1.

Proposition 1. *Suppose $f'(\cdot)$ is convex and $\psi(g,n) = \psi(g)$. Let g^u and g^c denote the equilibrium contribution levels with and without population uncertainty, respectively. Then $g^u \geq g^c$.*

Proof: By Jensen's inequality, $\sum_{n=2}^{\infty} \pi(n) f'(ng^c) \geq f'(\sum_{n=2}^{\infty} \pi(n) n g^c) = 1 - \psi'(g^c)$. Since $f'(\cdot)$ is decreasing due to concavity, g^u such that $\sum_{n=2}^{\infty} \pi(n) f'(ng^u) = 1 - \psi'(g^u)$ has to be at least as great as g^c. For the sake of contradiction, suppose $g^c > g^u$. Since $\psi(\cdot)$ is increasing and concave, $\psi'(g^u) > \psi'(g^c)$, or $1 - \psi'(g^c) > 1 - \psi'(g^u)$. This implies that $\sum_{n=2}^{\infty} \pi(n) f'(ng^c) > \sum_{n=2}^{\infty} \pi(n) f'(ng^u)$, and hence $g^u > g^c$, which contradicts the supposition. $\square$

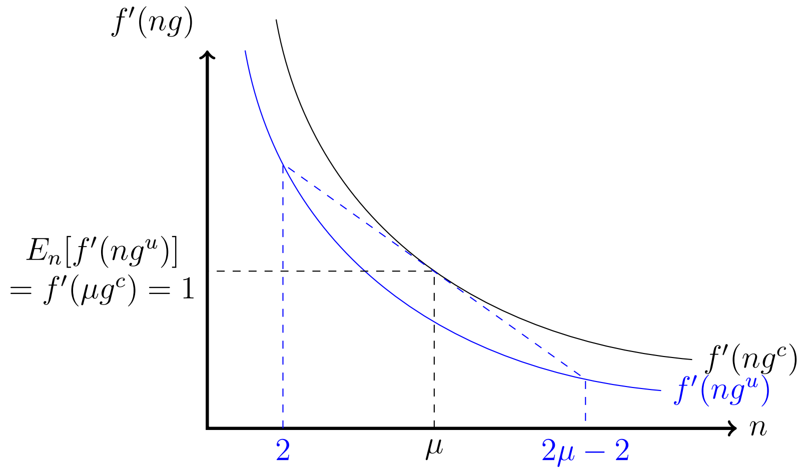


Figure 1.1: An illustration of Proposition 1

This figure illustrates a special case of population uncertainty, where the population is either 2 or $2\mu - 2$ with equal probability, and $\psi'(\cdot) = 0$. Since $f'(ng^c) > f'(ng^u)$, the individual contribution level under population uncertainty, g^u, is larger than the contribution level when the population is certain, g^c. This requires the marginal production function to be convex.

I claim that convexity of marginal production is more generally accepted than constant marginal production.[12] Conventional production functions, such as $\ln g$ and $g^\alpha, \alpha \in (0,1)$, satisfy the condition of convexity of marginal production. Note that $g^u \geq g^c$ holds with equality when the production function is linear, that is, when the marginal production is constant.

The intuition behind Proposition 1 is closely related to an opposite observation which Myerson and Wärneryd (2006) found in contests: Under population uncertainty, the aggregate level of effort (investments in the war of attrition, or bids in an all-pay auction) is smaller than when the population is certain. Both in contests for private prizes and in voluntary contributions to public goods,

[12] Admittedly, not every increasing concave function has a positive third-order derivative. For example, $f(g) = \alpha g - g^2, \alpha > 0$, is concave on $\mathbb{R}$, and $f'(g) = \alpha - 2g$, which is not convex. In general, however, such functions are increasing only up to some point, and then decreasing thereafter. In the example, the production function is decreasing when g is greater than $\alpha/2$.

each individual's marginal cost of investment is certainly known to her/him. The population uncertainty plays a role in the marginal benefit of investment. In contests where payoffs are given only to the winners, players are reluctant to exert additional effort, because their marginal benefit would be small when the population turns out to be large. In voluntary contribution games where payoffs are distributed to all the participants, players are encouraged by the possibility of a small population, which will render their contributions more influential, even to themselves. To put it differently, in a voluntary contribution game where the group size will be either large or small, subjects will be more sensitive to the possibility of its being small. I utilized this idea in the laboratory experiments.

Another direct observation from Proposition 1 is that the mean-preserving spread of a population distribution leads to a larger contribution in equilibrium.

Corollary 1. *Suppose $f'(\cdot)$ is convex and $\psi(g,n) = \psi(g)$. Let Π_1 denote the population distribution and Π_2 a mean-preserving spread of Π_1. Let g_1^u and g_2^u denote the equilibrium contribution levels under population uncertainty whose distributions are Π_1 and Π_2, respectively. Then $g_2^u \geq g_1^u$.*

Proof: Let $\pi_1(n)$ and $\pi_2(n)$ denote the probability density functions of Π_1 and Π_2, respectively. Applying Jensen's inequality again, we have $\sum_{n=2}^{\infty} \pi_2(n) f'(ng_1^u) \geq \sum_{n=2}^{\infty} \pi_1(n) f'(ng_1^u)$. The rest of the proof is the same as that of Proposition 1. □

If the warm-glow utility from a contribution is additively separable from the utility of the public goods provided and does not depend on the population size, the conclusion of Proposition 1 holds regardless of the existence of the warm-glow utility. Thus individuals' pro-social behavior may be decomposed into their warm glow[13] and their response to population uncertainty. The first step in investigating the validity of such a result is to check whether the warm-glow utility does depend on population uncertainty. We can utilize the standard linear VCM here, because with this linear production function, population uncertainty by itself plays no role. Responses to population uncertainty in the case of a linear production function tell us whether (and how) the warm-glow utility depends on population size.

1.3.2 When $\partial\psi(g,n)/\partial n > 0$ and $\partial^2\psi(g,n)/\partial n^2 < 0$

Taking findings from Andreoni (2007) as an initial point, I assume here that $\psi(g,n)$ is increasing and concave in n and the production function is linear, that is, $f'(\cdot) = k$, where k is a constant. Then the conclusions of Proposition 1 and Corollary 1 do not hold, and an individual's voluntary contribution level decreases with population uncertainty.

Proposition 2. *Suppose $f'(\cdot) = k$, $\partial\psi(g,n)/\partial n > 0$, and $\partial^2\psi(g,n)/\partial n^2 < (resp. >, =)\, 0$. Let g^u and g^c denote the equilibrium contribution levels with and without population uncertainty, respectively. Then $g^c > (resp. <, =)\, g^u$.*

Proof: In this case, equation (1.1) becomes $\sum_{n=2}^{\infty} \pi(n)[\partial\psi(g^u,n)/\partial n + kg^u] = 1$. If $\partial^2\psi(g,n)/\partial n^2 < 0$, by Jensen's inequality $1 - kg^u = \sum_{n=2}^{\infty} \pi(n)\partial\psi(g^u,n)/\partial n > \partial\psi(g^c,n)/\partial n = 1 - kg^c$. The proofs of the other two cases ($\partial^2\psi(g,n)/\partial n^2 > 0$ and $\partial^2\psi(g,n)/\partial n^2 = 0$) are analogous. □

[13] Andreoni (2006) used impure altruism as a synonym of warm glow. Here the term warm glow refers to the direct utility derived from the giving, which is captured by $\psi(\cdot)$.

By shutting down the channel of responses to the nonlinear production function, we can make direct predictions of experiment participants' behavior: If their warm glow is increasing and concave in n, then population uncertainty drags down their contribution in the linear VCM. If the warm-glow utility is constant in n, as assumed in the previous section, there will be no significant changes. Of course, an increasing and convex (at least for the group sizes being tested) warm-glow utility may imply that their contribution will increase with population uncertainty, but this may be counterintuitive.

It may be difficult or impossible to tell how people will respond to population uncertainty when both the public goods production function and the warm-glow utility are increasing and concave. In that case, uniqueness of the equilibrium is not guaranteed, as opposed to the case where the warm-glow utility is independent of n. On top of the contrasting theoretical predictions, there may be some other contrasting directions in the response to population uncertainty. If experiment participants interpret the uncertain population size as ambiguity of return on their contribution to the production of public goods, they might want to increase the allocation to their private account so that their utility will come from a more certain source. On the other hand, if conservative participants worry more about the worst-case scenario, where the population size turns out to be small, that is, their risk averseness drives them to put more weight on the possibility that the contributor pool is small, they may want to contribute more. In this case, population uncertainty may still play an important role, even when the mean population size is large, if a potential contributor subjectively perceives that the probability of a small population is substantially high. Another possibility is that the salience of population uncertainty may change the subjects' decision process by directly affecting their warm glow. If population uncertainty prompts subjects to give greater consideration to the strategic aspects of the experiment, they may behave more rationally and in a self-interested manner, that is, population uncertainty may drive out warm glow. However, we cannot exclude the possibility that population uncertainty will encourage them to be more altruistic.

Though the sign of the change in contribution levels with population uncertainty is unpredictable, it is predictable that population uncertainty will render equilibrium contribution levels more stable. The following propositions help to clarify why this would happen. To exclude the unnecessary complexity of dealing with multiple equilibria, I consider the concavity of warm glow in n and the concavity of the public goods production function separately, and specify the form of the utility function. Proposition 3 considers a situation where the public goods production function is increasing and concave, and Proposition 4 addresses the case where the production function is linear, both of which were used to specify a payoff function in the experiments. To emphasize the expected population size, let $g^u(n)$ and $g^c(n)$ denote the symmetric equilibrium contribution level with and without population uncertainty, respectively, when the expected population is n. When the population uncertainty grows, the free-riding incentive grows more slowly. I use big-$\mathcal{O}$ notation to describe limiting behavior.[14]

Proposition 3. *Suppose $U(x_i, g_i, G) = x_i + a \ln g_i + b \ln G$. Suppose that the number of players is n for $g^c(n)$, and that it is randomly drawn from a discrete uniform distribution $U[2, 2n-2]$ for $g^u(n)$. Then $(g^u(n) - a)/(g^c(n) - a) = \mathcal{O}(\ln(2n))$.*

[14]Let $f(x)$ and $g(x)$ be two functions on $\mathbb{R}$ and $g(x) \neq 0$ for all x. $f(x)$ is $O(g(x))$ as $x \to \infty$, or $f(x)$ is the same-order relation with $g(x)$ if there exist positive constants M and X such that $|f(x)/g(x)| \leq M$ for all $x \geq X$.

Proof: To avoid unnecessary algebra, consider instead that the number of players is drawn from a discrete uniform distribution $U[1, 2n-1]$. This modification does not change the limiting behavior of the rate of convergence. By equation (1.3), $g^c(n) = a + b/n = \mathcal{O}(1)$, and $\lim_{n\to\infty} g^c(n) = a$. By equation (1.2), $g^u(n) = a + b/n \sum_{i=1}^{2n-1} 1/i$. Since $\sum_{i=1}^{2n-1} 1/i$ is a left Riemann sum of $1/x$ from 1 to $2n$ and $1/x$ is decreasing in x, $\sum_{i=1}^{2n-1} 1/i \geq \int_1^{2n}(1/x)dx = \ln(2n)$. Similarly, $\sum_{i=1}^{2n-1} 1/(i+1)$ is a right Riemann sum of $1/x$ from 1 to $2n$, hence $\sum_{i=1}^{2n-1} 1/(i+1) \leq \ln(2n)$, or $\sum_{i=1}^{2n-1} 1/i \leq \ln(2n) + 1 - 1/(2n)$. Thus $a + (b/n)\ln(2n) \leq g^u(n) \leq a + (b/n)\left(\ln(2n) + 1 - 1/(2n)\right)$. Now $0 < 1 - 1/(2n) < \ln(2n)$ and $\lim_{n\to\infty}(1/n)ln(2n) = 0$. Therefore, $g^u(n) = \mathcal{O}(1)$, $lim_{n\to\infty} g^u(n) = a$, and $(g^u(n) - a)/(g^c(n) - a) = \mathcal{O}(ln(2n))$. $\square$

Proposition 4. *Suppose* $U(x_i, g_i, G) = x_i + n^a \ln g_i + bG$, $a \geq 0$, $b \in (0,1)$. *If the number of players is* n, *then* $g^c(n) = \mathcal{O}(n^a)$. *If it is randomly drawn from a discrete uniform distribution* $U[2, 2n-2]$, *then* $g^u(n) = \mathcal{O}(n^{a-1})$ *if* $a < 1$, *and* $\mathcal{O}(n^a)$ *if* $a \geq 1$.

Proof: By equation (1.3), $g^c(n) = n^a/(1-b) = \mathcal{O}(n^a)$. Consider again that the number of players is drawn from a discrete uniform distribution $U[1, 2n-1]$. By equation (1.2), $g^u(n) = \sum_{i=1}^{2n-1} i^a/((2n-1)(1-b))$. When $a < 1$, $g^u(n)$ is $\mathcal{O}(n^{a-1})$, since the largest term in the summation is $(2n-1)^a/((2n-1)(1-b)) = (2n-1)^{a-1}/(1-b)$. All the other smaller terms shrink to zero. The k-th largest term $(2n-k)^a/((2n-1)(1-b)) = \{(2n-k)/(2n-1)\}^a(2n-1)^{a-1}/(1-b)$ converges to zero since $\{(2n-k)/(2n-1)\}^a$ converges to 1 and $(2n-1)^{a-1}$ converges to 0 as n goes to infinity, for all $k \in \{2, 3, \ldots, 2n-1\}$. When $a > 1$, however, $(2n-1)^{a-1}$ diverges so each term in the summation diverges at the rate of $(2n-1)^{a-1}$. Since the number of terms is $2n-1$, $g^u(n) \leq (2n-1)(2n-1)^a/(2n-1)/(1-b) =$

$(2n-1)^a/(1-b)$, hence $g^u(n) = \mathcal{O}(n^a)$. $\square$

Proposition 3 states that as n, the mean population size, goes to infinity, both $g^c(n)$ and $g^u(n)$ shrink to a, that is, the voluntary contribution level in equilibrium asymptotically depends only on the warm glow (Andreoni (2006)). However, the rate of convergence to a is $\ln(2n)$ times slower when the population uncertainty grows as the mean population size does. Of course, this rate of convergence depends on the functional form of the utility and the shape of the population distribution. The upshot of this observation is that if the population uncertainty gets larger as the expected population grows, players are more reluctant to free ride. Proposition 4 states that as n goes to infinity, $g^u(n)$ converges while $g^c(n)$ does not when $a < 1$. If $a \in (0,1)$, that is, the warm-glow utility is increasing and concave in n, as assumed, then the equilibrium contribution level diverges without population uncertainty, and converges with population uncertainty. Since charitable giving is stable and consistent in the real world (List (2011)), this may suggest that people who derive utility from warm glow may take population uncertainty into account. If $a \geq 1$, $g^u(n)$ diverges as fast as $g^c(n)$ does, but this case is less relevant to the real world, since $a \geq 1$ implies that the warm glow increases exponentially as the population size grows.

A general idea of Proposition 3 can be applied to many similar cases where an individual's observed behavior is believed to be a combination of a decision-theoretic behavior (here, a) and a strategic behavior (here, b/n): Population uncertainty mainly affects the strategic behavior, so it provides a structural way to separate the decision-theoretic behavior from the strategic behavior, as long as a social planner (or an experimenter in lab experiments) can perturb the population uncertainty. However, this idea was not applied here, because the results of my experiments suggest that individuals' warm glow did indeed change strategically with the population size.

The experimental design is described in the following section. Because of limitations on lab capacity and other practical considerations, the experiments have a simpler form than the models discussed in this section, but the fundamental ideas that I set out to capture are the same.

1.4 Experimental Design and Procedures

To test how much of a voluntary contribution is driven by warm glow and how much by the response to population uncertainty, I conducted four sets of experiments, which are summarized in Table 1.1.

The purpose of the LWS experiment was to investigate how warm glow is affected by population uncertainty. The NWS experiment was performed to examine how subjects respond to population uncertainty, the NN experiment was intended to determine how warm glow is affected by group size with a nonlinear production function, and the NU experiment was performed to observe how subjects respond to volatility in the population uncertainty. The details follow.

Subjects in the LWS experiment played a series of linear voluntary contribution games: They were endowed with 10 tokens per round, and their task was to allocate the tokens between a private account and a group account in order to earn as much as they could. Tokens allocated to the private account earned 10 cents apiece. Tokens allocated to the group account earned 3 cents per token for

Table 1.1: Summary of Experimental Design

N per Session ≤ 24	Size of Each Group	#Sessions
LWS ($f(G) = 3\sum g_i$)	$n = 4, 8, 4or8$, or $4or12$	2
NN ($f(G) = 30\ln(\sum g_i)$)	$n = 4, 6, 8,$ or 12	1†
NU ($f(G) = 30\ln(\sum g_i)$)	$n = 2or6, 4or8, 2or12$, or $4or12$	2
NWS ($f(G) = 30\ln(\sum g_i)$)	$n = 4, 6, 8, 2or6, 4or8$, or $2or12$	2

* In each round, 10 tokens are given. Each experiment consists of 20 rounds.

* Subjects' task: Allocate the tokens to a private account and a group account.

The linear-within-subjects (LWS) experiment was designed to check how warm glow is affected by population uncertainty. With a linear public goods production function, population uncertainty should not play a role as long as the warm-glow utility is independent of the group size. The nonlinear-with-no-uncertainty (NN) experiment was designed to examine how subjects respond to changes in population size, and the nonlinear-with-uncertainty (NU) experiment was designed to see how they respond to population uncertainty. The nonlinear-within-subjects (NWS) experiment combined NN and NU for within-group comparisons. $n = 2or6$ denotes that the size of the group will be either 2 or 6 with equal probability, and the actual group size was revealed after the subjects made their decisions.
† Because of technical glitches, data from one session of the NU experiment were not recorded.

each member of the group. For example, if a participant allocated eight tokens to the private account and his group allocated a total of 11 tokens to the group account, then he would earn \$1.13 (10*8 + 3*11 = 113¢) for the round. As long as the group size is at least 4, the socially optimal contribution to the group account is 10, while the non-cooperative Nash equilibrium contribution is 0.[15] With this linear public goods production function, population uncertainty by itself plays no role as long as the subjects' warm glow is unaffected by population uncer-

[15]In general, let y, n, p, and k denote the endowment per round, the group size, the earnings per token in the private account, and the earnings per token in the group account, respectively. If $k < p < nk$, then the Nash equilibrium contribution level is 0, because the marginal benefit of contribution, k, is smaller than the marginal cost of contribution, p; however, the Pareto-optimal contribution level is y, because the sum of the marginal benefits, nk, is greater than the marginal cost.

tainty. The LWS experiment tested whether population uncertainty directly affects warm glow. Subjects made decisions under four different predetermined situations (corresponding to two "No Uncertainty" module experiments and two "Uncertainty" module experiments) in terms of the group size or the uncertainty in the group size: In each round of a No Uncertainty module experiment, the group size was some $n^{LWS} \in \{4, 8\}$. At the beginning of the round, n^{LWS} was randomly drawn, and subjects were informed of its value before making their decisions. In each round of an Uncertainty module experiment, a pair $(n_1^{LWS}, n_2^{LWS}) \in \{(4, 8), (4, 12)\}$ was randomly selected and the group size would be either n_1^{LWS} or n_2^{LWS}. At the beginning of the round, subjects were informed of the actual pair (n_1^{LWS}, n_2^{LWS}), and were told that the group size would be either n_1^{LWS} or n_2^{LWS}, with a 50% chance for each, but the actual group size was not revealed until after they made their decisions.[16] They practiced many times with virtual players,[17] to understand what the game was about and think about their strategy, before the actual games began. Some studies, including Andreoni and Croson (2008), considered the unintended possibility of certain undesirable strategic behavior on the part of subjects when the members of a group are the same for all or consecutive rounds: Once the group is formed, in the first several rounds a member might send a false signal to the other members to get them to believe they are altruistic, and then exploit this belief in the final rounds. To

[16]For clarification, I provide pseudo-codes for the determination of the group sizes in the following:

```
module1list=[4,8]; module2list=[[4,8], [4,12]];
round1=random.choose(module1list,1);
round2uncertainty=random.choose(module2list,1);
round2realized=random.choose(round2uncertainty,1).
```

[17]Subjects were allowed ten minutes to play with a tutorial. The tutorial consisted of a detailed introduction and a series of games with a group that (in addition to the subject) was comprised of artificial experimental participants (computers). They were told that the computers would make their decisions randomly, thus computer players' decisions may or may not be similar to those of real participants. Ten minutes was sufficient for most participants to play more than ten rounds of the game. On average, they practiced with the tutorial for 16 rounds. See Appendix B for screen captures of the tutorial.

exclude this strategic behavior, a new group was formed for every round. The experiments ran for 20 rounds: 10 rounds of the No Uncertainty module and 10 rounds of the Uncertainty module. To minimize a final-round bias, subjects were not informed of the number of rounds for either type of experiment.

The NWS experiment was similar to the LWS experiment, with two differences. One difference is that the amount of money earned by subjects from tokens allocated to the group account is given in Table 1.2, which represents a production function of roughly $30\ln(G)$.[18] Since inequalities in Proposition 1 and Corollary 1 hold strictly when the marginal production function is convex, such a nonlinear production function was necessary to see the effect of population uncertainty. Based on the total number of tokens allocated to the group account, every member of the group earned the amount of money shown in the table, whether or not she had contributed to the group account. For example, if a total of 11 tokens was allocated to the group account, every member earned 73 cents for the round. If a subject whose group allocated a total of 11 tokens to the group account allocated 8 tokens to her private account, she earned $1.53 (73 + 10*8 = 153¢) for the round. If a group allocated no tokens to the group account, every member forfeited 10 cents.[19] The other difference is that the NWS experiment had greater variations in the group size. Subjects made decisions under six different predetermined situations (corresponding to three No Uncertainty module experiments and three Uncertainty module experiments) in terms of the group size or the uncertainty in the group size: In each round of a No Uncertainty module experiment, the group size was some

[18] During pilot trials, experiment participants understood the production schedule better with the table than with either (a) an exact but far longer conversion table or (b) a calculator and a formula.

[19] In order for the production function to exactly represent $30\ln(G)$, every member's entire earnings should be forfeited when $G = 0$, since $\ln(0) = -\infty$. I admit that the results of the NWS experiment could have been very different if total forfeiture of earnings had been a possibility.

$n^{NWS} \in \{4, 6, 8\}$. In each round of an Uncertainty module experiment, a pair $(n_1^{NWS}, n_2^{NWS}) \in \{(2, 6), (4, 8), (2, 12)\}$ was randomly selected and the group size would be either n_1^{NWS} or n_2^{NWS}. In the LWS experiment, the smallest nontrivial group size was 4, because when the group size is less than 4, no contributions are both socially and individually optimal. The NWS experiment did not have such a restriction.

The NN experiment and the NU experiment were similar to the No Uncertainty module and the Uncertainty module, respectively, in the NWS experiment. The NN experiment was conducted in two sessions, as was the NU experiment. Each session ran for 20 rounds. In each round of the NN experiment, the group size was some $n^{NN} \in \{4, 6, 8, 12\}$. At the beginning of the round, n^{NN} was randomly drawn, and subjects were informed of its value before making their decisions. The Nash equilibrium for this case is $30/(10n^{NN}) = 3/n^{NN}$. In each round of the NU experiment, a pair $(n_1^{NU}, n_2^{NU}) \in \{(2, 6), (4, 8), (2, 12), (4, 12)\}$ was randomly selected and the group size would be either n_1^{NU} or n_2^{NU}. At the beginning of the round, subjects were informed of the actual pair (n_1^{NU}, n_2^{NU}), and were told that the group size would be either n_1^{NU} or n_2^{NU}, with a 50% chance for each, but the actual group size was not revealed until after they made their decisions. The Nash equilibrium for this case is $30/10\left(1/(2n_1^{NU}) + 1/(2n_2^{NU})\right) = 3/2(1/n_1^{NU} + 1/n_2^{NU})$. They also practiced sufficiently with virtual participants, and in the real games the group sizes and uncertainties came in a random order. By setting the order of the rounds randomly, the experimenter's intention played a minimal role.

All the experimental sessions were conducted at the Laboratory for Experimental Economics & Decision Research (LEEDR) at Cornell University from

Table 1.2: Earnings from the Group Account

Total Tokens	Earnings (¢)	Total Tokens	Earnings (¢)	Total Tokens	Earnings (¢)
0	-10	8	62	30–39	106
1	0	9	66	40–49	114
2	21	10	69	50–59	120
3	33	11–12	73	60–69	125
4	42	13–15	79	70–79	129
5	48	16–19	86	80–89	133
6	54	20–24	93	90–99	136
7	58	25–29	99	100–109	139

This table maps the total number of tokens allocated to the group account to the total value of those tokens. For example, if the subjects in a group allocated a total of 11 tokens to the group account, then every member of the group would earn 73¢. If no subject in a group allocated tokens to the group account, every member forfeited 10¢.

June 9 to June 20, 2014. Python and its application Pygame were used to computerize the games and establish a server–client platform. The experiments were advertised in summer classes, and it was indicated that the anticipated average earnings for participating in the experiment would be $34, including a participation reward of $5. The participants were Cornell undergraduate students, who were recruited through the Laboratory's online recruitment system. Sessions ran from 60 minutes to 80 minutes, depending on treatment specifications. Because of no-show subjects, the session sizes varied from 15 to 24,[20]

[20]The lab has 24 computers for participants. Accordingly, the experiment was designed by assuming that all 24 students who had signed up would attend. Thus the group sizes were chosen to be divisors of 24. When the number of subjects was not divisible by the group size, so that the last group had too few group members, the decisions of some subjects who were assigned to one of the other groups were also applied to the last group, in order to calculate the payoffs of the members in the last group properly. Since all the payoff calculations and group formations were internally determined at the server computer, subjects could neither recognize

and a total of 141 subjects participated in the experiments. Participants were randomly assigned to separate desks equipped with a computer interface. They were not allowed to communicate with other participants during the experiment. It was also emphasized to participants that their allocation decisions would be anonymous. Though new groups were formed every round, there was no physical reallocation of the subjects. The participants input their decisions on their computer interface. The server computer collected all the decisions, formed new groups, calculated the payoffs, and returned each of the payoffs to a corresponding computer interface. They read instructions and practiced with a tutorial program. An instructor answered all questions until every participant thoroughly understood the experiment.

Participants earned $33.71 on average, which is close to the advertised earnings expectation of $34. Only one participant allocated all of his tokens to the group account for all rounds and earned the lowest amount, $16.28; all the others earned more than $22. The highest amount earned was $43.99. In every group, some allocation was made to the group account, so no one's endowment was forfeited.

1.5 Results

The main results of the lab experiments are summarized as follows:

1. The salience of population uncertainty partly drove out warm glow. In the linear VCM where the subjects' contributions could be explained only by

that their actions may be affecting members of the last group nor know that the last group had an insufficient number of members (so some decisions were adopted from the other groups).

warm glow, contribution levels were halved.

2. The changes in contribution level by group size were smaller under population uncertainty. The subjects' decisions were determined mainly by the lower bound of the population distribution.

3. The more volatile the population, the greater the total amount contributed.

4. After controlling for the driving-out effects, subjects responded to the population uncertainty to a greater extent than predicted by theory.

Most of these results are completely new observations which could not have been captured using the setups for previous experiments.

1.5.1 Warm glow partly driven out under population uncertainty

Subjects who made a nonzero contribution in the linear public goods production environment contributed *less* when there was population uncertainty. This observation confirms that the warm-glow utility is concave in the population size.

The results of the LWS experiment are summarized in Table 1.3. In this experiment, where the production function is linear, there is no theoretical difference between the equilibrium contributions with and without population uncertainty for self-interested rational agents. As long as the group size is at least 4, the Nash equilibrium contribution level is 0. Of the 44 subjects who participated in the LWS experiment, 45.45% of them (20 subjects) kept contributing nothing, as predicted by theory, or contributed nothing except for small contributions in one or two rounds. Seven of the other 24 subjects (15.91% of all the participants in the LWS experiment) maintained a consistent contribution level with little variation (a small change in only one or two rounds). An interesting observation pertains to the remaining 38.64% of subjects, who kept making nonzero contributions to the group account: They showed warm glow, which varied with the group size. Most of these latter subjects contributed *less* when faced with population uncertainty. In fact, the contribution level, averaged over all subjects in the LWS experiment, decreased significantly under population uncertainty: by 0.5361 tokens in experiments with a mean group size of 6 and by 0.6687 tokens in those with a mean group size of 8; both of these differences are statistically significant at the 1% level.[21] The differences were tested under the null hypothesis for the same average contribution levels. All subjects contributed on average 1.6591 tokens to the group account when there was no population uncertainty, so their average contribution level decreased by at least about 32% (the smaller of the ratios 0.5361/1.6591 and 0.6687/1.6591) when there was population uncertainty. When comparing the average contribution for those who actually contributed to the group account in at least one round, the reduction in warm glow is even more pronounced. Their contribution level under population uncertainty was halved, from 3.6077 to 1.8385. In one session the Uncertainty module was conducted first, but this change of order yielded no significant differences. The learning effect was insignificant.

[21] I intended to compare the average contribution for a fixed group size (for example, 8) to that for a random group size with the same mean (for example, either 4 or 12 with equal probability). Some colleagues claimed that I should instead compare the weighted average of the contributions from two fixed group sizes (for example, 4 and 8) to the corresponding average contribution for a random group size with the same mean (for example, either 4 or 8 with equal probability). I used both comparison methods. The differences are statistically significant at the 1% level.

Table 1.3: Linear-within-Subjects (LWS) Experiment

Module	Obs.	Group Size	Avg. Contribution (pooled)	NE	St. Dev. (pooled)
No Uncertainty	224	4	1.2366	0	2.3718
	216	8	2.0972	0	2.9531
Uncertainty	244	$4or8$	1.1230	0	2.1491
	196	$4or12$	1.4286	0	2.1460

* Difference between "4and8" and "4or8": 0.5361^{***}

* Difference between "8" and "4or12": 0.6687^{***}

The fourth and sixth columns show the average pooled contribution levels and standard deviations, respectively. The fifth column shows the Nash equilibrium contribution level under the assumption of self-interested rational agents. A total of 44 subjects (20 in the first session, 24 in the second session) participated in the LWS experiment. In the No Uncertainty module, they played a standard VCM. In the Uncertainty module, their task was the same, but the size of the group wasn't revealed until after they made their decisions. I compared a weighted average of the contribution levels when the group size was fixed at 4 and at 8 (denoted in the table by "$4and8$") to the average contribution level when the group size was either 4 or 8 with equal probability ("$4or8$"). The difference between these two is 0.5361 tokens, with a p-value of 0.0085. I also compared the average contribution level for a fixed group size of 8 ("8") to that for a random group size of either 4 or 12 with equal probability ("$4or12$"). The difference between these two is 0.6687 tokens, with a p-value of 0.0047. Both differences are statistically significant at the 1% level.

This result is interesting and had never been observed in previous studies. It strongly confirms that the warm glow is increasing and concave in the population size (Andreoni (2007)). There are no theories involving self-interested rational agents which support this observation. Even if the subjects' rationality was bounded as in the level-k theories (Camerer et al. (2004)) or in the cognitive hierarchy theories (Costa-Gomes and Crawford (2006)), their optimal decision should be to contribute 0 as long as $k \geq 1$. If those who contributed were the $L0$, that is, if such players made choices randomly, differences as large as the ones observed in these experiments would not be expected.

Another possible explanation is that the salience of population uncertainty encouraged subjects to recognize more of the strategic aspects of the game situation. Many studies have found that social preferences are affected by economic incentives (Bowles and Polania-Reyes (2012)), peers (Gächter et al. (2013)), risks (Saito (2013)), and/or contexts (Keisner et al. (2013)), so it is plausible that some kind of incentives affected subjects' preferences in my experiments. Though it has been noted that the salience of uncertainty can prompt people to consider fairness more (van den Bos (2001)), experimental/empirical evidence of the effect of the salience of uncertainty on social preferences has been meager.

The change in warm glow was not due primarily to changes in the group size, but rather to uncertainty in the group size. The results of the NN experiment are summarized in Table 1.4. Without population uncertainty, the average contribution levels tended to decrease as the group size increased, as predicted by theory (Andreoni (2006)). When the group size was 4, the average contribution level was 2.4048. It decreased to 2.3333, 2.0595, and 2.0340 for groups of 6, 8, and 12, respectively. The last column of Table 1.4 shows the difference between the actual contribution levels and the equilibrium contribution levels. Interpreting such differences as the warm glow, there is no significant pattern between warm glow and group size. The contribution level due to warm glow lay between 1.6548 and 1.8333 tokens, and the differences are not statistically significant. Another observation is that the contribution levels due to warm glow in the NN experiment were almost identical to 1.6591, the average contribution level in the LWS experiment without population uncertainty.

Table 1.4: Nonlinear-with-No-Uncertainty (NN) Experiment

Group Size	Obs.	Avg. Contribution (pooled)	NE	St. Dev. (pooled)	Warm Glow†
4	126	2.4048	0.7500	1.7672	1.6548
6	63	2.3333	0.5000	1.9757	1.8333
8	84	2.0595	0.3750	1.7518	1.6845
12	147	2.0340	0.2500	1.8335	1.7840

A total of 21 subjects participated in the NN experiment. In each round, the size of the group was randomly determined and was displayed at the top of the game screen. Differences in the numbers of observations are due to such randomness. The average contribution level decreased as the size of the group increased, as predicted by theory. However, the warm glow lay between 1.6548 and 1.8333 tokens, which is almost identical to 1.6591, the average contribution level in the LWS experiment without population uncertainty.
† The difference between the average contribution level and the Nash equilibrium contribution level is used as a proxy measure of the warm-glow utility.

1.5.2 Contribution level determined mainly by lower bound of population distribution

With population uncertainty, the average contribution level neither increased nor decreased with the mean group size. Rather, the average contribution level was larger when the lower bound of the population was smaller. This observation confirms the idea presented in Proposition 1: that the main driving force behind an increase in the contribution level is the strategic response to the possibility that the contributor pool will turn out to be small. The results of the NU experiment are summarized in Table 1.5.

When the size of the group was either 4 or 12, that is, when the mean group size was 8, the average contribution was 2.0242. However, when the size of the

Table 1.5: Nonlinear-with-Uncertainty (NU) Experiment

Group Size (Mean)	Obs.	Avg. Contribution (pooled)	NE	St. Dev. (pooled)	Mean−NE
$2or6$ (4)	201	2.2239	1.0000	2.0651	1.2239
$4or8$ (6)	165	1.9515	0.5625	2.0025	1.3890
$2or12$ (7)	147	2.5238	0.8750	2.1655	1.6488
$4or12$ (8)	207	2.0242	0.5000	2.0490	1.5242

* Average contribution when the lower bound was 2: 2.3506

* Average contribution when the lower bound was 4: 1.9919

* Difference between lower bound 2 and lower bound 4: 0.3586^{***}

* Difference between "$2or12$" and "$4or8$": 0.5723^{***}

A total of 36 subjects participated in the NU experiment. In each round, the uncertainty in the group size was randomly chosen and was displayed at the top of the game screen. Differences in the numbers of observations are due to such randomness. The group size was revealed after all the participants made their decisions. As suggested by the fundamental idea behind Proposition 1, the average contribution level decreased as the lower bound of the population distribution increased. The difference between the average contribution when the lower bound was 2 and the average contribution when the lower bound was 4 is statistically significant at the 1% level. Also, subjects contributed more when the population was more volatile. The difference between the average contribution when the group size was either 2 or 12 and the average contribution when the group size was either 4 or 8 is statistically significant at the 1% level.

group was 2 or 12, and hence had a mean size of 7, the average contribution was 2.5238. A similar tendency was observed with the smaller mean group sizes. When the size of the group was either 2 or 6, the average contribution level was 2.2239, while when the size of the group was either 4 or 8, the average was 1.9515. In short, the contribution was determined mainly by the lower bound of the population distribution. When the lower bound was 2, subjects contributed more, regardless of the mean group size. Note that the fundamental idea behind Proposition 1 stems from individuals' responses to the possibility of the contributor pool being small, so this observation is as expected. Also, though it should be further verified with a larger population size, this observation may suggest that an individual's voluntary contribution behavior is affected by their subjective concern that the contributor pool will be small. In other words, the "threat" of a potentially small contributor pool encourages individuals to contribute to the production of public goods.

Unlike the NN experiment, the difference between the actual average contribution level and the equilibrium contribution level cannot be understood as a proxy for warm glow, as we observed that population uncertainty partly drives out warm glow. The overall average contribution levels in the NU experiment were not significantly different from those in the NN experiment.

1.5.3 Increase in contributions with increase in volatility of population distribution

As predicted in Corollary 1, subjects contributed more when the population distribution was more volatile but with almost the same mean. In the NU experiment, the difference between 2.5238, the average contribution when the group size was either 2 or 12, and 1.9515, when it was either 4 or 8, is statistically significant at the 1% level.[22] Though statistically insignificant, a similar pattern was also observed in the NWS experiment: The average contribution level when the group size was either 4 or 8, namely 1.7125, is smaller than 1.7902, the average contribution when the size was either 2 or 12. It was impossible to extract the

[22]Note that the mean group sizes in these two cases are slightly different. When the group size was either 4 or 8, the mean group size was 6, while the mean was 7 when the group size was either 2 or 12. Since the lab capacity is 24, I chose the group sizes to be divisors of 24. Given this restriction, "$4or8$" and "$2or12$" are the best possible sets of results to compare.

effect of only the variance of the population distribution, because with population uncertainty subjects behaved in a more self-interested manner, as observed in the LWS experiment.

Institutions and organizations that rely heavily on voluntary contributions cannot change the size of the contributor pool in the short term. Still, this observation has practical value in that it suggests that the size of the contributor pool should not be mentioned if the size is large. However, they may stand to benefit from mentioning the smallest possible size of the contributor pool, as that may serve to increase the voluntary contribution level.

1.5.4 Response to population uncertainty greater than predicted by theory

Table 1.6 summarizes the results of the NWS experiment. Results from the No Uncertainty module and the Uncertainty module resembled those of the NN and NU experiments: In the No Uncertainty module, the average contribution level decreased as the group size increased, but after subtracting the equilibrium contribution level the warm glow was not affected by the group size. In the Uncertainty module, the average contribution level was higher when the lower bound of the population distribution was 2. As predicted in Proposition 1, the contribution levels in the Uncertainty module were higher than those in the corresponding No Uncertainty module. Although all the differences were positive, none of them is statistically significant. This insignificance is due mainly to the opposite effect of population uncertainty, that is, the effect of warm glow being partly driven out, as observed in the LWS experiment.

Table 1.6: Nonlinear-within-Subjects (NWS) Experiment

Module	Obs.	Group Size	Avg. Contribution (pooled)	NE	St. Dev. (pooled)	Mean−NE	Drive-Out Adjustment†
No Uncertainty	217	4	1.8018	0.7500	1.8263	1.0518	1.0518
	84	6	1.5952	0.5000	1.4736	1.0952	1.0952
	99	8	1.6465	0.3750	1.5992	1.2715	1.2715
Uncertainty	177	2 or 6	1.8814	1.0000	1.5821	0.8814	1.4175
	80	4 or 8	1.7125	0.5625	1.4337	1.1500	1.6861
	143	2 or 12	1.7902	0.8750	1.3767	0.9222	1.4583

* Difference between "$2or6$" and "4": 0.3657^{**}

* Difference between "$4or8$" and "6": 0.5909^{***}

A total of 40 subjects (19 in the first session, 21 in the second session) participated in the NWS experiment. In the first session, the No Uncertainty module experiment was conducted first, while in the second session the Uncertainty module experiment was. In each round of the No Uncertainty module, the group size was randomly determined and was displayed at the top of the game screen. In each round of the Uncertainty module, the uncertainty of the group size was randomly chosen and the subjects were informed of the uncertainty, but the group size wasn't revealed until after all the subjects made their choices. The contribution levels in the Uncertainty module were higher than those in the corresponding No Uncertainty module.

† The last column shows the contribution level adjusted for the effect of warm glow being partly driven out: In the LWS experiment, the overall contribution level with population uncertainty was at least 0.5361 tokens smaller than that without population uncertainty. After controlling for the Nash equilibrium contribution level, I adjusted the net contribution level by adding 0.5361.

The last column of Table 1.6 shows the driving-out-effect-adjusted contribution level. In the LWS experiment, the average contribution level with population uncertainty was at least 0.5361 tokens smaller than that without population uncertainty. After controlling for the Nash equilibrium contribution level, I adjusted the net contribution level for the NWS experiment by adding 0.5361. With this adjustment, the differences between the contribution levels with and without population uncertainty are more distinctive. The difference between 1.4175 (the adjusted average contribution level when the group size was either 2 or 6) and 1.0518 (the contribution level when the group size was 4) is statistically significant at the 5% level. The difference between 1.6861 (when the group size was 4 or 8) and 1.0952 (when the size was 6) is significant at the 1% level. The remaining case also had a positive difference, but it was insignificant.

1.6 Conclusions

Population uncertainty has rarely been studied in the literature on voluntary contribution of public goods despite its importance. With population uncertainty, the equilibrium voluntary contribution level is greater than that when the population size is fixed at the mean of the population distribution. As the population size grows, the equilibrium contribution level decreases, but the decreasing tendency is weaker than predicted by the model for the case where there is no uncertainty in the size of the population. From the lab experiments, we learned that an individual's voluntary contribution level does respond to population uncertainty, and we were able to verify many aspects of the theoretical predictions. Subjects were more concerned with the possibility of a small contributor pool. When the population distribution was more volatile, subjects contributed more. These observations suggest that institutions and organizations that rely heavily on individual voluntary contributions may bring in more contributions by suppressing the size of the contributor pool.

The salience of population uncertainty drove out warm glow. This is an unexpected, but interesting observation that previous studies have not captured. Though it confirms that warm glow is congestive, it is still puzzling, because once population uncertainty is salient, a more volatile population distribution yields more contributions. Behavioral studies have considered a variety of certainty effects, but the certainty in population size is distinct because it appeals to individuals' strategic aspects while other forms of certainty appeal to an individual's risk preferences. My interpretation of this is that such changes prompt people to recognize the strategic aspects of the game situation more, but I admit that it may have other interpretations.

There are many directions for extension of this study. Many previous studies of the voluntary contributions mechanism have considered the effects of individual characteristics such as gender, education, and risk preference. Those studies could be redone by adding population uncertainty to answer how individual characteristics bring about different responses to population uncertainty. Also, although this study has some theoretical predictions for a large population, it still is unclear whether the actual contribution levels would increase or decrease with population uncertainty. Cooperation with charities to carry out field experiments would be ideal, because charitable giving is a type of contribution that brings little in the way of practical benefits to the donors. If population uncertainty drives out the purely altruistic aspects of charitable giving, the contribution level would decrease.

Appendix A

Sample Experimental Instructions

[Let participants sign in.]

Hi everyone. Welcome to the group-decision experiment. Please make sure you have a pen, two copies of the consent form, and a table which you will need during the experiments. We want you to focus on the experiment, so please do not anything unrelated to the experiment. Please take a moment to turn off your cell phone and any electronic devices with sound notifications. Please read carefully and fill out one copy of the consent form. The form requires your initials at the end of the first page, and your signature at the end of the second page. Note that one copy is for our records, and the other copy is for your records. Please raise your hand if you are done filling out the form.

[Let them fill out the consent form.]

As you have read the consent form, we will conduct experiments in group decision-making. At the end of the experiment you will be paid in cash. The amount of money you earn will depend on the decisions you make, as well as the decisions other participants make.

The whole experiment consists of several, but no more than 30 rounds of simple games whose overall procedure is the same. In each round, you will be asked to make a choice in a slightly different situation and input your decision to the computer interface.

Your choices and answers will be linked with a computer number of your seat. We will never link names with your responses in any way. Your personal information provided for your payments will never be stored nor used for any research. You will neither learn about other participants' identity in the course of this experiment, nor will they learn about your identity.

You are not allowed to talk to others during the experiments. If you have a question, please raise your hand so that I can come to you and answer your question in private.

Now please wake up your computer. You will see a welcome screen in a yellow window. This is a tutorial which will introduce what you will do during the actual experiments, and make you feel familiar. This tutorial is self-contained, so please read through and follow instructions. I especially recommend you to take a careful look on the table I distributed, because your earnings are mainly determined by the table. I will give you ten minutes to play with the tutorial. If you finish it earlier, you may want to start over. Note that I set computers choose their decision randomly, so computers decisions may or may not be similar to that of real participants.

[Give them 10 minutes for the tutorial.]

We are ready to begin. Please close the tutorial. Click on "Experiment" on the taskbar. Everything will be the same with the tutorial, except two things: First, now you play with real participants here and second, your earnings will be paid. The total sum of your earnings will be stored in the server computer, so do not worry about the payments and please focus on the experiment by itself. Let's start the first round.

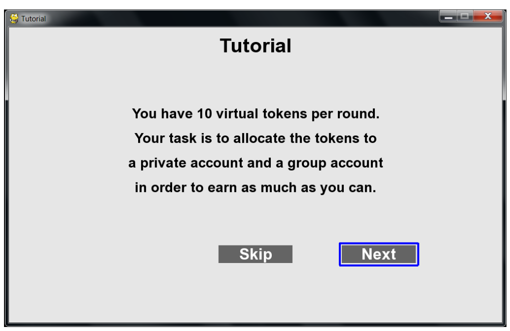
[After the experiment ends.]

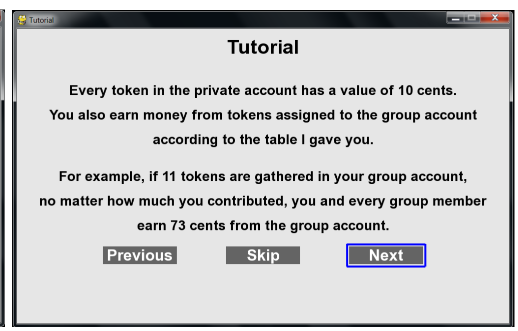
All experiments are done. Please bring all of your materials to the front one at a time. Another set of experiments will be conducted this week, so please do not share your results with anyone until the end of the week.

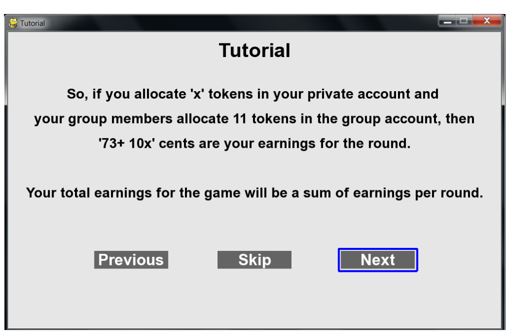
[Pay subjects in a debriefing area and dismiss them one at a time.]

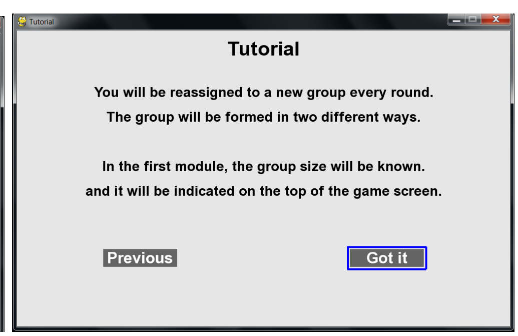
Appendix B

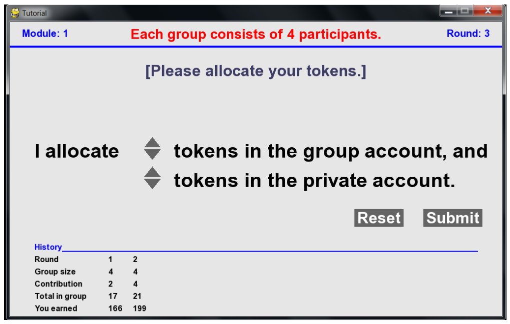
Screen Captures of the Tutorial (for Main Experiments)

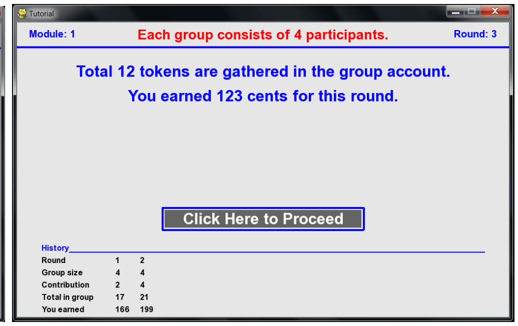


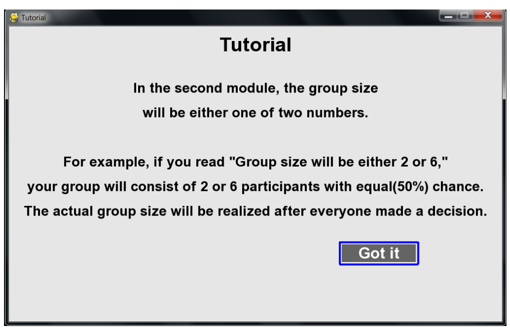


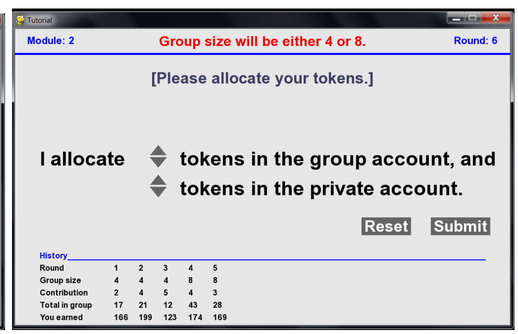


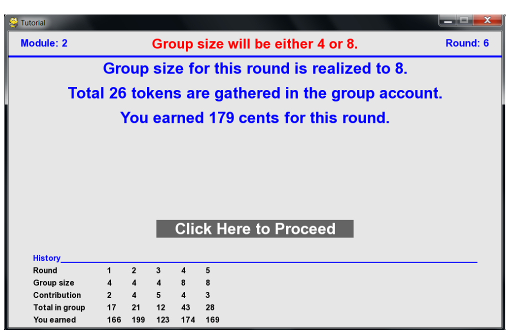


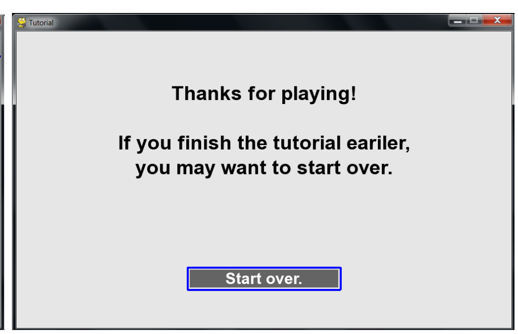

Tutorial
Module: 1
Each group consists of 4 participants.
Round: 3
[Please allocate your tokens.]
I allocate
tokens in the group account, and
tokens in the private account.
Reset
Submit
History
Round 1 2
Group size 4 4
Contribution 2 4
Total in group 17 21
You earned 166 199


Tutorial
Module: 1
Each group consists of 4 participants.
Round: 3
Total 12 tokens are gathered in the group account.
You earned 123 cents for this round.
Click Here to Proceed
History
Round 1 2
Group size 4 4
Contribution 2 4
Total in group 17 21
You earned 166 199


Tutorial
Tutorial
In the second module, the group size
will be either one of two numbers.
For example, if you read "Group size will be either 2 or 6,"
your group will consist of 2 or 6 participants with equal(50%) chance.
The actual group size will be realized after everyone made a decision.
Got it


Tutorial
Module: 2
Group size will be either 4 or 8.
Round: 6
[Please allocate your tokens.]
I allocate
tokens in the group account, and
tokens in the private account.
Reset
Submit
History
Round 1 2 3 4 5
Group size 4 4 4 8 8
Contribution 2 4 5 4 3
Total in group 17 21 12 43 28
You earned 166 199 123 174 169


Tutorial
Module: 2
Group size will be either 4 or 8.
Round: 6
Group size for this round is realized to 8.
Total 26 tokens are gathered in the group account.
You earned 179 cents for this round.
Click Here to Proceed
History
Round 1 2 3 4 5
Group size 4 4 4 8 8
Contribution 2 4 5 4 3
Total in group 17 21 12 43 28
You earned 166 199 123 174 169


Tutorial
Thanks for playing!
If you finish the tutorial eariler,
you may want to start over.
Start over.

CHAPTER 2

THE SECOND-TIER TRAP: THEORY AND EXPERIMENTAL EVIDENCE

2.1 Introduction

I consider a winner-take-all competition among n players in which their environmental supports are random and heterogeneous. In the first phase, players choose an environment to which they want to belong, based on some informative statistics—either limited or complete—about the environments. In the second phase, they choose their effort level, and after that their environmental support is realized. The second phase of the game can be interpreted in a manner similar to that of Lazear and Rosen (1981), namely, that the environmental support is the random or luck component. It is well known that in a many-player competition with a winner-take-all payoff structure, the variance of the environmental support (or of some random component in other contexts) is significant, and therefore it is straightforward to predict that the ranking of the expected environmental supports does not consistently rank the expected utilities of the players.

My main research question was what ex-ante information is sufficient for choosing an optimal (i.e., expected payoff maximizing) environment, and whether economic agents will indeed choose the optimal environment. I was particularly interested in the situation where the best environment is not allowed to be chosen, so agents are asked to pick the second-best environment. I claim that they are tempted to choose the second-tier environment (the second-best environment by expectation) over the third-tier environment when they should have chosen the third-tier one to maximize their expected payoff. I call this wrong decision the second-tier trap (STT), because a sufficient condition for the STT is so weak that a player's preference for the second-tier environment over the third-tier one could seem reasonable.

In the first stage of my model, identical players reveal their preferences of environments and are assigned to environments according to their preference orders. If two or more players have the same preference order, they are randomly assigned to different environments with equal probability. Alternatively, this could be thought of as a random ordering of identical players who take turns choosing the environment to which they want to belong. The player's environmental support is randomly drawn from an environment-specific support distribution at the end of the game. The support distribution can be interpreted as a different market situation that each player faces;[1] a characteristic of the group, such as a team, school, or career (Akerlof and Kranton (2005)), with which the player chooses to identify; or simply a distribution of the luck component. Players know the support distributions, and are able to calculate some informative statistics: means, variances, and ex-ante advantages. The ex-ante advantage of an environment is the winning probability of a player from that environment when all the players exert the same amount of effort. In the second stage, players choose their level of effort, and environmental supports (accordingly, payoffs) are realized at the end of the game. The player with the highest output, which is the sum of the effort and the realization of the environmental support, wins the prize. Equilibrium payoffs are determined by the prize, the winning probability, and the cost of the effort.

[1]For example, consider a situation where one of three workers will be promoted based on their outputs (the sum of their effort and the growth rate of the market), and the three workers will be in charge of separate international markets whose potential growth rates are random and heterogeneous. Before choosing their effort level, they have to exclusively choose one market whose growth rate is not yet realized.

The tiers are defined according to the ranks of the expected environmental supports. This definition is well justified, because equilibrium payoffs are consistent with tiers in pairwise competitions. In three-player competitions, a sufficient condition for the STT is that the second- and third-tier environments have equal ex-ante advantages. This implies that the STT may arise even when the second-tier environment has a higher mean and a (slightly) higher ex-ante advantage than the third-tier one. I claim that this sufficient condition is so weak that players can easily be tempted to choose the second-tier environment, which is the wrong decision.

I conducted laboratory experiments to observe how subjects chose their environment to maximize their expected payoff. The experiments were conducted at the Cornell Lab for Experimental Economics & Decision Research and employed undergraduate students at Cornell University for ten sessions and graduate students for two sessions. A total of 176 students (155 undergraduates and 21 graduates) completed the experiments. In each session, experiment participants played 10 rounds of rank-order tournament games. In the first stage of the game, each subject exclusively chose one of three environments, which were described by nonidentical uniform distributions. In the second stage, they chose an individual investment level with costs. At the end of the game, an environmental support was randomly drawn from the distribution, and payoffs were determined based on the rank of the output, which was the sum of the environmental support and the individual investment. They chose one of three environments in four of the rounds (which I call the unrestricted rounds), and they were restricted to choose an environment other than the first-tier one in the other six rounds (the restricted rounds). None of the subjects chose the environment that maximized their expected payoffs in all the restricted rounds, while 52.57% of subjects chose the optimal environment in all the unrestricted rounds. On average, subjects choose the optimal environment in 28.67% of the restricted rounds and in 75.57% of the unrestricted rounds. It is interesting that those who always chose the optimal environment in the unrestricted rounds were more likely to fall into the STT. On average, they chose the optimal environment in only 16.67% of the restricted rounds. In the follow-up survey, most of the subjects indicated that they were more confident about their choices of environments than their choices of investment levels, and found that choosing the environment was an easier task than choosing an individual investment level.

Following Lazear and Rosen (1981), many researchers have analyzed contests and all-pay auctions of asymmetric agents. This paper contributes to this literature. Some authors, including Krishna and Morgan (1998) and Moldovanu and Sela (2001), assume that ability includes some random components and that differences in ability are captured by the different and deterministic costs of effort. Nevertheless, they assume that the ability distributions are identical. Dubey (2013) takes stochastic ability and incomplete information into account. Pérez-Castrillo and Wettstein (2014) have a model in which abilities work in the same manner as environmental supports in this paper, but abilities are private information when effort is made. The main differences between the existing literature and this paper are that all agents decide the level of effort before the random component is realized and the ability distributions are not identical among agents. To the best of my knowledge, there have been no models of all-pay auctions among three players that involve non-identical and random environmental supports. Therefore, the model presented here can be understood as a generalization of previous models. Once players are exclusively assigned to the environments in the first stage, the second stage of the model has a form similar to that of the Lazear-Rosen rank-order tournament model (Lazear and Rosen (1981)) and its descendants. Though rent-seeking behavior models are not the focus of my model, the equilibrium allocation of models presented in Nti (1999), Stein (2002), Allard (1988), and Tullock (1980) can be described as solutions of special cases of my model.[2]

Another difference between this paper and the existing literature is that there are more than two agents. When allowing for asymmetries among agents, most of the literature on all-pay auction contests assumes that there are exactly two players as in Amann and Leininger (1996) or many ex-ante identical players as in Krishna and Morgan (1997). Some recent studies consider more than two agents. Siegel (2009) studies many-player all-pay contests to capture general asymmetries among contestants and analyses the players' participation. Parreiras and Rubinchik (2010) consider three bidders in contests where participants have distinct risk preferences, and finds that these differences can cause some players to drop out. Kirkegaard (2013) studies an incomplete information model among three groups where a "strong" group is handicapped, in order to allow for affirmative action, and shows that some of the players in the favored group may become worse off when the favored group is diverse. The thrust of this paper is similar to that of Kirkegaard (2013), since it shows that properties of two-bidder contests may not necessarily extend to many-bidder contests.

An analogue of this model is one where the environmental support distributions represent risks: The unrealized supports can be represented by error terms

[2] If the realizations of the environmental supports were publicly known before choosing the level of effort, then my model would reduce to the models presented in Nti (1999), Stein (2002), and Allard (1988). In this case, the ranks of the supports (abilities, or costs in some contexts) would yield a strong prediction of the ranks of the equilibrium payoffs. Moreover, if the environmental supports of all the players were non-stochastic and identical, then a player's probability of winning would be captured simply by the players' individual levels of effort relative to the aggregate sum of their efforts, which is a basic model provided by Tullock (1980).

with different means and variances. In this regard, this paper extends Kräkel and Sliwka (2004), where two players with different abilities choose effort and risk levels, and Gilpatric (2009), where three players in the contest choose one of the error terms, whose means are all zero but whose variances vary.

A very large number of studies on competitions have used lab experiments.[3] However, the problem of choosing a supporting environment for a competition has not been considered, despite its importance. Such a restriction on the experimental design decreases the external validity of the research because in many realistic situations we first choose an environment which will support our effort *before* we choose a level of effort for competitions. Though the overall methodology of my laboratory experiments resembles that of Gneezy and Smorodinsky (2006), the unique goal of my experiments was to observe whether players can choose the environment that maximizes the expected payoff under complete information.

The organization of the paper is as follows: Section 2 presents the model, section 3 shows the relationship between the ranks of the expected environmental supports and the ranks of the equilibrium payoffs, and section 4 concludes.

2.2 The Model

Consider a two-stage game with n identical players indexed by $i \in \{1, \ldots, n\} \equiv N$, where the players compete for a prize. In the first stage, players reveal their preferences of n heterogeneous environments (e.g., n markets,

[3] For a review of experimental studies on contests, see Sheremeta (2013). For a more extensive review of the experimental literature on contests, rank-order tournaments, and all-pay auctions, see Dechenaux et al. (2014).

n schools, or n careers) with a single-dimensional characteristic that randomly affects the outputs of the players. Throughout this paper, I call this characteristic an "environmental support" in that a player's choice of environment may provide benefits (or impose penalties) over and above those that stem from that player's effort. For example, every school may adopt different pedagogics. After students are disciplined in a particular academic environment, they may be randomly affected by the values emphasized by that school when they face a competitive job market. Let G_i denote the continuous cumulative distribution for environment i's support, θ_i. Θ_i denotes the support of θ_i, but I assume that $\Theta_i = \mathbb{R}$ unless otherwise noted. Assume further that the probability density function for the support due to environment i, g_i, is unimodal and symmetric and has finite moments. With a slight abuse of terminology, I say that the environment i is where player i belongs.

In the first stage, players know the support distributions and are able to calculate some informative statistics: means (μ_i) and ex-ante advantages (A_i).[4] The ex-ante advantage of environment i is the winning probability of the player from environment i when all the players exert the same amount of effort, that is,

$$A_i = \int \left[\prod_{j \neq i} G_j(\theta) \right] g_i(\theta) d\theta, \qquad i = 1, \ldots, n. \tag{2.1}$$

Since the same amount of effort neutralizes changes in the winning probabilities of all the players, the ex-ante advantages can be calculated by setting the effort made by every player to zero. I believe means and ex-ante advantages are, respectively, the first summary statistics when subjects look at each distribution

[4] If all the distributions are known and the players are rational, they will be able to calculate all the existing statistics which summarize the distributions. I specify their ability to calculate the means and ex-ante advantages, because I consider the possibility of extending this model to one with bounded rationality.

separately and all distributions jointly. Once the players reveal their preferences, they are exclusively assigned to different environments by means of a simple matching algorithm in the manner of Gale and Shapley (1962). I assume the players are identical, so all rational players will have the same preference order. Since identical players have identical preferences for environments, they are assigned randomly with equal probability. This first stage is fairly simple, but I allow for the possibility of adopting more general environments and preference matching algorithms.[5] Alternatively, this setup could be thought of as a random ordering of identical players who take turns choosing the environment to which they want to belong.

In the second stage, players choose an effort level $e_i \geq 0$. The winner will receive a finite prize $w > 0$, and the others will receive nothing. The probability of winning w is determined by a player's output, $e_i + \hat{\theta}_i$, the sum of the effort level and the realization of the support due to environment i. Player i's effort costs him $c(e_i)$, where $c(\cdot)$ is a strictly increasing, twice continuously differentiable convex function. Player i's reward, R_i, is determined as follows:

$$R_i(e_i|\hat{\theta}_i, \hat{\theta}_{-i}, e_{-i}) = \begin{cases} w & \text{if } e_i + \hat{\theta}_i = \max_{j \in N}\{e_j + \hat{\theta}_j\}, \\ 0 & \text{otherwise}, \end{cases} \tag{2.2}$$

where the subscript $-i$ refers to all the players except i.[6] Each player's objective is to maximize

$$EU_i(e_i|\theta_i, \theta_{-i}, e_{-i}) \equiv E[R_i(e_i|\theta_i, \theta_{-i}, e_{-i})] - c(e_i). \tag{2.3}$$

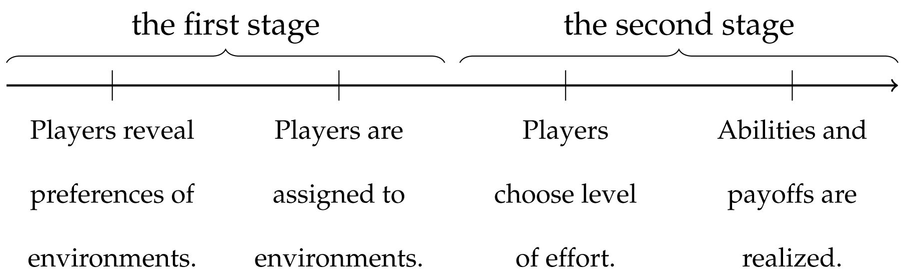
Note that exertion of a greater amount of effort will increase the probability of

[5] Though the model can be directly interpreted as one in which the number of environments is equal to the number of agents, I do not mean to impose such a severe restriction. Rather, I consider a situation where all other candidate–environment pairs have cleared the market and each of the three remaining candidates looks for an environment that has one spot left.

[6] A tie-break rule is unnecessary, because a tie will almost surely not occur.

winning w but will also increase the cost of the effort. After all players choose their level of effort, their payoffs are determined. Figure 2.1 summarizes the timing of events.

Figure 2.1: Sequence of Events in the Two-Stage Game



My first goal was to find a non-cooperative equilibrium for the second stage of the game. $G_j(\theta + e_i - e_j)$ is the probability that player j's realization of environmental support plus e_j is less than player i's output. Then the best response for player i, $BR_i(e_{-i})$, will solve

$$BR_i(e_{-i}) \in \arg\max_{e_i \geq 0} \quad w \int \left[\prod_{j \neq i} G_j(\hat{\theta} + e_i - e_j) \right] g_i(\hat{\theta}) d\hat{\theta} - c(e_i), \tag{2.4}$$

where $\int \left[\prod_{j \neq i} G_j(\hat{\theta} + e_i - e_j) \right] g_i(\hat{\theta}) d\hat{\theta} \equiv P_i(e_i|e_{-i})$ is the probability that player i wins w when the effort choice is e_i, given G_{-i} and e_{-i}. Note that when the realization of support is $\hat{\theta}$, player i's winning probability is equal to the product of the probabilities that all the other players' realizations of support $\hat{\theta}_{-i}$ given e_{-i} are less than player i's realization of output. Since $G_j(\cdot)$ is a nondecreasing function whose lower limit is 0 and upper limit is 1, $P_i(e_i|e_{-i})$ also has these properties: $P_i(e_i|e_{-i})$ is nondecreasing in e_i, $P_i(0|e_{-i}) \geq 0$ (> 0 when $G_j(x) > 0$ for all x), and $\lim_{e_i \to \infty} P_i(e_i|e_{-i}) = 1$. The winning probability for player i is nondecreasing in e_i and bounded above by 1.

Since support is random when players choose their level of effort, the effort choice e_i acts as a location shift parameter that shifts the support distribution of player i's environment. The best response of player i is therefore determined by the amount of the location shift, given the other players' support distributions and location shifts.

The optimal choices of environment and effort can be described as a subgame perfect Nash equilibrium. In the second stage, a Nash equilibrium is a profile of effort choices, $e^* = (e_1^*, \ldots, e_n^*)$, such that $e_i^* \in BR_i(e_{-i}^*)$ for all i. Note that $\lim_{e_j \to \infty} BR_i(e_{-i}) = 0$ for every $j \neq i$, because if any contestant j chooses a sufficiently large level of effort, player i will not be compensated for the cost of any positive amount of effort.[7] By Berge's maximum theorem, $BR_i(e_{-i})$ is continuous. Since the effort choice is always nonnegative, a Nash equilibrium always exists for this game.[8] In the first stage, the players reveal their preferences of environments according to the order of the expected payoffs in equilibrium.

2.3 Analysis

In this section, I focus mainly on analysis of the second stage. Because of the assumption that all the players have identical and rational preferences of environments according to the expected payoffs, the first stage of the problem becomes trivial.

[7]Suppose, for example, that the supports for all the players are drawn from the same distribution. If player i chooses $e_i \geq \sqrt{w}$, then the best response for all the other players is zero.

[8]See Appendix A for an existence proof.

2.3.1 A Two-Player Competition

I rank the environments by the expected supports of the distributions to check whether the ranks of the expected supports predict equilibrium payoffs. Player i is said to be in a higher tier than player j if $E(\theta_i) > E(\theta_j)$.[9] This definition of tiers is well justified, because the tiers are a strong predictor of the ranks of the equilibrium payoffs and the rank of effort levels in a pairwise competition. In a two-stage game, if players know only the expectations of the supports in the first stage, revealing preferences based on those expectations is optimal.

Proposition 5. *Suppose $n = 2$ and (e_1^*, e_2^*) is an equilibrium. Then $E(\theta_1) > E(\theta_2)$ if and only if $EU_1^*(e_1^*|\theta_1, \theta_2, e_2^*) > EU_2^*(e_2^*|\theta_2, \theta_1, e_1^*)$. In any equilibrium, $e_1^* \geq e_2^*$.*

Proof. See Appendix A.

Proposition 5 is intuitive when we consider a shift of the location parameter, $\theta_1 \overset{d}{=} \theta_2 + x$, for a deterministic $x > 0$, so that $E(\theta_1) - E(\theta_2) = x > 0$. Then $E[R_1(e_1^*|\theta_1, \theta_2, e_2^*)] - e_1^{*2} > E[R_2(e_2^*|\theta_2, \theta_1, e_1^*)] - e_2^{*2}$, because the first-tier player has already made a positive amount of effort, x, for free. Now if $E[R_1(e_1^*|\theta_1, \theta_2, e_2^*)] - e_1^{*2} > E[R_2(e_2^*|\theta_2, \theta_1, e_1^*)] - e_2^{*2}$, then it cannot be the case that $E(\theta_2) \geq E(\theta_1)$. For if $E(\theta_2) \geq E(\theta_1)$, then (e_1^*, e_2^*) is not an equilibrium, because for player 2, e_1^* is affordable and player 2's expected payoff can be at least as large as that of player 1 by choosing e_1^*. Uniqueness of equilibrium is not guaranteed, but there are no equilibria where $e_2^* > e_1^*$.

[9] Note that the definition of tier considers neither the higher moments of the distributions nor the players' effort choices. In addition, the fact that player 1 is in a higher tier than player 2 does not necessarily imply that θ_1 first-order stochastically dominates θ_2. For example, if $\theta_1 \sim U[2, 4]$ and $\theta_2 \sim U[0, 5]$, where $U[a, b]$ is a uniform distribution between a and b, then player 1 is in a higher tier than player 2, even though the variance and the maximum possible support of the second tier are greater than those of the first tier.

Proposition 5 has two implications. First, the second and higher moments of the support distributions are irrelevant in determining the ranks of the expected payoffs in a pairwise competition; what matters is only the expectations of the supports. Second, the binary relation $E(\theta_i) > E(\theta_{i+1})$ implies transitivity of the equilibrium payoffs: If $EU_1^*(e_1^*|\theta_1, \theta_2, e_2^*) > EU_2^*(e_2^*|\theta_2, \theta_1, e_1^*)$ and $EU_2^*(e_2^*|\theta_2, \theta_3, e_3^*) > EU_3^*(e_3^*|\theta_3, \theta_2, e_2^*)$, then $EU_1^*(e_1^*|\theta_1, \theta_3, e_3^*) > EU_3^*(e_3^*|\theta_3, \theta_1, e_1^*)$. Thus, the definition of tiers is justified because it reveals the ranks of the equilibrium payoffs in a pairwise competition directly. Note also that the higher-tier player will not exert less effort than the lower-tier player.

Suppose now the ranks of the environments are determined by a different statistic of the environments, namely, their ex-ante advantages. The ex-ante advantage of environment i, A_i, is calculated by (2.1). For example, if $\theta_1 = 3$ and $\theta_2 \sim U[0, 4]$, then $A_1 = 3/4$ and $A_2 = 1/4$. In a two-player competition, the ranks of the ex-ante advantages are consistent with the ranks of the expected environmental supports,[10] and thus, by Proposition 5, they are consistent with the equilibrium payoffs as well as with the equilibrium effort levels.

Since the means and the ex-ante advantages convey sufficient information about the ranks of the expected payoffs, the players can simply reveal preferences according to the tiers in the first stage. Whether they have complete information of the support distributions is irrelevant.

[10] See Lemma 1 in Appendix A.

2.3.2 A Three-Player Competition

In a three-player competition, the ranks of the expected supports can be inconsistent with the ranks of the equilibrium payoffs as well as the ranks of the ex-ante advantages. It is well known that the variances of the support distributions are a significant factor in the ranks of the equilibrium payoffs, so this claim is straightforward. At this point, I provide several numerical examples, for two purposes: to observe some regularities and to illustrate setups similar to those used in the laboratory experiments. To minimize unnecessary complexity, all the examples have a unique equilibrium. Consider Example 1, shown in Table 2.1. If $\theta_1 = 5$, $\theta_2 \sim U[3,6]$, and $\theta_3 \sim U[0.5, 7.5]$, then $E(\theta_1) > E(\theta_2) > E(\theta_3)$.[11] However, the ex-ante advantage and the equilibrium payoff for player 2 are smaller than those for player 3.

Table 2.1: Example 1: Tiers $\not\rightarrow$ Payoffs

Example 1	Player 1	Player 2	Player 3	**Rank**
θ_i	5	$U[3,6]$	$U[0.5,7.5]$	-
$E(\theta_i)$	5	4.5	4	$E(\theta_1) > E(\theta_2) > E(\theta_3)$
A_i	0.4286	0.2481	0.3333	$\mathbf{A_1 > A_3 > A_2}$
e_i^* (when $w = 1$)	0.2332	0.1324	0.0714	$e_1^* > e_2^* > e_3^*$
$EU_i^*(e_i^*\|\Theta, e_{-i}^*)$	0.4120	0.2013	0.3097	$\mathbf{EU_1^* > EU_3^* > EU_2^*}$

The tiers are inconsistent with the ranks of the equilibrium payoffs and with those of the ex-ante advantages.

The ranks of the ex-ante advantages also do not predict the ranks of the equilibrium payoffs. When $\theta_1 = 5, \theta_2 \sim U[3,6]$, and $\theta_3 \sim U[0.5, 6.8]$, as shown in Table 2.2, $A_1 > A_2 > A_3$, but still the STT arises. That is, the second-tier player is

[11] I set θ_1 to a constant for convenience. The main result is independent of this simplification.

trapped despite obviously being better than the third-tier player in the pairwise competition, but it is the worst in terms of the the expected equilibrium payoff in a three-player competition, even though the second-tier player exerts more than the third-tier player.

Table 2.2: Example 2: Ex-ante Advantages $\not\rightarrow$ Payoffs

Example 2	Player 1	Player 2	Player 3	**Rank**
θ_i	5	$U[3,6]$	$U[0.5,6.8]$	-
$E(\theta_i)$	5	4.5	3.65	$E(\theta_1) > E(\theta_2) > E(\theta_3)$
A_i	0.4762	0.2646	0.2593	$A_1 > A_2 > A_3$
e_i^* (when $w = 1$)	0.2620	0.1473	0.0794	$e_1^* > e_2^* > e_3^*$
$EU_i^*(e_i^*\|\Theta, e_{-i}^*)$	0.4553	0.2184	0.2297	$\mathbf{EU_1^*} > \mathbf{EU_3^*} > \mathbf{EU_2^*}$

The ranks of the ex-ante advantages are inconsistent with the ranks of the equilibrium payoffs.

Greater effort on the part of the second-tier player does not necessarily cause him to have a lower equilibrium payoff. The second-tier player always has a higher equilibrium payoff with a higher level of effort in the pairwise competition. In many cases, this is also true in a three-player competition, as shown in the example in Table 2.3.

In addition, the ranks of the equilibrium effort choices cannot be predicted by the tiers or by the ex-ante advantages, as shown in the example in Table 2.4. To summarize, unlike a two-player competition, the tiers can be inconsistent with the ex-ante advantages, and neither the tiers nor the ex-ante advantages reveal the order of the equilibrium payoffs or of the equilibrium effort levels.

One observation worth noting can be made by a comparison of Examples 1 and 3, which is summarized in Table 2.5. Note that $U[0.5, 7.5]$ is a mean-

Table 2.3: Example 3: Greater Effort $\not\rightarrow$ STT

Example 3	Player 1	Player 2	Player 3	**Rank**
θ_i	5	$U[3,6]$	$U[1.6,6.4]$	-
$E(\theta_i)$	5	4.5	4	$E(\theta_1) > E(\theta_2) > E(\theta_3)$
A_i	0.4722	0.2708	0.2569	$A_1 > A_2 > A_3$
e_i^* (when $w = 1$)	0.2599	0.1545	0.1042	$e_1^* > e_2^* > e_3^*$
$EU_i^*(e_i^*\|\Theta, e_{-i}^*)$	0.4523	0.2248	0.2206	$EU_1^* > EU_2^* > EU_3^*$

Greater effort on the part of the second-tier player does not cause a lower equilibrium payoff.

Table 2.4: Example 4: Tiers $\not\rightarrow$ Efforts, Ex-ante Advantages $\not\rightarrow$ Efforts

Example 4	Player 1	Player 2	Player 3	**Rank**
θ_i	5.2	$U[4,6]$	$U[3.2,6.4]$	-
$E(\theta_i)$	5.2	5	4.8	$E(\theta_1) > E(\theta_2) > E(\theta_3)$
A_i	0.3750	0.3000	0.3250	$\mathbf{A_1 > A_3 > A_2}$
e_i^* (when $w = 1$)	0.1837	0.2240	0.1563	$\mathbf{e_2^* > e_1^* > e_3^*}$
$EU_i^*(e_i^*\|\Theta, e_{-i}^*)$	0.3336	0.2712	0.2868	$\mathbf{EU_1^* > EU_3^* > EU_2^*}$

Neither the tiers nor the ex-ante advantages can predict the equilibrium effort levels.

preserving spread of $U[1.6, 6.4]$. If the variance of the third-tier environment gets larger, the ex-ante advantage of this environment will also get larger, while the ex-ante advantages of the other environments will get smaller. This is because the third-tier player has more of a possibility for a higher realization of support.[12] Every player's equilibrium effort choice will decrease in such a scenario, because the increased uncertainty of the support will dilute the marginal

[12]Of course, he has more of a possibility for a lower realization of support, but under the winner-take-all payoff structure, such possibility does not affect the ex-ante advantage.

benefit of the effort. Proposition 6 states how a mean-preserving spread affects equilibrium payoffs.

Table 2.5: Changes Due to a Mean-Preserving Spread of θ_3

Example 1 and 3	$E(\theta_i)$	$A_i \Rightarrow A_i'$	$e_i^* \Rightarrow e_i^{*\prime}$	$EU_i^* \Rightarrow EU_i^{*\prime}$
$\theta_1 = 5$	5.0	0.4772 $\Rightarrow$ 0.4286 ($\Downarrow$)	0.2599 $\Rightarrow$ 0.2332 ($\Downarrow$)	0.4523 $\Rightarrow$ 0.4120 ($\Downarrow$)
$\theta_2 \sim U[3, 6]$	4.5	0.2708 $\Rightarrow$ 0.2481 ($\Downarrow$)	0.1545 $\Rightarrow$ 0.1324 ($\Downarrow$)	0.2248 $\Rightarrow$ 0.2013 ($\Downarrow$)
$\theta_3 \sim U[1.6, 6.4]$ $\Rightarrow \theta_3' \sim U[0.5, 7.5]$	4.0	0.2569 $\Rightarrow$ 0.3333 ($\Uparrow$)	0.1042 $\Rightarrow$ 0.0714 ($\Downarrow$)	0.2206 $\Rightarrow$ 0.3097 ($\Uparrow$)

Proposition 6. *Suppose $n = 3$ and $E(\theta_1) > E(\theta_2) > E(\theta_3)$. A mean-preserving spread of θ_i, $i = 2, 3$, causes A_i to increase, A_{-i} to decrease, and $e^* = (e_1^*, e_2^*, e_3^*)$ to decrease. Thus $EU_i^*(e_i^*|\theta_1, \theta_2, \theta_3, e_{-i}^*)$ increases, but $EU_j^*(e_j^*|\theta_1, \theta_2, \theta_3, e_{-j}^*)$ does not increase for any $j \neq i$.*

Proof. See Appendix A.

Proposition 6 implies that the ranks of the equilibrium payoffs can be changed as a result of a change in the variance of the support of a lower-tier environment. In other words, if the variance of the support of a lower-tier environment does not exceed that of a higher-tier one, the STT does not arise. $Var(\theta_3) > Var(\theta_2)$ is a necessary condition for the STT.

Corollary 2. ***[A necessary condition for the second-tier trap]*** *When $n = 3$, there exists a mean-preserving spread of θ_3, denoted by θ_3', such that $EU_3^*(e_3^*|\theta_1, \theta_2, \theta_3', e_{-3}^*) >$*

$EU_2^*(e_2^*|\theta_1, \theta_2, \theta_3', e_{-2}^*)$. *Thus* $Var(\theta_3') > Var(\theta_2)$.

Proof. Consider positive numbers x and y with $x > y$. If $\theta_1 \stackrel{d}{=} \theta_3 + x$, and $\theta_2 \stackrel{d}{=} \theta_3 + y$, then it does not satisfy the necessary condition for the STT because the θ_i's have the same variance. In this case, the first/second-tier player will always be better off by keeping the level of effort the same as that of the second/third-tier player, because the cost of effort will be the same but the higher-tier player has the greater chance of winning. Thus there is no STT. By Proposition 6, there exists a mean-preserving spread of θ_3, denoted by θ_3', such that $EU_3^*(e^*|\theta_1, \theta_2, \theta_3') > EU_2^*(e^*|\theta_1, \theta_2, \theta_3')$. Then $Var(\theta_2) = Var(\theta_3)$ and $Var(\theta_3') > Var(\theta_3)$, so $Var(\theta_3') > Var(\theta_2)$. $\square$

The following proposition states a sufficient condition for the existence of the STT.

Proposition 7. ***[A sufficient condition for the second-tier trap]*** *In a three-player competition, if* $E(\theta_1) > E(\theta_2) > E(\theta_3)$ *and* $A_2 = A_3$, *then* $EU_3^*(e_3^*|\theta_1, \theta_2, \theta_3, e_{-3}^*) \geq EU_2^*(e_2^*|\theta_1, \theta_2, \theta_3, e_{-2}^*)$.

Proof: See Appendix A.

When combined with Proposition 6, this sufficient condition implies that the STT can also arise if $A_3 > A_2$. This sufficient condition for the STT can be interpreted in terms of the source of the ex-ante advantages. $A_2 = A_3$ and $E(\theta_2) > E(\theta_3)$ jointly imply that the second-tier player's ex-ante advantage is driven by the first moment of the support distribution, while the third-tier player's ex-ante advantage is driven by the second moment. Intuitively speaking, when the second-tier environment is not as good as the first-tier (third-tier) environment in terms of the first (second) moment, it is wise to conclude that the second-tier environment is not the second-best one. The sufficient condition also implies that the two statistics, means and ex-ante advantages, are sufficient to determine the second-best environment.

Since the second stage has been analyzed, dealing with the first stage is straightforward. If all the players are rational, then they will prefer the third-tier environment over the second-tier one in cases where the STT can arise. However, I claim that the sufficient condition for the STT is weak enough for players to be tempted to prefer the second-tier environment over the third-tier one. The STT can arise even when the second-tier environment has a higher mean and a (slightly) higher ex-ante advantage than the third-tier environment, as illustrated in Example 2. Conventional wisdom tells us that, given the best possible environment, we will reap reasonable rewards if we put forth our best effort. The underlying assumption of this bit of wisdom is that we can always choose the best environment among a set of options available to us, which I doubt.

2.4 Experimental Design and Procedures

The lab experiments were designed to observe how subjects choose their environment to maximize their expected payoffs. The experiments were conducted at the Cornell Lab for Experimental Economics & Decision Research and employed undergraduate students at Cornell University for ten sessions and graduate students in math-related fields for two sessions.[13] A total of 175 stu-

[13] In recruiting graduate students, I added the following sentence to the eligibility description: "The study is open to Cornell graduate students who can calculate mathematical expectations."

dents (154 undergraduates and 21 graduates) participated in the experiments, and the average payment, including a reward for participation, was \$12.61.

A general description of the experiments is as follows: Each session consisted of ten rounds of winner-take-all competitions whose setup is similar to the model presented in section 2. During the experiments, they earned "points," which were converted to U.S. dollars at the end of the experiments at the rate of 1,000 points = 1 USD. In each round, subjects were endowed with 40 virtual "tokens" and they competed with two players (both computers). In the first phase of each round, they exclusively choose one of several environments, which were described by uniform distributions, and then in the second phase they chose their investment level in terms of tokens. At the end of every round, the environmental support for each player was drawn randomly from the distribution for that player's chosen environment. The winner was the one whose output (= individual investment + environmental support) was largest. The net payoff per round was $1600 - X^2 + 10(40 - X)$ when the subject won, and $-X^2 + 10(40 - X)$ when s/he lost, where $X \in [0, 40]$ was the amount of the token investment.

Table 2.4 summarizes the construction of the experiments. In four of the rounds (2, 4, 7, and 9), subjects chose one of three environments. I call these the unrestricted rounds. In the other six rounds, which I call the restricted rounds, they were informed that one environment (the first-tier environment[14]) was already been taken by a competitor, and they chose one of the two remaining environments. I was able to identify their preferences of environments by in-

I also asked them to fill in their major on the sign-in form, and all of those who participated were in math-related fields.

[14] I deliberately did not use terms that could imply anything about ranks or orders. Subjects were simply told that "one of the environments" had already been taken.

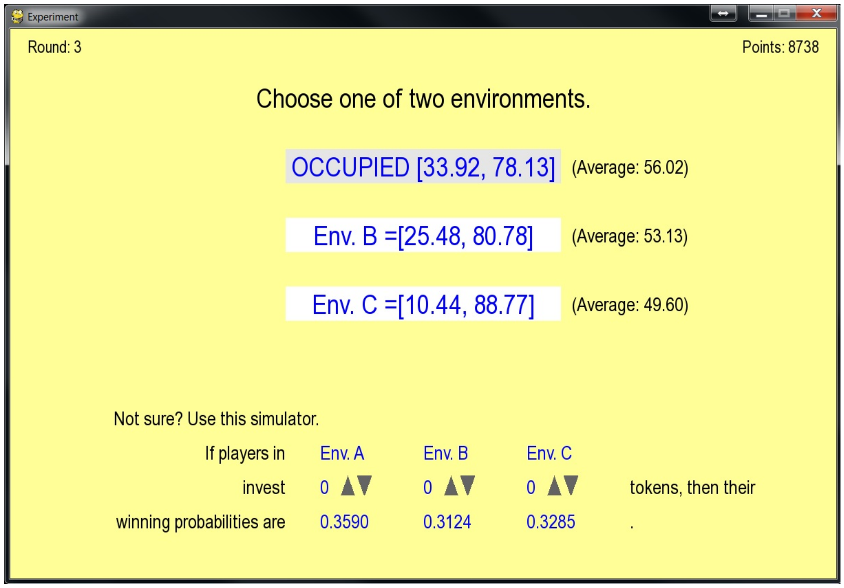
terpreting their selection in the unrestricted rounds to be their preferred environment and their selection in the restricted rounds to be their second choice. (I assumed that their first choice in the restricted rounds would have been the first-tier environment.) To exclude the possibility of choices made as a result of miscalculation, the mean of each support distribution was displayed. I also provided a simulator that could be used to calculate the winning probabilities for any contingent set of effort choices (see Figure 2.4). Without any additional action on their part, subjects were able to obtain averages and ex-ante advantages, which were sufficient to determine the environment that maximized the expected equilibrium payoff in the restricted rounds. A simple calculator and scratch paper were also provided, and I encouraged subjects to use them whenever necessary. I acknowledge that providing averages and ex-ante advantages may have been interpreted as particular rules of thumb and that subjects may simply have used the information provided as their guide. I also realize that subjects may have found that using the simulator to calculate expected payoffs was a complicated operation. To address these issues, I also ran supplementary experiments: one in which 39 subjects were provided with a different simulator—one that could be used to directly calculate the expected payoffs for any contingent set of effort choices—and one in which 40 subjects were provided with no simulator and not even the means of the support distributions were displayed (see Figure 2.4). Note that when the expected payoff calculator was provided, subjects would have been able to find a Nash equilibrium by carrying out three or four operations with the simulators. I could not find any significant differences between results from the main experiment and those from the supplementary experiments.

Table 2.6: Construction of Experiments

Round	**Env. A**	**Env. B**	**Env. C**	**Available options**	**Optimal choice**	**Ranks of the means**	**Ranks of the exp. eqm. payoffs**
1	$[3.80, 68.87]$	$[27.28, 58.73]$	$[18.84, 62.38]$	A, C	A	$B > C > A$	$B > A > C$
2	$[23.03, 65.87]$	$[6.49, 73.06]$	$[29.97, 63.42]$	A, B, C	C	$C > A > B$	$C > B > A$
3	$[33.92, 78.13]$	$[25.48, 80.78]$	$[10.44, 88.77]$	B, C	C	$A > B > C$	$A > C > B$
4	$[33.50, 77.04]$	$[41.94, 73.39]$	$[18.46, 83.53]$	A, B, C	B	$B > A > C$	$B > C > A$
5	$[1.52, 79.85]$	$[16.56, 71.86]$	$[25.00, 69.21]$	A, B	A	$C > B > A$	$C > A > B$
6	$[33.17, 110.47]$	$[50.61, 105.82]$	$[18.13, 117.76]$	A, C	C	$B > A > C$	$B > C > A$
7	$[35.86, 69.31]$	$[12.38, 78.95]$	$[28.92, 71.76]$	A, B, C	A	$A > C > B$	$A > B > C$
8	$[32.78, 64.23]$	$[9.30, 74.37]$	$[24.34, 67.88]$	B, C	B	$A > C > B$	$A > B > C$
9	$[31.64, 86.94]$	$[16.60, 94.93]$	$[40.08, 84.29]$	A, B, C	C	$C > A > B$	$C > B > A$
10	$[20.82, 120.45]$	$[35.86, 113.16]$	$[53.30, 108.51]$	A, B	A	$C > B > A$	$C > A > B$

The second through fourth columns show the support distributions. For example, if a participant chose environment A in round 1, the environmental support was randomly drawn from the uniform distribution between 3.80 and 68.87. The fifth column shows the available options. When only two options were available, subjects were told that the other one had been chosen by one of the computer players. The sixth column shows the choice of environment that maximized the expected equilibrium payoff given the available options. The seventh column shows the ranks of the expectations, and the last column shows the ranks of the expected equilibrium payoffs.

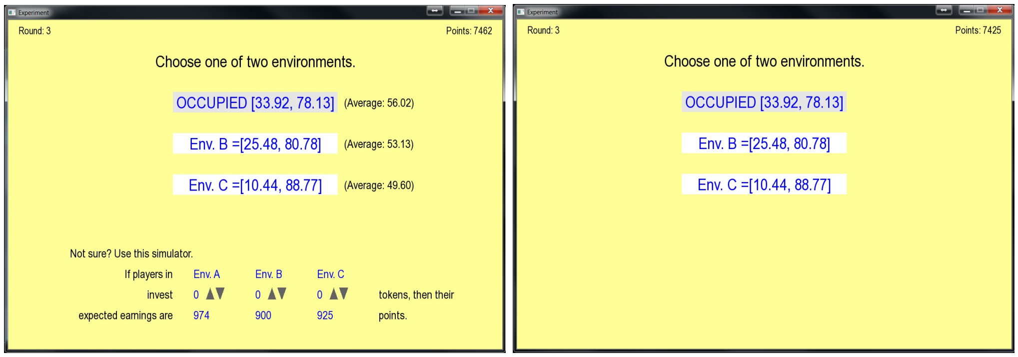
Figure 2.2: Screen Capture of the First Stage of Round 3 in the Main Experiment



Subjects were informed that environment A had already been chosen by a competitor, so they chose either environment B or environment C. Without any further action or calculation, they obtained the means and ex-ante advantages of the support distributions. Since the mean of environment B is greater than that of environment C and the ex-ante advantage of environment C is greater than that of environment B, they should have chosen environment C to maximize their expected payoff.

The support distributions varied from one round to another, but were specified in such a way that the STT arose in every round, that is, if not given the option of choosing the first-tier environment, a fully rational agent would choose the third-tier environment even though the second-tier one may seem more attractive. In rounds 1, 4, and 8, the second-tier environment's ex-ante advantage was slightly greater than that of the third-tier one. In rounds 2 and 7, the ex-ante advantages were almost the same. In rounds 3, 5, 6, 9, and 10, the third-tier environment's ex-ante advantage was slightly greater than that of the second-tier one. The environments were displayed in random order, to prevent subjects from inferring the advantages of the environments from the order of display.

Figure 2.3: Screen Captures of the First Stage of Round 3 in the Supplementary Experiments



Left: A simulator that could be used to calculate the expected payoffs for any contingent set of effort choices. Subjects could find a Nash equilibrium by carrying out a few operations with this simulator. Right: Any information that could have been used as a guide was not provided.

Subjects were also told that the two computer competitors would make their own best possible decisions given their environment, provided that subjects played the best possible strategies given their own environment. I preset the two computer competitors to always choose Nash equilibrium effort levels. Since subjects knew that the computer players' investment choices were independent of their choices, they did not worry about bounded rationality of the other players. At the end of every round, environmental supports were drawn from the respective distributions, and subjects were informed whether they won and how much they earned (or lost). To prevent subjects from learning from earlier rounds, the computer players' investment choices were not divulged.

Before participating in the experiments, subjects followed the instructions on the tutorial screen and answered six multiple choice questions to check their understanding of the instructions. They were allowed to participate in the experiments only if all of their answers were correct. See Appendix B for the screening test questions. 23 undergraduates failed to pass the screening test. After passing the screening test, subjects played two practice rounds without payment.

After the experiments, subjects were surveyed on their confidence in their decisions. This follow-up survey consisted of the following two sets of two questions:

1.1. "Overall, which of the following is the closest description of your choices of environments?" (followed by four sentences describing different levels of confidence)

1.2. "Overall, which of the following is the closest description of your choices of investments?" (followed by four sentences describing different levels of confidence)

2.1. "Overall, how hard was it to choose an environment?" (followed by a five-level Likert scale, from "very easy" to "very hard")

2.2. "Overall, how hard was it to choose an investment level?" (followed by a five-level Likert scale, from "very easy" to "very hard")

2.5 Results

The main results from the lab experiments are summarized as follows.

1. Subjects chose the optimal environment in 75.57% of the unrestricted rounds (529 out of 700 rounds). However, they chose the optimal environment in only 28.67% of the restricted rounds (301 out of 1050 rounds). That is, subjects were likely to fall into the STT.

2. The 92 subjects who chose the optimal environment in all the unrestricted rounds were more likely to fall into the STT. No one chose the optimal environment in all six restricted rounds. In fact, those 92 subjects chose the optimal environment in only 16.67% of the restricted rounds.

3. Those 92 subjects were more confident in their choices of environments, though they were less likely than their counterparts to choose the optimal environment. They also reported that choosing environments was an easier task than choosing investment levels.

Those observations strongly suggest that the STT consistently arose. The level of understanding of optimization problems did not help them to do better. There was no significant difference between sessions with undergraduate students and those with graduate students. In fact, the average payment for the math-related graduate student sessions was slightly lower than that of the undergraduate student sessions, and a slightly smaller proportion of graduate students chose the optimal environment, though differences in choice patterns between undergraduate and graduate subjects were not significant. Also there were no noticeable differences by gender or ethnicity.

Table 2.7: Summary: All Subjects

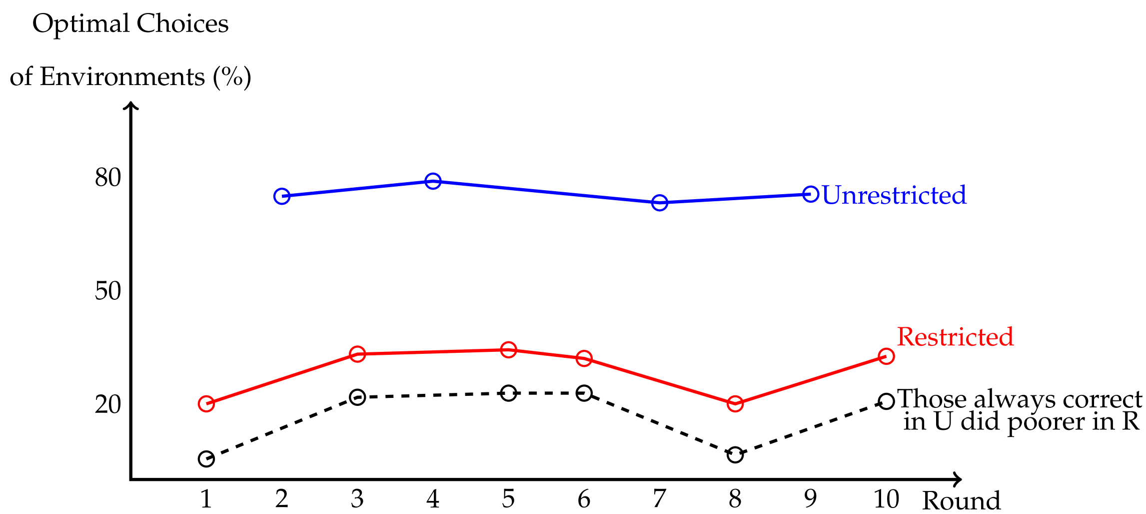
Round	1	2	3	4	5	6	7	8	9	10
Game Type	R	U	R	U	R	R	U	R	U	R
SPNE	(A,7)	(C,16)	(C,5)	(B,17)	(A,5)	(C,3)	(A,16)	(B,7)	(C,12)	(A,3)
Mode of Environmental Choices	C	C	B	B	B	A	A	C	C	B
Correct Decision (%)	20.00	74.86	33.14	78.86	34.29	32.00	73.14	20.00	75.43	32.57
Average Investment Choices	13.73	16.19	15.42	16.69	14.19	14.51	16.21	14.41	16.34	14.55
Overinvestment	5.10	5.66	8.96	5.13	7.83	10.67	5.84	5.72	8.39	10.35

This table shows how well subjects did in finding the environment that maximized their expected payoff in equilibrium. In the second row, R stands for a restricted round and U stands for an unrestricted round. The third row shows the subgame perfect Nash equilibrium strategy for the given constraints, where the first entity is the optimal environment choice and the second one is the optimal investment choice. The fourth row shows the most frequently chosen environment. The fifth row shows the proportion of subjects who chose the optimal environment. The sixth row shows the average of the individual investment choices. In the last row, overinvestment is the mean difference between the optimal investment choices for the players' chosen environments and their actual investment choices.

Table 2.5 shows some basic descriptive statistics about subjects' environment choices by round. The fifth row of the table shows the proportion of subjects who chose the optimal environment. For the unrestricted rounds, denoted by U in the table, their choices were quite good overall: In each unrestricted round, 73.14% or more of subjects chose the environment which gave the highest expected payoff in equilibrium. However, for the restricted rounds, denoted by R in the table, subjects' choices were surprisingly incorrect. Up to 80.00% of subjects chose the environment which did not provide the highest expected payoff in equilibrium. See Figure 2.4, where the blue (red) line shows the proportion of subjects who made a correct choice of environment in the unrestricted (restricted) rounds. My model does not explicitly consider risk aversion, but if that were taken into account, the accuracy of the subjects' choices would be even lower, because they could have attained a more stable income stream by choosing the third-tier environment and a smaller investment level.

One possible concern is that experiment participants may have made their environment choices randomly. Since the variances of the environmental supports were large enough to prevent any player from having a winning probability close to 1, and the monetary prize was not large enough to bring about a sizable loss in case of a wrong choice of environment, some of the subjects may simply have wanted to make random choices or to make "unusual" choices (unusual from their perspective). To address this concern, in Table 2.8 I provide summary statistics on the cohort of subjects who made the correct environment choices in all the unrestricted rounds. I call them the ACU (Always Correct in the Unrestricted rounds) subjects. Note that they did poorer in the restricted rounds. See the dashed line in Figure 2.4. When it came to the investment choices, the subjects overinvested in every round on average. The last

Figure 2.4: Result Summary



The blue (red) line shows the proportion of subjects who chose the optimal environment in the unrestricted (restricted) rounds. In the unrestricted rounds, 73.14% or more of subjects chose the environment which gave the highest expected payoff in equilibrium. In the restricted rounds, however, subjects' choices were in general incorrect. Up to 80.00% of subjects chose the environment which did not provide the highest expected payoff in equilibrium. The dashed line shows the environment choices of the subjects who made the correct choice in all the unrestricted rounds; they did poorer in the restricted rounds.

row in Tables 2.5 and 2.8 shows how subjects' investment choices differed from the Nash equilibrium investment given their environment choices. The ACU subjects' overinvestments were slightly smaller for all the rounds, but not significant enough to conclude that in general the ACU subjects exercised greater discretion in their individual investment choices.

Table 2.8: Summary: The ACU Subjects Only

Round	1	2	3	4	5	6	7	8	9	10
Game Type	R	U	R	U	R	R	U	R	U	R
SPNE	(A,7)	(C,16)	(C,5)	(B,17)	(A,5)	(C,3)	(A,16)	(B,7)	(C,12)	(A,3)
Mode of Environmental Choices	C	C	B	B	B	A	A	C	C	B
Correct decision (%)	5.43	100.00	21.74	100.00	22.83	22.83	100.00	6.52	100.00	20.65
Average Investment Choices	13.54	16.79	15.86	17.79	13.80	14.11	17.15	14.12	16.50	13.77
Overinvestment	3.89	4.89	8.88	4.58	6.89	10.09	5.25	4.58	7.34	9.32

This table is the equivalent of Table 2.5 for the subjects who made the optimal choice of environment in all the unrestricted rounds. In each of the restricted rounds, the proportion of subjects who chose the optimal environment was smaller in this group.

Some participants, especially the ACU subjects, may have set their own rule of thumb and strictly followed it. As stated in the previous section, any single statistic which summarizes the environmental distributions—either separately or jointly—cannot provide a consistent way of predicting the ranks of the expected payoffs in equilibrium. That is, no matter what a participant's simple rule of thumb was,[15] their rule was wrong. Under this interpretation, the STT affected such participants even more severely because they consistently chose the second tier without contemplation and then backed up their (wrong) choices with overinvestment. The combination of these two mistakes, the wrong choices of environment and the overinvestments, caused them to have even lower expected payoffs.

Another observation may help to minimize any concern about whether the subjects used a simple, primitive rule of thumb to make their environment choices in earlier rounds and then modified their rule based on their previous experience. In 1,057 of the 1,400 "repeat" rounds (i.e., those other than the first unrestricted round and the first restricted round for each participant), the subject's choice of environment was consistent with that in their previous round. Among the 343 repeat rounds where they made a choice of environment that was inconsistent with their previous choice, 172 were from the first half of the eight repeat rounds, and 171 were from the second half. That is, I found no compelling evidence that subjects had modified their own decision rules about the choice of environment as a result of their experience on earlier rounds.

[15]If a rule of thumb was used by an ACU, we cannot identify whether it was the mean or a lower bound of the environmental support distribution. Note that I set the environmental distributions in a way that a distribution with a higher mean has a smaller variance, so that the STT could arise. In the experiment, all the environmental support distributions were uniform, so the ranks of the means are consistent with the ranks of the lower bounds of the uniform distributions.

Though analysis of investment patterns was not the primary purpose of my experiments, at least two interesting observations are worth noting. One of these is that subjects' overinvestment levels were statistically significant at the 5% level. That is, subjects tended to overinvest when they believed either that they were likely to be a runner-up or that they had chosen an advantageous environment. A common finding in the rank-order tournament literature is that theory does a good job of predicting the average effort level in tournament experiments (Bull et al. (1987), Schotter and Weigelt (1992), Harbring and Irlenbusch (2011), Agranov and Tergiman (2013)). To the best of my knowledge, there have been no reports of overinvestment behavior with heterogeneous environmental supports in rank-order tournaments. The other interesting observation is that risk-seeking behavior after a previous loss was associated with a loss *in competition*, not in payoff. Observations in other contexts of choice under uncertainty (Weber and Zuchel (2005), Langer and Weber (2008), and Andrade and Iyer (2009)) suggest that subjects become more risk averse after a "paper" loss in payoff.[16] See Table 2.9. When the subjects in my experiments lost the competition in the previous round, they tended to overinvest by 1.93 tokens more than their previous overinvestment level, while they overinvested by 0.89 tokens less than their previous overinvestment level if they won the competition in the previous round. Subjects who lost in competition but gained in payoff in the previous round overinvested by 3.75 tokens more than their previ-

[16] Imas (2014) reports mixed findings in regard to the influence of prior losses on risk attitudes, and shows that individuals become risk averse after losses are realized while they become risk seeking if the loss has not been realized (that is, a paper loss). In my experiments, subjects were informed of their wins/losses in competition and their gains/losses in payoff after every round, but the payoffs were realized only at the end of the game. In the winner-take-all contest, the level of overinvestment may have captured subjects' attitude toward risk, since the optimal level of investment was calculated under an assumption of risk neutrality. If a subject invested more (less) than the optimal level, s/he decreased the expected payoff but expanded (reduced) the variance of possible earnings. Therefore, the positive (negative) changes in overinvestment imply that s/he became more risk-seeking (risk-averse).

ous overinvestment level. On average, subjects who had a loss in payoff in the previous round overinvested by 2.70 tokens less than their previous overinvestment level, while those who gained in the previous round overinvested by 1.15 tokens more than their previous overinvestment level. However, this observation cannot be considered as a direct contribution to the literature on changes in risk attitude, because the structure of each round varied and each round could therefore be understood as a separate task.

Table 2.9: Risk Attitude after a Previous Loss in Competition/Payoff

		Changes in overinvestment* at round t
At round $t-1$	Loss in competition	1.93
	Win in competition	-0.89
	Loss in payoff	-2.70
	Gain in payoff	1.15
	Loss in competition + gain in payoff	3.75
	Win in competition + loss in payoff	—

(*) The overinvestment level is defined as the actual investment level minus the optimal investment level given the subject's choice of environment. Therefore, changes in overinvestment may not directly imply changes in investment. Positive (negative) changes in overinvestment can be understood as the subjects' becoming risk-seeking (risk-averse) after a previous event.

The results of the follow-up survey are summarized in Table 2.10. The ACU subjects were more confident than the other subjects in their environment choices and more likely to report that the environment choices were easy. 76.09% of the ACU subjects answered that the closest description of their environment choices was “consistently right” or “in general right, maybe except only a few rounds,” while only 58.33% of the non-ACU subjects chose one of those answers. Similarly, 54.35% of the ACU subjects found the environment choices “very easy”, or “easy,” while 34.52% of the others chose one of those answers. For similarly paired questions about individual investment choices, there were no noticeable differences between the ACU subjects and non-ACU subjects, except that a larger proportion of the non-ACU subjects answered that the investment choices were easy, at the 10% level of statistical significance. I acknowledge that this between-group comparison may not have captured the individual heterogeneity in subjects’ self-evaluation, so the simplest difference-in-differences estimator is also provided. Since the survey consisted of two sets of two questions each, I first calculated the difference between answers to the questions within each set. For example, if a subject answered that her environment choices were “consistently right” but her investment choices were “in general right, maybe one or two tokens more or less,” then I counted her as having more confidence in her environment choices than in her investment choices. Similarly, if a subject answered that her environment choices were “easy” and her investment choices were “neither easy nor hard,” then I counted her as considering that making the environment choices was the easier of the two tasks. Differences in these differences between the ACU subjects and the others are positive. That is, even after controlling for individual heterogeneity, we still observe that the ACU subjects were more likely than the others to feel that the environment choices were easier than the investment choices. These differences were tested under the null hypothesis of the same population mean.

Table 2.10: Summary: Survey

Survey Question	Positive answers (%)$^{(*1)}$		differences
	ACU	non-ACU	(% points)
1.1. How confident in your environment choices?	76.09	58.33	**17.75*****
1.2. How confident in your investment choices?	65.22	63.10	2.12
2.1. How easy were environment choices?	54.35	34.52	**19.82*****
2.2. How easy were investment choices?	11.96	21.43	-9.47^{*}

	Positive differences (%)$^{(*2)}$		difference-in-differences
	ACU	non-ACU	(% points)
More confident in environment choices$^{(*3)}$	31.52	26.19	5.33
Easier in environment choices$^{(*4)}$	65.22	40.74	**24.48*****

*,**,***: 10%, 5%, 1% level of statistical significance.
(*1) For questions 1.1 and 1.2, this shows the proportion of subjects who answered that the closest description of their environment choices (investment choices) was "consistently right" or "in general right, maybe except only a few rounds." For questions 2.1 and 2.2, it shows the proportion of subjects who answered "very easy" or "easy."
(*2) Questions 1.1 and 1.2, and questions 2.1 and 2.2, are paired, to capture the difference between answers in each pair.
(*3)(*4) After controlling for individual heterogeneity, we observe that the ACU subjects were more confident in their environment choices and found the environment choices easier. The differences are tested under the null hypothesis of the same population mean.

2.6 Conclusions

This paper's theoretical results can be summarized as follows: In a pairwise competition, only the first moment of the environmental supports matters, so the equilibrium payoffs reflect only the expected environmental supports. That is, a decision maker needs no information other than the expected environmental supports. With three players, the second moment of the environmental supports is also significant in determining the ranks of the equilibrium payoffs. The second-tier trap arises when the second-tier player is less competitive than the third-tier player in terms of the second moment and less competitive than the first-tier player in terms of the first moment. A sufficient condition for the STT is that the ex-ante advantages of the second- and third-tier environments be equal. That is, a decision maker needs no information other than the expected environmental supports and the ex-ante advantages, and should choose the third-tier environment when the ex-ante advantages of the second- and the third-tier environments are similar. I claim that the sufficient condition for the STT is so weak that players can easily be tempted to make the wrong decision in choosing their environments. The experimental evidence strongly supports this claim. A significant proportion of participants in my experiments failed to choose the second-best environment (or the better of two environments when they were not given the option of choosing the best environment of the three) in terms of the maximum expected payoff in equilibrium, though they were fairly good at choosing the best environment.

There are many potential directions for further research to extend this study, both theoretically and empirically. This study can be considered as an initial step in the investigation of income inequality from a new and different perspective. As societies are adopting many aspects of tournaments, individuals keep facing situations where they have to choose an environment that will support their effort. If households in the middle class constantly fall into the STT, then income inequality could be exacerbated without any of the technological changes or tax distortions that have been the focus of many existing studies dealing with income inequality. Also, in this study I assumed that players are identical in terms of the cost of their effort, so the first-stage matching becomes trivial. Considering a sequential competition with history-dependent human capital accumulation could be challenging but may address more of the issues that are relevant to real-life situations.

Appendix A

Proof of existence of a Nash equilibrium:

Note that players would not exert more effort than $\bar{e}$ such that $c(\bar{e}) = w$, as that would definitely yield a negative expected payoff. Define $\mathbf{BR}(\mathbf{e}) = (BR_1(e_{-1}), \ldots, BR_n(e_{-n}))$, where $\mathbf{e} = (e_1, \ldots, e_n) \in [0, \bar{e}]^n \equiv S$. Since S is a nonempty, closed, bounded, and convex subset of $\mathbb{R}^n$, and $\mathbf{BR}(\mathbf{e})$ is a continuous self-map on S, by Brouwer's fixed point theorem, there exists $\mathbf{e}^* \in S$ such that $\mathbf{BR}(\mathbf{e}^*) = \mathbf{e}^*$. $\square$

For the proof of Proposition 5, I will use the following observations and Lemma 1.

Observations. *Suppose $g_1(\theta)$ and $g_2(\theta)$ are unimodal symmetric probability distributions with means μ_1 and μ_2, respectively, and suppose $\mu_1 > \mu_2$.*

1. *Since* $\int g_1(\theta)d\theta = \int g_2(\theta)d\theta = 1$, $\int g_1(\theta)g_2(\theta)d\theta$ *can be interpreted as a weighted average of* g_1 *weighted by* g_2, *or a weighted average of* g_2 *weighted by* g_1.
2. *For* $G_i(x) = \int_{-\infty}^{x} g_i(\theta)d\theta$, $i = 1, 2$, $\int G_i(\theta)g_i(\theta)d\theta = \frac{1}{2}$.
3. $\int (G_2(\theta) - G_1(\theta))g_1(\theta)d\theta > 0$.
4. $\int (g_1(\theta) - g_2(\theta))G_1(\theta)d\theta > 0$.
5. *Suppose now that* $\mu_1 = \mu = \mu_2$, *and consider a location shift parameter* $e \in \mathbb{R}$. *Then* $\int g_1(\theta - e)g_2(\theta)d\theta$ *is maximized at* $e = 0$.

Proof: The first observation is trivial. The second observation follows from integration by parts: $\int G_i(\theta)g_i(\theta)d\theta = [G_i(\theta)G_i(\theta)]_{-\infty}^{\infty} - \int g_i(\theta)G_i(\theta)d\theta \Rightarrow 2\int G_i(\theta)g_i(\theta)d\theta = 1$. The third observation may be nontrivial. Since we assumed that the support distributions are symmetric and unimodal, there are only two possible cases with $\mu_1 > \mu_2$: either θ_1 is first-order stochastically dominant (FOSD) over θ_2, or G_1 and G_2 satisfy the single-crossing property, that is, there is θ^* such that for $\theta \geq \theta^*$, $G_1(\theta) \geq G_2(\theta)$, and for $\theta < \theta^*$, $G_2(\theta) > G_1(\theta)$. If θ_1 is FOSD over θ_2, then $G_2(\theta) - G_1(\theta) \geq 0$ for all θ and $G_2(\theta) - G_1(\theta) > 0$ for some θ, so $\int (G_2(\theta) - G_1(\theta))g_1(\theta)d\theta > 0$. If $G_2(\theta)$ single-crosses $G_1(\theta)$ at θ^*, then θ^* must be greater than μ_1. This is because $G_i(\mu_i) = \frac{1}{2}$, $i = 1, 2$, and $G_2(\mu_1) > G_1(\mu_1)$. Then $\int_{-\infty}^{\theta^*} g_1(\theta)d\theta > \int_{\theta^*}^{\infty} g_1(\theta)d\theta$, so $G_2(\theta) > G_1(\theta)$ for all $\theta < \theta^*$, and $\int_{-\infty}^{\theta^*}(G_2(\theta) - G_1(\theta))d\theta > \int_{\theta^*}^{\infty}(G_1(\theta) - G_2(\theta))d\theta$. Therefore, $\int (G_2(\theta) - G_1(\theta))g_1(\theta)d\theta = \int_{-\infty}^{\theta^*}(G_2(\theta) - G_1(\theta))g_1(\theta)d\theta - \int_{\theta^*}^{\infty}(G_1(\theta) - G_2(\theta))g_1(\theta)d\theta > 0$. The fourth observation follows from the second and third observations. Using integration by parts, $\int (G_2(\theta) - G_1(\theta))g_1(\theta)d\theta = [(G_2(\theta) - G_1(\theta))G_1(\theta)]_{-\infty}^{\infty} - \int (g_2(\theta) - g_1(\theta))G_1(\theta)d\theta = 0 + \int (g_1(\theta) - g_2(\theta))G_1(\theta)d\theta > 0$. The fifth observation states that the integral of the product of two symmetric probability distributions is maximized when they are peaked at the same point. The first order condition of $\max_e \int g_1(\theta - e)g_2(\theta)d\theta$ is $\int -\frac{dg_1(\theta-e)}{de} g_2(\theta)d\theta = \int \frac{dg_1(\tilde{\theta})}{d\tilde{\theta}} g_2(\tilde{\theta}+e)d\tilde{\theta} = 0$. The equality in the middle follows from the change of variables $\tilde{\theta} = \theta - e$. Since $\frac{dg_1(\theta)}{d\theta}$ is an odd function about μ, and $g_2(\theta)$ is an even function about μ, $\int \frac{dg_1(\theta)}{d\theta} g_2(\theta)d\theta = 0$. This observation is useful for evaluating $\int g_1(\theta - e)g_2(\theta)d\theta$ even when μ_1 and μ_2 are different. If $\mu_1 > \mu_2$, then $\int g_1(\theta - e)g_2(\theta)d\theta$ is maximized when $e = \mu_2 - \mu_1$. Also, $\int g_1(\theta - e)g_2(\theta)d\theta$ is smaller (greater) than $\int g_1(\theta)g_2(\theta)d\theta$ for $e > 0$ (for $\mu_2 - \mu_1 < e < 0$). $\square$

Lemma 1. *If $E(\theta_1) > E(\theta_2)$, $\int G_2(\theta)g_1(\theta)d\theta > \int G_1(\theta)g_2(\theta)d\theta$.*

Proof: $\int G_2(\theta)g_1(\theta)d\theta > \int G_1(\theta)g_1(\theta)d\theta = \int G_1(\theta)(g_1(\theta) - g_2(\theta) + g_2(\theta))d\theta = \int G_1(\theta)g_2(\theta)d\theta + \int G_1(\theta)(g_1(\theta) - g_2(\theta))d\theta > \int G_1(\theta)g_2(\theta)d\theta$, where the first inequality is from Observation 3, and the last inequality is from Observation 4. $\square$

Proof of Proposition 5

[$\Rightarrow$] First, assume $E(\theta_1) > E(\theta_2)$. Since $E(\theta_1) > E(\theta_2)$ implies $\int G_2(x)g_1(x)dx > \int G_1(x)g_2(x)dx$ by Lemma 1, player 1's expected utility is always greater than or equal to that of player 2 at an equilibrium. Note that if the two players choose the same level of effort, then their expected rewards will be exactly the same as their ex-ante advantages, the probability of winning when everyone chooses no effort, that is, $E[R_i(e|\theta_i, \theta_j, e)] = \int G_j(\theta + e - e)g_i(\theta)d\theta = \int G_j(\theta)g_i(\theta)d\theta$, where the value of the prize, w, is normalized to 1. Then $EU_1^*(e_1^*|\theta_1, \theta_2, e_2^*) = \max_{e_1} EU_1(e_1|\theta_1, \theta_2, e_2^*) \geq EU_1(e_2^*|\theta_1, \theta_2, e_2^*) = \int G_2(\theta)g_1(\theta)d\theta - c(e_2^*) > \int G_1(\theta)g_2(\theta)d\theta - c(e_2^*) = EU_2^*(e_2^*|\theta_2, \theta_1, e_2^*)$. In other words, if player 2 chooses an effort level e_2, then player 1's expected utility can always be greater by exerting the same level of effort, to keep the higher winning probability with the same cost of effort. Since this effort choice e_2 is attainable for player 1, his maximized expected utility must be at least as large as the expected utility when he chooses e_2.

[$\Leftarrow$] If $E[R_1(e_1^*|\theta_1, \theta_2, e_2^*)] - e_1^{*2} > E[R_2(e_2^*|\theta_2, \theta_1, e_1^*)] - e_2^{*2}$, then it is trivial to show that $E(\theta_1) > E(\theta_2)$ if we can prove that $e_1^* \geq e_2^*$ in equilibrium. Suppose for the sake of contradiction that $E(\theta_1) \leq E(\theta_2)$. Then (e_1^*, e_2^*) is not an equilibrium, because this case holds only when $e_2^* > e_1^*$. Thus all that remains is to show that $e_1^* \geq e_2^*$ in equilibrium.

For the two-player competition, player i's first order condition is $\int g_j(\theta + e_i - e_j^*) g_i(\theta) d\theta = c'(e_i)$, where the value of the prize, w, is normalized to 1. Similarly, player j's first order condition is $\int g_i(\theta + e_j - e_i^*) g_j(\theta) d\theta = c'(e_j)$. When $e_i = e^* = e_j$, both first order conditions are satisfied. Therefore (e_i^*, e_j^*) with $e_i^* = e_j^*$ is an equilibrium. This is not necessarily the only Nash equilibrium, because we have not checked whether (e_1^*, e_2^*) with $e_1^* \neq e_2^*$ can be an equilibrium.

My goal is to show that $e_2^* > e_1^*$ cannot be an equilibrium. Suppose for the sake of contradiction that $(\hat{e}_1, \hat{e}_2)$ with $\hat{e}_2 > \hat{e}_1$ is an equilibrium. Let $\varepsilon = \hat{e}_2 - \hat{e}_1 > 0$. Since $c'(\cdot)$ is monotone increasing, $\int g_1(\theta + \varepsilon) g_2(\theta) d\theta = c'(\hat{e}_2) > c'(\hat{e}_1) = \int g_2(\theta - \varepsilon) g_1(\theta) d\theta$. $\hat{e}_2 > \hat{e}_1$ also implies that when player 2 chooses $\hat{e}_1$, the marginal benefit is greater than the marginal cost, that is, $\int g_1(\theta + \hat{e}_1 - \hat{e}_1) g_2(\theta) d\theta \geq c'(\hat{e}_1)$, or $\int g_1(\theta) g_2(\theta) d\theta \geq c'(\hat{e}_1) = \int g_2(\theta - \varepsilon) g_1(\theta) d\theta$. This is a contradiction for $\varepsilon \in (0, 2(\mu_1 - \mu_2))$. Note that $\int g_2(\theta - \varepsilon) g_1(\theta) d\theta$ is maximized at $\varepsilon = \mu_1 - \mu_2$, by the proof of Observation 5. When $\varepsilon = 2(\mu_1 - \mu_2)$, by symmetry $\int g_2(\theta - \varepsilon) g_1(\theta) d\theta = \int g_2(\theta) g_1(\theta) d\theta$. Thus for $\varepsilon \in (0, 2(\mu_1 - \mu_2))$, $\int g_2(\theta -$

$\varepsilon)g_1(\theta)d\theta > \int g_2(\theta)g_1(\theta)d\theta$. Similarly, when player 1 chooses $\hat{e}_2$, the marginal benefit is smaller than the marginal cost, that is, $\int g_2(\theta+\hat{e}_2-\hat{e}_2)g_1(\theta)d\theta \leq c'(\hat{e}_2)$, or $\int g_2(\theta)g_1(\theta)d\theta \leq c'(\hat{e}_2) = \int g_1(\theta+\varepsilon)g_2(\theta)d\theta$. This is a contradiction for $\varepsilon > 2(\mu_1-\mu_2)$, because $\int g_2(\theta)g_1(\theta)d\theta > \int g_1(\theta+\varepsilon)g_2(\theta)d\theta$. It is also a contradiction for $\varepsilon = 2\mu_1 - 2\mu_2$, because $c'(\hat{e}_2) = \int g_1(\theta+2\mu_1-2\mu_2)g_2(\theta)d\theta = \int g_2(\theta-2\mu_1+2\mu_2)g_1(\theta)d\theta = c'(\hat{e}_1)$, but $c'(\hat{e}_2) > c'(\hat{e}_1)$. The equality in the middle follows from the change of variables $\theta' = \theta+\mu_1-\mu_2$. Therefore, in equilibrium $e_1^* \geq e_2^*$. $\square$

Lemma 2. *Suppose $E(\theta_1) = E(\theta_2) = E(\theta_3) = \mu$, and θ_2' is a mean-preserving spread of θ_2. Then $\int G_1(\theta)^2(g_2(\theta)-g_2'(\theta))d\theta < 0$ and $\int G_1(\theta)G_3(\theta)(g_2(\theta)-g_2'(\theta))d\theta < 0$.*

Proof: First, I show that $\int G_1(\theta)g_2'(\theta)d\theta = \int G_1(\theta)g_2(\theta)d\theta = 1/2$, to illustrate the tools I used in the proof of this lemma. $G_1(\theta)$ is mirror-imaged about $(\mu, 1/2)$, that is, for any $\epsilon > 0$, $G_1(\mu-\epsilon) = 1-G_1(\mu+\epsilon)$. In addition, $g_2(\theta)$ and $g_2'(\theta)$ are symmetric about μ, that is, for any $\epsilon > 0$, $g_2(\mu-\epsilon) = g_2(\mu+\epsilon)$ and $g_2'(\mu-\epsilon) = g_2'(\mu+\epsilon)$. Then $\int G_1(\theta)g_2(\theta)d\theta = \int_{-\infty}^{\mu} G_1(\theta)g_2(\theta)d\theta + \int_{\mu}^{\infty} G_1(\theta)g_2(\theta)d\theta = \int_0^{\infty} G_1(\mu-\epsilon)g_2(\mu-\epsilon)d\epsilon + \int_0^{\infty} G_1(\mu+\epsilon)g_2(\mu+\epsilon)d\epsilon = \int_0^{\infty} G_1(\mu-\epsilon)g_2(\mu+\epsilon)d\epsilon + \int_0^{\infty} G_1(\mu+\epsilon)g_2(\mu+\epsilon)d\epsilon = \int_0^{\infty}(G_1(\mu-\epsilon)+G_1(\mu+\epsilon))g_2(\mu+\epsilon)d\epsilon = \int_0^{\infty} g_2(\mu+\epsilon)d\epsilon = \frac{1}{2}$. This holds for any symmetric probability distribution about μ, including $g_2'(\theta)$. Thus, $\int G_1(\theta)g_2'(\theta)d\theta = \frac{1}{2}$.

$G_1(\theta)^2$ is not mirror-imaged about $(\mu, 1/2)$. For any $\epsilon > 0$, $G_1(\mu-\epsilon)+G_1(\mu+\epsilon) = 1$, but $G_1(\mu-\epsilon)^2 + G_1(\mu+\epsilon)^2 < 1$. (For example, consider a uniform distribution from 0 to 1 whose mean is 0.5. Then $(0.5-0.2)^2 = 0.09 < 1-(0.5+0.2)^2 = 0.51$.) When θ_2' is a mean-preserving spread of θ_2, there must be $d > 0$ such that $g_2(\theta) \geq g_2'(\theta)$ for $\theta \in [\mu-d, \mu+d]$, and $g_2'(\theta) > g_2(\theta)$ for

$\theta > \mu + d$ and $\theta < \mu - d$. Define $h(\theta) = g_2(\theta) - g_2'(\theta)$. Then $h(\theta)$ is symmetric about μ and $\lim_{\theta \to -\infty} h(\theta) = \lim_{\theta \to \infty} h(\theta) = h(\mu - d) = h(\mu + d) = 0$. $h(\theta)$ is positive for $\theta \in [\mu - d, \mu + d]$ and negative otherwise. Moreover, $\int_\mu^\infty h(\theta)d\theta = \int_\mu^\infty g_2(\theta)d\theta - \int_\mu^\infty g_2'(\theta)d\theta = \frac{1}{2} - \frac{1}{2} = 0$. Thus,

$$\int G_1(\theta)^2(g_2(\theta) - g_2'(\theta))d\theta = \int G_1(\theta)^2 h(\theta)d\theta = \int_{-\infty}^{\mu} G_1(\theta)^2 h(\theta)d\theta + \int_{\mu}^{\infty} G_1(\theta)^2 h(\theta)d\theta$$
$$= \int_0^\infty G_1(\mu - \epsilon)^2 h(\mu - \epsilon)d\epsilon + \int_0^\infty G_1(\mu + \epsilon)^2 h(\mu + \epsilon)d\epsilon$$
$$= \int_0^\infty (G_1(\mu - \epsilon)^2 + G_1(\mu + \epsilon)^2)h(\mu + \epsilon)d\epsilon < \int_0^\infty h(\mu + \epsilon)d\epsilon = \int_\mu^\infty h(\theta)d\theta = 0.$$

Here $G_1(\theta)^2 = G_1(\theta)G_1(\theta)$ could be replaced with the product of two cumulative distributions. Suppose θ_3 is another symmetric probability distribution with mean μ. Then $\int G_1(\theta)G_3(\theta)(g_2(\theta) - g_2'(\theta))d\theta < 0$. The proof is analogous after replacing $G_1(\mu - \epsilon)^2$ with $G_1(\mu - \epsilon)G_3(\mu - \epsilon)$. $\square$

Proof of Proposition 6

Let θ_i' be a mean-preserving spread of θ_i. Denote the pdf of θ_i' by $g_i'(\theta)$, so $\int \theta g_i(\theta)d\theta = \mu_i = \int \theta g_i'(\theta)d\theta$ and $\int \theta^2 g_i(\theta)d\theta < \int \theta^2 g_i'(\theta)d\theta$. Also, let A_j^i be the ex-ante advantage of player j with θ_i', that is, $A_i^i = \int G_j(\theta)G_k(\theta)g_i'(\theta)d\theta$, and $A_j^i = \int G_i'(\theta)G_k(\theta)g_j(\theta)d\theta$, where i, j, and k are distinct.

First, I show that $\int G_j(\theta)G_k(\theta)(g_i(\theta) - g_i'(\theta))d\theta < 0$, or $A_i < A_i^i$, where $i = 2, 3$. By Lemma 2, we know it is true when $E(\theta_i) = E(\theta_j) = E(\theta_k) = \mu$. The one further step needed to complete this proof is to show that $G_j(\mu_i - \epsilon)G_k(\mu_i - \epsilon) + G_j(\mu_i + \epsilon)G_k(\mu_i + \epsilon) < 1$. This will consist of three cases, but the main argument will be similar to the following: "For strictly positive A, B, C and D, if $A + C \leq 1$ and $B + D \leq 1$, then $AB + CD < 1$." (The proof of this claim is as follows: $AB + CD \leq A(1 - D) + (1 - A)D$. Redefine $A = 0.5 + \delta$,

$\delta \in (-0.5, 0.5)$, and $D = 0.5 + \eta$, $\eta \in (-0.5, 0.5)$. Then $A(1-D) + (1-A)D = (0.5+\delta)(0.5-\eta) + (0.5-\delta)(0.5+\eta) = 0.5 - 2\delta\eta < 1$.)

Consider a mean-preserving spread of θ_3, whose mean μ_3 is the smallest. For $\epsilon \in (0, \mu_1 - \mu_3]$, $G_2(\mu_3 - \epsilon)G_1(\mu_3 - \epsilon) + G_2(\mu_3 + \epsilon)G_1(\mu_3 + \epsilon) < 1$ holds, because even at $\epsilon = \mu_1 - \mu_3$, $G_2(\mu_3 + \epsilon) < 1$ and $G_1(\mu_3 + \epsilon) = 1/2$. Therefore, $G_2(\mu_3+\epsilon)G_1(\mu_3+\epsilon) < 1/2$. For $\epsilon > \mu_3 - \mu_1$, since $(\mu_3+\epsilon) - \mu_1 < \mu_1 - (\mu_3 - \epsilon)$, that is, $\mu_3 + \epsilon$ is closer to μ_1 than $\mu_3 - \epsilon$, we find $G_1(\mu_3+\epsilon) - 1/2 < 1/2 - G_1(\mu_3 - \epsilon)$, or $G_1(\mu_3-\epsilon) + G_1(\mu_3+\epsilon) < 1$. This also holds for G_2, so $G_2(\mu_3-\epsilon) + G_2(\mu_3+\epsilon) < 1$. Therefore, $G_2(\mu_3 - \epsilon)G_1(\mu_3 - \epsilon) + G_2(\mu_3 + \epsilon)G_1(\mu_3 + \epsilon) < 1$.

Next, consider a mean-preserving spread of θ_2, whose mean μ_2 is in the middle. For $\epsilon \in (0, \min\{\mu_1 - \mu_2, \mu_2 - \mu_3\}]$, $G_3(\mu_2-\epsilon)G_1(\mu_2-\epsilon) + G_3(\mu_2+\epsilon)G_1(\mu_2+\epsilon) < 1$, because even at $\epsilon = \min\{\mu_1 - \mu_2, \mu_2 - \mu_3\}$, $G_3(\mu_2+\epsilon) < 1$ and $G_1(\mu_2+\epsilon) \leq 1/2$ (with equality when $\mu_1 - \mu_2 \leq \mu_2 - \mu_3$.) Therefore, $G_3(\mu_2+\epsilon)G_1(\mu_2+\epsilon) < 1/2$. For $\epsilon > \min\{\mu_1 - \mu_2, \mu_2 - \mu_3\}$, similarly to the case above, $G_1(\mu_2-\epsilon) + G_1(\mu_2+\epsilon) < 1$.

This approach will not work for θ_1, whose mean μ_1 is the highest. For any $\epsilon > 0$, $G_3(\mu_1 - \epsilon) + G_3(\mu_1 + \epsilon) > 1$ and $G_2(\mu_1 - \epsilon) + G_2(\mu_1 + \epsilon) > 1$. In this case, $G_3(\mu_1 - \epsilon)G_2(\mu_1 - \epsilon) + G_3(\mu_1 + \epsilon)G_2(\mu_1 + \epsilon)$ can be larger or smaller than 1.

Next, I show that $A_j^i - A_j = \int (G_i'(x) - G_i(x))G_k(x)g_j(x)dx < 0$. Since θ_i' is a mean-preserving spread of θ_i, $G_i'(x) - G_i(x) \geq 0$ for all $x \leq \mu_i$, and $G_i'(x) - G_i(x) \leq 0$ for all $x > \mu_i$. Define $H(\theta) = G_i'(\theta) - G_i(\theta)$. Then $H(\theta)$ is symmetric about μ_i, so $H(\mu_i - \epsilon) = -H(\mu_i + \epsilon)$ for any $\epsilon > 0$. Thus,

$$\begin{aligned}
&\int (G_3'(\theta) - G_3(\theta))G_1(\theta)g_2(\theta)d\theta = \int H(\theta)G_1(\theta)g_2(\theta)d\theta \\
&= \int_{-\infty}^{\mu_3} H(\theta)G_1(\theta)g_2(\theta)d\theta + \int_{\mu_3}^{\infty} H(\theta)G_1(\theta)g_2(\theta)d\theta \\
&= \int_0^{\infty} H(\mu_3 - \epsilon)G_1(\mu_3 - \epsilon)g_2(\mu_3 - \epsilon)d\epsilon + \int_0^{\infty} H(\mu_3 + \epsilon)G_1(\mu_3 + \epsilon)g_2(\mu_3 + \epsilon)d\epsilon \\
&\leq \int_0^{\infty} \underbrace{(H(\mu_3 - \epsilon) + H(\mu_3 + \epsilon))}_{=0} \max\{G_1(\mu_3 - \epsilon)g_2(\mu_3 - \epsilon), G_1(\mu_3 + \epsilon)g_2(\mu_3 + \epsilon)\}d\theta = 0,
\end{aligned}$$

where equality holds only when $G_1(\mu_3 - \epsilon)g_2(\mu_3 - \epsilon) = G_1(\mu_3 + \epsilon)g_2(\mu_3 + \epsilon)$ for every ϵ, which is impossible with different means. Therefore, $\int(G_3'(\theta) - G_3(\theta))G_1(\theta)g_2(\theta)d\theta < 0$, or $A_1^3 - A_1 < 0$. $A_2^3 < A_2$, $A_1^2 < A_1$ and $A_3^2 < A_3$ can be shown analogously.

The marginal benefit for player i which would accrue from increasing the level of effort is $\frac{\partial \int G_j(\theta+e_i-e_j)G_k(\theta+e_i-e_k)g_i(\theta)d\theta}{\partial e_i}$ (if w is normalized to 1), and the marginal cost of increasing the level of effort is $c'(e_i)$. While the marginal cost is independent of the spread of the support distribution, the marginal benefit decreases, as θ_i has a larger variance. To prove this, it suffices to show that $\int G_j(\theta + e_i - e_j)G_k(\theta + e_i - e_k)(g_i(\theta) - g_i'(\theta))d\theta$ increases in e_i. This is straightforward, because $G_j(\theta+e_i-e_j)G_k(\theta+e_i-e_k)$ increases in e_i, and $g_i(\theta)-g_i'(\theta)$ is unchanged in e_i. Therefore, $\frac{\partial \int G_j(\theta+e_i-e_j)G_k(\theta+e_i-e_k)(g_i(\theta)-g_i'(\theta))d\theta}{\partial e_i} = \frac{\partial \int G_j(\theta+e_i-e_j)G_k(\theta+e_i-e_k)g_i(\theta)d\theta}{\partial e_i} - \frac{\partial \int G_j(\theta+e_i-e_j)G_k(\theta+e_i-e_k)g_i'(\theta)dx}{\partial e_i} > 0$. Since the marginal benefit of effort is smaller while the marginal cost of effort is the same, $e_i'^*$ has to decrease. This argument also holds for $e_j'^*$, $j \neq i$. Intuitively, the mean-preserving spread renders the effect of every player's effort less influential, so they would exert less effort.

Since the mean-preserving spread of θ_i drives increases in A_i, and since e^* decreases, as does A_j for $j \neq i$, it is natural for $EU_i'^*(e_i^*|\theta_1, \theta_2, \theta_3, e_{-i}^*)$ to increase. Even though the direction of $EU_j'^*$ is hard to determine from e_j^* and A_j^i, we can at least conclude that $EU_j'^*$ cannot be strictly larger than EU_j^*. Suppose for the sake of contradiction that $EU_j'^*$ is strictly greater than EU_j^*. That would mean that player j could attain a higher expected payoff with a lower ex-ante advantage. Since $e_j'^* \leq e_j^*$, $e_j'^*$ is a feasible effort choice for player j. Therefore, e_j^* cannot be an equilibrium effort for player j. $\square$

Proof of Proposition 7

First, consider the case where the environmental support distributions of the second and third tiers are identical. Denote the equilibrium effort choices in this case by $e^p = (e_1^p, e_2^p, e_3^p)$. Then it is obvious that $A_2 = A_3$ and $e_1^p \geq e_2^p = e_3^p$, just as in the pairwise competition. If the ex-ante advantages of the second and third players are also identical, they will have the same expected payoff, that is, $EU_2(e_2^p|\theta_1, \theta_2, \theta_3, e_{-2}^p) = EU_3(e_3^p|\theta_1, \theta_2, \theta_3, e_{-3}^p)$. Next, consider increasing the mean of θ_2, and decreasing the variance of θ_2 in such a way that $E(\theta_2) > E(\theta_3)$ while keeping $A_2 = A_3$. The smaller variance of the support will increase the marginal benefit of increasing the level of effort, as shown in the proof of Proposition 6. Since the support distribution is symmetric and unimodal, a positive location shift will cause the marginal benefit of increasing the effort evaluated at e_2^p to increase (or to remain the same when the distribution is uniform). Therefore, the second-tier player will choose the higher level of effort. By Proposition 6, e_3^p will decrease but the expected reward will be unchanged. Hence the second-tier player will have a smaller equilibrium payoff, and a support distribution that has a larger mean and a smaller variance. $\square$

Appendix B

Sample Experimental Instructions

[Have the participants sign in, read and sign the consent forms, and open the tutorial program.]

Welcome. This tutorial consists of instructions for the experiment, followed by a screening test and two practice rounds. Your close attention is important to this study. Please read the instructions very carefully.

General description:

During the experiment, you will earn "points." Your goal is to earn as many points as possible. The points will be converted to U.S. dollars at the end of the experiment, at the rate of 1,000 points = 1 USD. As a reward for your participation, you will be given 7,000 points at the start of the experiment. The exact amount you will earn depends on your decisions, the decisions of two virtual competitors, and some luck. The experiment will consist of 10 rounds, each with two phases. In each round, you will have 40 virtual tokens. In general, your task is to choose an "environment" in the first phase of each round, and then to choose an amount of "individual investment" in the second phase. The details follow.

In the first phase of each round:

You will choose one of three environments, each of which is described by a range of numbers. At the end of the round, your chosen environment will randomly determine the amount of "environmental support" you receive. For example, if you choose an environment described as [3.44, 11.87], then at the end of the round your environment will randomly pick a number between 3.44 and 11.87, which will be the environmental support. No two players can choose the same environment, so your two competitors cannot choose the same environment you chose. (Therefore, after one computer competitor chooses an environment, the other competitor will be assigned the remaining one.) In some rounds, one environment may already have been chosen by one of your competitors. In that case, you will choose one of the remaining two environments.

In the second phase of each round:

You will choose an amount of individual investment with the 40 tokens. Your "output" is the sum of the environmental support you receive and your chosen individual investment.

Calculating your payoff:

If your output is the largest of the three players, you will win 1600 points; otherwise, you will win nothing. If you invest X tokens in the round, the cost of investment in terms of points is X^2, the square of X. The amount of your unused tokens, $40 - X$, will be converted to points at the rate of 1 token = 10 points. Thus, your payoff for the round will be $1600 - X^2 + (40 - X) * 10$ points if you win, and $-X^2 + (40 - X) * 10$ points if you lose. Examples follow.

Examples:

Suppose you invest 10 tokens and your environmental support is 7.58. If your output, 17.58, is the largest of the three players, you will win and earn 1600 points, but you will pay 100 points (the square of 10) as the cost of investment. Your 30 unused tokens will be converted to 300 points. Therefore, your payoff for the round will be $1600 - 10^2 + (40 - 10) * 10 = 1600 - 100 + 300 = 1800$ points if you win. If you lose, it will be $-100 + 300 = 200$ points.

Suppose instead that you invest 30 tokens. You will pay 900 points as the cost of investment. The 10 unused tokens will be converted to 100 points. Your payoff will be $1600 - 900 + 100 = 800$ points if you win, and $-900 + 100 = -800$ if you lose.

Though your points will automatically be updated to reflect the amount of the payoff, you must understand how your payoff is determined. Three questions on the screening test will ask you to calculate the payoff in hypothetical situations.

Other information:

Your virtual competitors will make their own best possible decisions given their environment, assuming that you make your best decisions on investment choices in your chosen environment. That is, their decision strategies are preset; they will not adjust their decisions based on your investment. At the end of the round, you will be informed whether you have won and how much you have earned (or lost). After you begin with 7,000 points in round 1, your points in each new round will be cumulative. Please note that the cost of investment cannot exceed the cumulative points you currently have. For example, if you have 400 points now, you cannot invest more than 20 tokens, because the square of 20 is 400.

Now you will be given the screening test.

Screening Test:

You will answer six multiple choice questions. You can participate in the experiment only if ALL of your answers are correct. If you do not pass the screening test, you will be asked to leave without payment. The main purpose of this screening test is to help you understand the instructions, not to cause you any stress. It is okay for you to ask an experimenter to help you if you are in doubt.

Q1 The experiment will consist of (A) rounds. In each round, you will have (B) tokens. You will start with (C) points. What are the numbers (A), (B) and (C) that will make these statements true?

Q2 Suppose you have 22,000 points at the end of the experiment. How much will you get paid in cash?

Q3 Suppose you choose an environment described by the range, [101.78, 200.30]. Which of the following numbers CANNOT be your environmental support: 144.34, 199.00, 103.55, 204.23?

Q4 Assume that in the first round you invest 0 tokens and you win. What will your payoff be?

Q5 Assume that in the first round you invest 20 tokens and you lose. What will your payoff be?

Q6 Assume that in the first round you invest 14 tokens and you win. What will your payoff be?

[Let those who fail the screening test leave. The experiment begins.]

[The experiment ends. After filling out a short survey form, subjects leave with payments.]

CHAPTER 3

THE COIN STRATEGY AND CHARITABLE GIVING

3.1 Introduction

Some charities, including UNICEF (see Figure 3.1) and the March of Dimes (Figure 3.2) send direct mail with coins attached hoping for a larger return. According to a news report,[1] their solicitation strategy, which I call 'the coin strategy,' is successful in terms of both response rate and returns. Would they have reported the success of the coin strategy based on rigorous comparisons? Does the coin make the letter heavier, unbalanced and curious enough to allow more chance for potential donors to open the envelope? Does the coin strategy send a signal that the project the charity is working on is so serious that potential donors will believe that it is worth reading the solicitation letter more carefully? On the other hand, does the coin simply trigger pro-sociality? Provided that the effect of the coin strategy had been rigorously examined by the time the fundraising organizations that adopted the coin strategy reported their results to the news writer, it is a bit of conundrum: Even though many theories proposed in behavioral economics and public economics attempted to explain why people donate,[2] most of these theories cannot convincingly explain why the coin strategy causes a significant increase in donations. If the coin stimulates potential donors' inequity aversion (Fehr and Schmidt (1999)), sending the coin back

[1] Jones, Stacy. "Charities mail out coins, hope for larger return" USA Today July 14, 2010. http://usatoday30.usatoday.com/news/sharing/2010-07-14-charity-coins_N.htm. Access: July 6, 2013.

[2] Impure altruism (Andreoni (1990)), inequity aversion (Fehr and Schmidt (1999)), the Rawlsian motivation (Charness and Rabin (2002)), social pressure to abide by pro-social norms (DellaVigna et al. (2012)) and the reputation incentives to do pro-social deeds (Benabou and Tirole (2006)) may, though not exhaustively, explain why people donate.

would be optimal, provided that the recipient would not have donated if they received a solicitation without a coin. Moreover, since some charities whose purpose is not mitigating inequity have also used the coin strategy,[3] we cannot simply conclude that the coin strategy appeals to the recognition of inequity. Studies of reciprocity or gift exchange (Gneezy and List (2006), Falk and Fischbacher (2006), and Falk (2007)) may partly explain the success of the coin strategy if potential donors recognize the coin as a gift, but this interpretation is also puzzling because we do not usually present coins as gifts, and sometimes small monetary compensation can actually reduce recipients' goodwill or even invoke negative feelings.[4] Moreover, even if potential donors do regard the coin as a gift whose monetary value is obvious and fixed, the expected marginal contribution cannot be greater than the coin value unless there is a certain type of leverage process. Admitting that the coin does not make the recipients happier, the success of the coin strategy may suggest a new source of philanthropy initiatives.

If the success of the coin strategy could be rigorously examined and verified, I would claim that people overshoot to relieve a sense of involuntary indebtedness *regardless of* whether the coin provokes positive or negative senti-

[3] As of March 2015, I have received actual solicitation letters with real coins from UNICEF (Purpose: Relief of needy children), Children's Hunger Relief Funds (Relief of needy children), Leukemia & Lymphoma Society (Research & support of patients), and March of Dimes (Health of mothers and babies). I also found that Mothers Against Drunk Driving (Prevention of drunk driving and underage drinking), Covenant House (Helping homeless youth), and 20/20/20 (Restoring vision to blind children and adults) have used the coin strategy at least once. Note that many charities have adopted the coin strategy even though their mission is not directly related to the mitigation of inequity.

[4] Ariely (2009) argues that work done as a favor can produce much better results than paid work in some cases. For example, when AARP asked some lawyers to provide destitute retirees with services at a low cost, about $30, they did not accept the offer. However, when asked to offer services for free, they agreed. Experiments also showed that giving a small gift would not offend anybody, but mentioning the monetary value of the gift evokes market norms, such as prices, wages, rents, costs, and benefits relevant to the value of the gift. Zelizer (1997) argued similarly that the social value of money is determined in the process.

Figure 3.1: A Nickel Attachment Solicitation Letter from UNICEF

Figure 3.2: A Dime Attachment Solicitation Letter from March of Dimes

ment. When we are voluntarily indebted and can identify whom we owe, as when taking out a loan, feeling indebted does not encourage us to be pro-social. However, when we feel that we are unexpectedly indebted to others, the anonymous, or the intangible, we may try to compensate for the sense of indebtedness by making a leveraged contribution to society. Reciprocity explains this repayment behavior when such a feeling of indebtedness comes with positive sentiment.[5] But reciprocity may not necessarily consist entirely of the response to the positive sentiment[6] provoked by unexpected goodwill from others. The primary goal of my research was to identify whether the pro-social behavior comes mainly from feeling involuntarily indebted or from positive sentiment created by receiving another's goodwill. To elaborate, reciprocal behavior is often regarded as a response to the combination of two factors—a sense of unexpected indebtedness and that of unexpected happiness. The coin attachment worked as a key treatment to discern those two factors, because lab experiments or existing data cannot provide variations to control for positive sentiment from another's goodwill. I assume that the coin attachment does not make potential donors feel happier enough to give more than what they have received.[7]

Even if people respond more to the solicitation letter with a coin attachment, we are still not sure if the value of the coin affects donations any more than similarly designed solicitation letters without a coin that contain a coin-sized, no real-value, medallion attachment, which may also have the same effect. It might have been the case where the coin (or any metal) makes the letter heavier, unbalanced, and curious enough to allow more chance for potential donors to open the envelope. (See Figure 3.3.) To rigorously test the effect of a coin attach-

[5]For example, some successful celebrities who believe that their fame and wealth were achieved by not only their abilities but also their fans' priceless support have made large donations to society. Some successful businessmen/investors make similar donations partly because they want to pay off the consumers' favor or lucky market conditions. Some religious people donate because they feel that their large share of well-being is indebted to God. Similar examples and related field experiments are found in Cialdini (2009).

[6]A substantial amount of studies summarized in Isen (2008a) and Isen (2008b) show how mild and positive feelings influence decision making and thought processes significantly. For example, subjects who found a dime in the return slot of a public telephone more likely to spontaneously pick up papers that were dropped in front of them (Isen and Levin (1972)).

[7]Some self-interested agents may obtain some utility from the coin attachment by regarding it as a monetary payoff. I would claim that this would not matter substantially. Many charities which do not currently adopt the coin strategy refused to cooperate for this project when I contacted them because they believed the coin strategy may send a negative signal to potential donors that the charity misuses the funds which should be used for the main purpose of the charity.

ment, I conducted a randomized controlled trial with the cooperation of *Human in Love*, a charity whose headquarters is located in Seoul, South Korea, with four different attachments in direct mail: no coins, a 100 Korean won coin, a 500 won coin, and a 500-won-sized medallion of no real value.

Figure 3.3: Three Cent Attachment Solicitation Letter from the Children's Hunger Relief Fund

Instead of using envelopes with an additional window that displays the coins inside, Children's Hunger Relief Fund used a standard envelope so the recipients could not observe what was inside without opening the envelope. By placing three cents on the left, however, they made the letter unbalanced so people can recognize immediately that something other than paper is in the envelope.

One of the lasting questions that many researchers have struggled to answer is whether moral action depends on reasoning. The field experiment aimed to disentangle the effects of reciprocity motivation and generosity. In addition, I anticipated that any results from this project would have practical relevance for charitable organizations, as they can understand the market better and find more cost-effective solicitation strategies.

When it comes to reciprocity initiatives, I could not tell anything further than that feeling involuntary indebtedness by itself may not prompt people to be pro-social, because the coin strategy did not particularly bring any significant effect. The charity collected only one donation from the entire sample in eight weeks. The donation was made from the group which received the letter with a medal attachment, and the donor decided to make monthly donations of 10,000 Korean won (roughly equivalent to $10). This is a surprisingly low return, both when considering the project expenses of $12,620 and when compared to similar studies. One conclusion for fundraising organizations that consider using the coin strategy is that they might have been better off if they had looked for more cost-effective solicitation strategies. One caveat for researchers and practitioners is that the results from the previous studies should be extrapolated to a general situation with extra care because of the sample selection bias: Unlike this experiment, where the samples were selected from the entire population, previous studies have selected samples from a narrower (or preselected) set of the population to increase response rates and returns. Other plausible reasons of almost zero donations are discussed in Section 4.

Though the charity had only one donation from this project, they collected 381 'actively returned' letters out of 15,718 during the same data collection period. By actively returned, I mean that the mail recipient decided to return the solicitation letter. The Korean mail delivery system allows mail recipients to return unopened letters for free by putting the letters in the designated return box, or to refuse to receive the letters by indicating it to a mail delivery person. The return box is usually located near the mailboxes of the condominium, so the active return could be understood as a simple choice between throwing the letter into a trash can and returning it. An interesting observation is that a significantly larger proportion of those who received a letter with an attachment returned the letter than those without any attachment. Though it should be further tested, the coin attachment seems to appeal to the recipients' inequity aversion. In this regard, the coin strategy creates some social costs by making the national mail delivery system bear the cost of return.

The rest of this paper is organized as follows: Section 2 elaborates on the detailed process of conducting the field experiment. Section 3 analyzes the responses. Section 4 discusses why the return could be so low, and Section 5 summarizes the lessons from this project. All supplementary notes and further considerable extensions for this project are in the Appendices.

3.2 Experimental Procedure

3.2.1 Experimental Design

The obvious starting point of this project was the desire to rigorously test the effect of the coin strategy. Therefore, the main job of this project was to deliberately control for other factors that may explain either the increased response rates or gift amounts. In the course of controlling for other factors, I hoped to identify how different factors account for an individual donor's philanthropy.

I conducted a field experiment with the cooperation of *Human in Love*, an international charity whose headquarters is located in Seoul, South Korea. The purpose of the charity is to "improve the quality of life for the poor by delivering interventions for the issues of absolute poverty, hunger, and deficient public health and education in developing countries."[8] I considered three main com-

[8] Who We Are, *Human in Love*, http://www.humaninlove.org. Access: April 2, 2015.

parison groups: one group whose members receive a solicitation letter with no attachment, another one with a 100 South Korean won[9] coin attachment, and the other one with a medallion of no real value. Additionally, I added another group with a 500 won coin[10]. For notational convenience, let the capital letters in parentheses, (N), (C), (F) and (M), denote the groups of mail recipients who receive no coins, a 100 won coin, a 500 won coin, and a 500 won-sized medallion, respectively. The logo image of the charity was embossed on the medallion (Figure 3.2.1). Groups (N) and (C) consisted of 5,000 mail recipients, group (F) of 2,000, and group (M) of 4,000, respectively. In total, 16,000 solicitation letters were sent to households randomly selected from the population of Seoul, South Korea. From the day of the mailing (February 24, 2015), the charity collected data for two months. If response rates and returns to (C) were higher than those to (M), I would have concluded that people overshoot the feeling of involuntary indebtedness, because the medallion attachment looks similar to the coin attachment from the perspective of the recipients who have not opened the envelope yet, and the medal has no real value. One possible concern is that the medallion may have subjective nonzero value to some recipients. To prevent this possibility, the medallion is designed in a way that it cannot be used as a souvenir: It has neither a ring to hang it nor a magnet on the back panel. The charity is not popular enough to have a brand effect from the logo. If response rates and returns to (C) were lower than those to (M), but higher than those to (N), I would have concluded that the overshooting behavior is dampened by negative feelings because the coin makes them feel a sense of guilt. If cost-

[9] 100 won is approximately equivalent to 10 cents. With the exchange rate as of April 2, 2015, 100 won equals 9.119 United States cents. Since the Korean won was undervalued by 21% in January 2015 according to the Big Mac Index, the purchasing power of 100 won is greater than that of 10 cents in the US.

[10] 500 won is the smallest unit of Korean coins greater than 100 won. In the proposal stage where I assumed that I would conduct the experiment in the United States, I planned to use a quarter.

adjusted returns to (N), (C) and (F) were not significantly different, I may have suggested that the charities find more cost-effective solicitation strategies.

Figure 3.4: *Human in Love*'s Logo and the Medallion

The medallion is designed in a way that it has no real value. It has neither a ring to hang it nor a magnet on the back panel. The embossed logo of the charity does not work as a signaling device to others because few people recognize the logo is from a charity.

Solicitation letters were sent to 25 randomly selected large condominiums, one in each district (*gu*) of Seoul. The 25 *gu* comprise Seoul. Six hundred and forty solicitation letters were sent to randomly selected households in each condominium. Among the 640 letters, 200 were letters without any attachment, 200 letters with 100 won attached, 160 with a coin-sized medallion attached, and 80 with 500 won attached. I believed that conducting the field experiment in South Korea would provide cleaner data for several reasons. First, South Korea is free from several problems that make the interpretation of results harder. For example, if a similar field experiment were to be conducted in the United States, where some solicitation letter recipients recognize which charities use which solicitation strategies, we cannot completely distinguish the effect of the coin strategy with the responses to recognition that styles and forms of the solicitation letter have changed.[11] In South Korea, sending direct mail for solici-

[11] At the same time, this endogeneity issue applies to the charities based in the United States. Most of the charities that I contacted have already used the coin strategy, or at least recognized

tation is less common, so it may capture the effect of solicitation letters without any endogeneity problems. Second, it is hard in the United States to control for a household's wealth and education level unless I ask them directly to reveal it and they report it truthfully. Since it is known that the annual income of households and education level significantly vary by *gu*, I was able to utilize that information as controlling factors. I and the charity deliberately chose the period of data collection (late February–April) to prevent any seasonal/holiday effects. Since my goal was to distinguish if the responses were due to a feeling of indebtedness or from the positive sentiment, and I assumed that people in general have positive sentiment from the end of the year to the New Year celebration periods,[12] I excluded January and early February from the data collection period. I also excluded November and December because taxes are due then and I did not want the possibility of a tax exemption to confuse the interpretation of the results. The experimental design is summarized in Table 3.1.

3.2.2 Project Expenses

Excluding the travel expenses to have meetings with the charity, the cost of the project was more than \$12,620 in total: \$5,790 to purchase postage stamps, \$1,500 to attach coins, \$4,180 to print solicitation letters and return forms, and \$1,150 to produce custom medallions. Itemized project expenses are summarized in Table 3.2, which shows the USD equivalence of the actual expenses. Since the charity sent 16,000 letters, the unit cost of sending the letter was about

some other charities using the coin strategy. I had struggled to find a cooperating charity in the United States, but it was futile. For charities which already tried or currently use the coin strategy, my request of cooperation may not have sounded beneficial to them. For those that had already decided not to use the coin strategy for any reason, my request could not alter their decisions.

[12] Korean New Year was February 19, 2015.

Table 3.1: Summary of Experimental Design

Charity	N	Group	Attachment	#Letters to Each District
Human in Love	5,000	(N)	—	200
	5,000	(C)	100 won	200
	4,000	(M)	Medallion	160
	2,000	(F)	500 won	80

- Diameter of 100 won (500 won, and the medallion): 24mm (26.5mm, and 27mm)

- Mailed on February 24, 2015

- Data collection: until April 30, 2015

$0.79.

For fundraising organizations, this project expense could be a comparison point to decide whether they would adopt the coin strategy, or use direct mail marketing in general. One may claim that the unit cost could have been lower when having multiple projects in consecutive periods due to the economies of scale. However, since most of the expenses were from variable costs, multiple projects would not substantially decrease the unit cost. Also, the project expenses would have been much higher if the project were to be conducted in the United States and domestic product vendors were chosen.[13]

[13] I was able to reduce a significant amount of project expenses from the custom medallion production. The supplier of the custom medallions was found from a supplier list on Alibaba.com. They submitted a very competitive bid against suppliers in North America. I had contacted four suppliers based in the United States or Canada, and their unit prices of a similar product ranged from $0.75 to $1.21. Production cost of direct mail was also much cheaper in South Korea compared to the quotes that I received from the US based direct mail service providers.

Table 3.2: Itemized Project Expenses

Items	Specifics	Unit Price($)*1	Quantity	Expenses($)
Medallion	Mold	100	1	100
	Medallions	0.185	4,000	740
	Freight*2	310	1	310
Coin	100 won	0.10	5,000	500
	500 won	0.50	2,000	1,000
Letter	Letters	0.04	32,000	1,280
	Envelopes	0.07	16,000	1,120
	Labels	0.07	16,000	1,120
	Labor	30	22 (hrs)	660
Mailing	Postage(regular)	0.30	5,000	1,500
	Postage(irregular)*3	0.39	11,000	4,290
			Total Expenses	**$12,620**

*1: I approximately applied the exchange rate of the date the actual expenses are made on.
*2: Freight from China to South Korea plus a customs fee.
*3: Letters with non-paper items are classified as irregular letters.

The images of the solicitation letters, return forms and envelopes are in Appendix A. The actual timeline and practical challenges are discussed in Appendix B.

3.3 Analysis

Table 3.3 summarizes the responses by letter type. The charity usually asks for donations by conducting campaigns at one of the subway junctions, and it was practically the first trial for them to send solicitation letters. In that period, they did not conduct any other fundraising campaigns.

Table 3.3: Responses by Letter Type

Letter Type	**#Letters Delivered (%)**†	**#Donations**	**#Returns (%)**
(N)	4,929 (98.58%)	0	107 (2.1708%)
(M)	3,931 (98.275%)	1	93 (2.3658%)
(C)	4,916 (98.32%)	0	137 (2.7868%)
(F)	1,942 (97.10%)	0	44 (2.2657%)
Total	15,718 (98.2375%)	1	381 (2.4240%)

†: The number of letters sent excludes letters returned for delivery failure such as unidentified mailing addresses and addresses without current residents.

The charity collected a total of 382 responses in eight weeks. The charity collected only one donation from the 15,718[14] households. Thus, in terms of reciprocity initiatives, I could not conclude anything further than that feeling involuntary indebtedness by itself without positive sentiments may not prompt people to be pro-social, because the coin strategy did not bring any significant effect. The donation was made from the group which received the letter with a medal attachment. No other related donations, for example, an online donation indicating the letter as the answer to "where did you hear about us?", were collected. This is a surprisingly low return, both when compared to the project expenses and when compared to similar studies. The project expenses were more than $10,000, and the donor who responded to the solicitation letter made monthly donations of $10. The proportion of mail recipients who donated in the previous studies where a similar field experiment was conducted vary from

[14] 282 out of 16,000 letters were returned to the charity for logistic reasons such as unidentified mailing addresses and addresses without current residents.

2.07% to 66.46%. In retrospect, the biggest lesson I learned from this low donation rate is that I should not have controlled all other factors that could increase donations, even though those controls were done for good reasons. To minimize the sample selection bias, the charity sent the solicitation letters to households randomly selected from the entire population. This is the most distinctive attribute of this experiment: Other similar studies selected samples within a narrower set of the population to increase response rates and returns. Specifically, most of them sent the solicitation to individuals who had contributed to the fundraising organization at least once. I still believe that controlling for all other arguable factors can provide clearer interpretations of experimental data, but I learned that this claim is valid only if the data can be appropriately collected. For fundraising organizations currently using the coin strategy or considering to use it, this result may suggest that they should have considered other cost-effective solicitation strategies.

Though the charity had only one donation from this project, they collected 381 'actively returned' letters out of 15,718 during the same data collection period. By actively returned, I mean that the mail recipient decided to return the solicitation letter, and had to perform a task to return the letter. Since 2.42% of the sample population (382 out of 15,718 households) responded to the solicitation letter, the response rate by itself was not low compared to similar studies. The Korean mail delivery system allows mail recipients to return unopened letters for free by putting the letters in the designated return box or to refuse to receive the letters by indicating it to a mail delivery person.[15] In these cases,

[15]The US mail delivery system also allows returning letters to the sender. However, most residents living in a house with a single, separate mailbox do not usually have a return box, so they should leave the letter in the mailbox, and write clearly on the envelope that they want to return it to the sender and why they want to do so. Since this return process requires more action than throwing away the letter, we cannot assume that their decision would have been made from a choice between throwing the letter into a trash can and returning it.

though it raises some social costs, neither the sender nor the receiver pays the extra cost of the return process. Even if a mail recipient opens the envelope, they can return it at the cost of the sender. In this case, the sender must pay 110% of what a postage stamp costs. Only 6 letters were returned open. An interesting observation is that a significantly larger proportion of those who received a letter with 100 won returned the letter than that of those without any attachment. The letters with either a 500 won or the medallion were returned more than those with no attachment, but less than those with 100 won. Though it should be further tested, I claim that the coin attachment appeals to the mail recipients' inequity aversion. Simply put, recipients who received 100 won were reluctant to keep 100 won, because keeping the coin marginally exacerbates the inequity between the potentially benefited person through the charity and the mail recipient, while such reluctance decreased as the monetary payoff went up. Though the attachment is not visible from the outside, an actual-sized image of 500 won is visible through the address window (Figure 3.7). If the recipients could guess the value of the attachment by comparing the image of 500 won to the size of the attachment, then they might have believed that both 500 won and the medallion attachment would be 500 won.

3.3.1 Generalized Inequity Aversion and Returned Letters

This section is for elaboration of how inequity aversion predicts more returned letters with a coin attachment and how the effect of the coin attachment, even if it were to exist, cannot be explained by inequity aversion. Fehr and Schmidt (1999) postulated that people are self-interested, but dislike inequity between themselves and others, so they make decisions to minimize inequity.

The "linear inequity aversion" model for Player 1 in a two-player game is described by the following utility function:

$$U_1(x, y) = x - \alpha_1 \max\{x - y, 0\} - \beta_1 \max\{y - x, 0\},$$

where x and y are, respectively, Player 1's and 2's monetary payoffs, α_1 captures the averseness of advantageous inequity, and β_1 captures the averseness of disadvantageous inequity. Player 2's utility function is analogous, and $\beta_i \geq \alpha_i$ is assumed for $i = 1, 2$. This simple model's prediction is generally consistent with observations in standard economic experiments, such as the dictator game[16], and the ultimatum game[17].

The model implicitly assumes that there is no inequity between players before the game starts. Such an assumption was reasonable to conduct well-controlled lab experiments, but for other cases, such as responding to a solicitation from charity, it is more reasonable to assume that a potential giver (henceforth, giver) is wealthier than a potential recipient (henceforth, recipient.) Instead of a difference in monetary payoffs, I assumed inequitable outcomes based on their current situations, or reference points. For simplicity, I assumed further that givers only take one corresponding recipient into account when they receive a solicitation. Let $g \in \mathbb{R}_+$ denote an amount of reallocation. Then the net utility from this reallocation given current economic states, $v(g|x, y)$, is defined by $U_1(x - g, y + g) - U_1(x, y)$. Consider a case $x > y$ without loss of

[16]One subject (dictator) splits given rewards for himself and a partner. If the dictator is self-interested, then he would keep the full amount of the rewards. Experimental evidence shows that many, though not the majority, choose to give some rewards to their partner.

[17]One subject (proposer) offers a way to split rewards between himself and a partner (recipient). If the recipient accepts the offer, they earn the rewards as offered. If he vetoes the deal, both subjects receive nothing. Experimental evidence shows that recipients prefer getting nothing to receiving a small share, which is contradictory to the prediction under the assumption of self-interested rational agents who always choose to receive a greater monetary reward.

generality.

$$
\begin{aligned}
v(g|x,y) =& U_1(x-g, y+g) - U_1(x,y) && (3.1)\\
=& x - g - \alpha_1 \max\{x-g-(y+g), 0\} - \beta_1 \max\{y+g-(x-g), 0\}\\
& - [x - \alpha_1 \max\{x-y, 0\} - \beta_1 \max\{y-x, 0\}]\\
=& -g - \alpha_1 \max\{x-y-2g, 0\} - \beta_1 \max\{y-x+2g, 0\} + \alpha_1(x-y)\\
=& \begin{cases} (2\alpha_1 - 1)g & \text{if } g \le \frac{x-y}{2} \\ (\alpha_1+\beta_1)(x-y) - (2\beta_1+1)g & \text{if } g > \frac{x-y}{2} \end{cases} && (3.2)
\end{aligned}
$$

Hence the prediction of this simple inequity aversion model is straightforward: if $\alpha_1 < 1/2$, $g^* = 0$ is optimal, while if $\alpha_1 \geq 1/2$, $g^* > 0$.[18] This prediction is natural, so it may explain why people donate. However, it still cannot explain why direct mail with coins gets returned more. When the giver receives $\varepsilon > 0$, and the current economic state becomes $(x+\epsilon, y-\epsilon)$, he still will not donate when his averseness to advantageous inequity is not large enough. Even if the aversion to advantageous inequity is sufficiently large, sending it back makes him less likely to feel indebted, given that the giver did not initially plan to give. Therefore the inequity aversion may explain why more solicitation letters with a coin attachment were returned, but can neither explain the increased response rates nor the increased returns.

This claim holds for an extended model of inequity aversion with impure altruism. Let $g \geq 0$ denote an amount of charitable giving, $W \geq 0$ and $y \geq 0$ denote, respectively, the giver's and the recipient's wealth, and $\delta \in (0,1]$ denote the proportion of donations directed to the recipient. Then the giver's utility

[18] In this linear model, $g^* = \frac{x-y}{2}$, so that both players would have the same final outcome. However this overstated result is mainly due to the linearity assumption.

function is

$$U(g|W,y) = u(W-g) + \psi_i(g) + \alpha_i(1+\delta)g\mathbb{1}_{g\geq 0} + \beta_i(1+\delta)g\mathbb{1}_{g<0}, \tag{3.3}$$

where $u(\cdot)$ is utility from his own wealth, $\psi_i(\cdot)$ is the giver i's utility by giving, and the last two terms capture the inequity aversion based on the current inequity. When the giver donates g, his final wealth becomes $W-g$, while the recipient's wealth becomes $y+\delta g$, so the inequity between the giver and the recipient is $W-g-y-\delta g$ and it decreases inequity by $(1+\delta)g$ compared to $W-y$. A negative g would not happen in general, but it represents the cases where the giver receives a little money from the coin attachment and keeps it. Consider first person i who decides not donate when solicited without a coin attachment. It implies that

$$u(W) \geq u(W-g) + \psi_i(g) + \alpha_i(1+\delta)g \quad \text{for any } g \geq 0. \tag{3.4}$$

Suppose that person i receives a solicitation letter with a coin whose value is ϵ. If he keeps the coin without donation, his utility will be $u(W+\epsilon) - \beta_i(1+\delta)\epsilon$. Even though there may exist g^* such that $g^* \geq \epsilon$ and $u(W+\epsilon-g^*) + \psi_i(g^*) + \alpha_i(1+\delta)(g^*-\epsilon) > u(W+\epsilon) - \beta_i(1+\delta)\epsilon$, such g^* must be equal to ϵ due to (3.4). Now consider person j who decides to donate $\hat{g} > 0$ when solicited without a coin attachment. It implies that

$$u(W-\hat{g}) + \psi_i(\hat{g}) + \alpha_i(1+\delta)\hat{g} \geq U(g|W,y) \quad \text{for any } g \geq 0. \tag{3.5}$$

In this case, the contribution level is generally determined by the warm-glow effect and the aversion to advantageous inequity, but it will not be affected by the value of the attached coin, ϵ, as long as $\hat{g} > \epsilon$. Nontrivial cases may arise when $\hat{g} \leq \epsilon$, but it is unlikely for givers to donate less than the value of a coin. All other possible variations, including inequity aversion models with an endogenous reference point, cannot explain the leveraged effect of the coin attachment.

In summary, the main issue is that in the context of charitable giving, the aversion to disadvantageous inequity, β_i, which is usually assumed to be greater than the aversion to advantageous inequity, α_i, plays no role.

3.4 Discussion on Low Donation Rates

The coin project does not particularly help the fundraising of the charity. Only one donation out of 15,718 is shockingly low, at first glance. Retrospectively speaking, I controlled various factors that may have affected the donation decision and gift amounts to the solicitation letters, and all those controls turned out to be a double-edged sword: By controlling for all other factors, the proportion of people who donated was almost zero. The donation rates of previous studies where a similar field experiment was conducted vary from 2.07% to 66.46%, and the donation rate of this study (0.00636%) is substantially low compared to the response rate of the online fundraising conducted by Chen et al. (2006), 0.0163%. Table 3.4 summarizes some previous studies where a natural field experiment was conducted by sending direct mail or e-mail. I especially focused on the sample size and the number of donations regardless of the treatment. The summary of this study is juxtaposed on the last row of Table 3.4.

Table 3.4: Summary of Previous Studies

	Sample Size	#Resp-onses	Response Rate	Season	Features	Main Treatment	Random Sample?
LL02	3,000	183	6.10%	Dec	New building construction at a local University	Seed money	No
KL07	50,083	1,035	2.07%	Aug–Sep	A politically liberal nonprofit organization in the US	Matching Grant	No
M07	11,379	7,563*1	66.46%	7 register-ing periods	Support to students (including themselves)	Matching Grant	Yes/No*2
F07	10,000	1,553	15.53%	Dec–Jan	Support to children in need	Postcards*3	No
RL08	3,000	137	4.57%	Jun–Jul	Education program by the Sierra Club of Canada	Matching and challenge gifts	No
C14	19,636	787	4.01%	May–Jul	A public radio station's membership renewal	Thank-you gifts	No
EHM14	16,005	896	5.60%	Dec	Seeking alumni support for the University	Option to direct a gift	No
CLM06	153,183	25	0.0163%	Oct–Jun	Seeking user support to the Internet Public Library	Matching, Seed money, Gifts	Yes*4
This		1 donations	0.00636%		Charity's Name/Mission	Coin	

3.4.1 Randomly Selected Households

To the best of my knowledge, almost all of the previous researchers conducting a natural field experiment sent solicitation letters to those already in the organization's database (List and Lucking-Reiley (2002), Karlan and List (2007), Falk (2007), Rondeau and List (2008), Chao (2014), and Eckel et al. (2014)), and in most of the cases they contacted those who had contributed to the organization at least once or had been associated with the organization at least for a certain period, either currently or previously (Meier (2007) and Chen et al. (2006)). The results are by themselves meaningful from the perspective of the fundraising organizations because most of the organizations sent solicitation letters to those who already contributed to the organization.[19] However, I do not believe that such sample households indeed represent the entire population. Rather, the sample from the existing database represents the population which feels the "warm glow" (Andreoni (1989)). I claim that the results from the previous studies should be extrapolated to a general situation with extra care due to the sample selection bias (Heckman (1979)). Since *Human in Love* had a list of about 4,000 previous donors who stopped donating for unidentified reasons, we could have used the list to call their attention to the solicitation. I and the charity decided not to use the list, because even if we observed some noticeable differences in responses with the coin attachment, we still cannot interpret that the coin works as a philanthropy initiative; rather, it may work as a (maybe negative) signaling device to the former donors who might believe that some part of their donation[20] was used to reinstate a relationship with them.

[19] Some charities share their database with other networked charities, so people may receive a solicitation letter from somewhere to which they had never donated. However, in the beginning they were on the list because they had contributed to at least one charity at least once.

[20] Since the entire project expenses were covered by research grants, the revenue of the charity was not used for sending the solicitation letters. However, we did not disclose it in the solic-

The selected sample of Chen et al. (2006) is the closest to a random sample of the population, and therefore the study was relatively free from sample selection bias. They sent solicitation e-mails to those who visited the Internet Public Library (IPL) regardless of whether they had contributed to the IPL or not.[21] Their low response rate, 25 out of 153,183, if it is mainly due to random sampling, may suggest that the single donation of my study is also due to random sampling.

3.4.2 Holiday/Seasonal Effects

The period of data collection (late February–April) was used to control for other seasonal and holiday effects, as during that period few people are thinking about charitable giving. In the United States, online giving was particularly strong during the holidays in 2013; the proportion of total 2013 online giving was highest in December (18.8%), and slightly more than 35% of online giving occurred in the months of October, November, and December 2013 (Giving USA 2014 (2014)). With an assumption that the monthly giving trend in Korea is similar to that in the US,[22] the solicitation letters might have brought less attention. Results from the previous studies that conducted experiments by sending direct mail confirm this claim. The response rates of experiments conducted in December varied from 5.60% (Eckel et al. (2014)) to 15.53% (Falk (2007)), while those in the other months varied from 2.07% (Karlan and List (2007)) to 4.57% (Rondeau and List (2008)).

itation letter, so people might have believed that the charity spent some of their revenue for marketing.

[21]Still we cannot say their sample is random in a strict sense, since their contribution will eventually help to improve the IPL they have already visited and relied upon and thus it naturally features a voluntary provision of public goods.

[22]Statistics of monthly giving in Korea is unavailable.

However, since one of the main purposes of this project was to discern the overshooting incentives to compensate for a sense of involuntary indebtedness with the response to the positive mood, it was important to avoid holiday seasons in which people may in general have a positive mood. If I were to conduct the same experiment in December and find some significant differences in donation rates, still we would not have been able to answer whether the coin attachment worked as I hypothesized, or it amplified or dampened the positive mood.

3.4.3 Brand Effects

UNICEF Korea, an internationally recognizable charity which extensively used direct mail, reported that the response rate to their solicitation letters had been about 1% but had dropped to 0.5% in recent years.[23] Therefore, I am not sure whether the responses to the solicitation letters of UNICEF Korea were caused by the appeal of the letter or by the brand name. I believe the latter explains the responses to a larger extent. *Human in Love*, on the contrary, does not have such a reputation. Even though they have a reasonably long history, the name of the charity does not have significant value as a brand because they changed the name from *The World Disaster Relief Organization* in 2011 when they changed the mission of the charity from the ad-hoc relief of people suffering from natural disasters to the support of building infrastructure for human capital.

If direct mail in general is regarded to be an effective tool to send a

[23] "Fundraising by Direct Mail - Application in Korea", lecture note prepared by Doum&Nanum Inc. (in Korean) www.doumnet.net Access: April 17, 2015

costly signal, compared to e-mails, saying that the services or the products the firms/organizations provide are reliable,[24] the recipients' recognition of the brand may endogenously determine the response rates. If the direct mail is delivered to the recipients for multiple periods, we may think of the possibility of using direct mail for building brand values (Bawa and Shoemaker (1987)), but it was neither in the scope of the study nor one of our main concerns.

3.4.4 Too Old School for Koreans?

I believed that the donations from the direct mailing in South Korea could allow me to interpret the effect of each treatment in a clearer manner because the recipients had not formed any prior belief about the types of solicitation letters, but I overlooked that people may not be familiar with direct mail itself.[25] Direct mail could have been regarded as a more credible source of getting better quality products in some countries where direct mail has been used for a longer period. Direct mail has been less popular in South Korea, not because the postal service is underdeveloped, but because the time that firms and charities relied heavily on the postal service for solicitation were extremely short due to the rapid growth from the economy after the war in the 1960s. In general, until the 1970s there was nothing to solicit using direct mail, and in the late 1990s the Internet quickly occupied the realm of the postal service. It is reasonable to expect that fewer people in the world would care for direct mailing as

[24]Electronic mail, on the other hand, may not work as a costly signal in a similar manner to direct mail because the marginal cost of sending e-mail is practically zero. As a consequence, the response rate of electronic solicitation is in general lower than that of direct mail. In 2012 the average response rate for direct mail was 4.4% for both business-to-business and business-to-consumer mailings, while electronic mail's response rate was just 0.12% (Response Rate 2012 Report (2012)).

[25]Postal Industry Trend, Vol. 4. August, 2009. (in Korean)

more tasks can be handled electronically. I claim that this tendency is stronger in South Korea than in the United States. South Korea is known to be one of the more IT advanced countries. By Internet connection speed, South Korea ranked first, with an overwhelming difference with the second ranked country, Hong Kong,[26] ranked first by 4G LTE subscriptions by percentage of country population,[27] and ranked second in terms of Smartphone penetration[28] (Table 3.5). The wide usage of the Internet does not directly mean that Koreans are less concerned about actual mail, but I believe this could be the part of reason for few donors responding to solicitation mail.

3.4.5 Immature Giving Culture

The low response rate to the solicitation letter may be because South Korea is immature in charitable giving. South Korea in the 1960s was a country supported by other countries, and it became a supporting one around the late 1990s. Korea's wealth level is getting closer to other developed countries, but the amount of charitable giving is still less than that of those countries.

In the United States, charitable giving from individuals totaled $242.60 billion, and the total giving as a percentage of GDP was 2.0% in 2013 (Giving USA 2014 (2014)). In the United Kingdom it was 0.61% in 2014.[29] Koreans donate less than people in other developed countries. Koreans, on average, donated 0.56% of GDP in 2013 (Giving Korea 2014 (2014)). In terms of participation rates,

[26] "The Akamai State of the Internet Report". akamai.com. Access: April 7, 2015.

[27] "Countries With the Most 4G Mobile Users: Top 10 Nations - Bloomberg". bloomberg.com. Access: April 3, 2015.

[28] "The 15 Countries With the Highest Smartphone Penetration". mashable.com. Access: April 3, 2015.

[29] The estimated total giving amount is £10.6 billion (UK Giving 2014 (2015)), and the GDP of the UK in 2014 was £1,732.9 billion.(Office for National Statistics)

Table 3.5: The Ranks of the IT-related Measures

Rank	Internet Speed Country (Mbps)	4G subscriptions Country (penetration)	Smartphone usage Country (penetration)
1	**South Korea** (25.3)	**South Korea** (62.0%)	UAE (73.8%)
2	Hong Kong (16.3)	Japan (21.3%)	**South Korea** (73.0%)
3	Japan (15.0)	Australia (21.1%)	Saudi Arabia (72.8%)
4	Switzerland (14.5)	**United States** (19.0%)	Singapore (71.7%)
⋮	⋮	⋮	⋮
11	**United States** (11.5)	⋮	⋮
⋮	⋮	⋮	⋮
13	⋮	⋮	**United States** (56.4%)

Internet speed: measured by the average data download speed. Source: Akamai Technologies.
4G LTE penetration: The percentage of the population subscribing the 4G LTE. Source: Bloomberg.com
Smartphone penetration: The percentage of the population using a smartphone. Source: Mashable.com

fewer Korean households donate. About eight out of ten UK citizens (79%) participated in at least one charitable giving or social action activity in 2014, while 48.5% of Koreans donated in 2013. The proportion of US households who ever donated varies by estimation method and time from 67% (List (2011)) to 89% (Sullivan (2002)). In terms of overall donation activities, South Korea ranked 60th among 135 countries, while the US and the UK ranked first and seventh, respectively. (World Giving Index (2014))

3.4.6 Loss of Personal Identification in Recent Years

Loss of personal identification has been a serious issue in South Korea since 2006, and it peaked in 2014. The personal data of at least 20 million bank and credit card users was in January 2014.[30] Information breaches have arisen across almost all online-based platforms, such as online portal services,[31] telecommunication companies,[32] cosmetic companies and online education providers, so the ID numbers and personal details of an estimated 80% of the country's 50 million people had been stolen from banks and other targets by October 2014.[33] Even in the course of legalizing a new ID system to deal with the accumulated information breaches, 750,000 fake Internet Personal Identification Numbers (I-PINs), government-backed encrypted IDs for Internet transactions, were illegally produced from February 28 to March 2, 2015.[34] Since the letters were sent on February 24, most recipients would have received the letter around the time when news media reported that the I-PINs were hacked. This coincidence may make potential donors reluctant to provide their private information during donation.

Though I believe that the ideas I discussed above are reasonable claims, I

[30]"Huge South Korean Data Leak Affects Almost Half The Country" Business Insider. January 19, 2014. http://www.businessinsider.com/south-korea-data-leak-2014-1. Access: April 25, 2015.

[31]Kim, Young-won. "Stolen data used in attack on Naver" The Korea Herald. March 26, 2014. http://www.koreaherald.com/view.php?ud=20140326001543 Access: April 26, 2015.

[32]Yoon, Lina and Paul Armstrong. "Hackers steal data for 12 million customers at South Korean phone giant" CNN. March 6, 2014. http://edition.cnn.com/2014/03/06/business/south-korea-telecoms-hackers/ Access: April 26, 2015.

[33]"South Korean ID system to be rebuilt from scratch" BBC Technology. October 14, 2014. http://www.bbc.com/news/technology-29617196. Access: April 25, 2015.

[34]Lee, Kyung-min. "I-PIN identification system hacked" The Korea Times. March 5, 2015. http://www.koreatimes.co.kr/www/news/nation/2015/03/116_174690.html Access: April 25, 2015.

acknowledge that those remain as untestable ones because we do not have any counterfactuals to test them.

3.5 Conclusions

The results reported in the previous studies may have been exposed to sample selection bias: The response rates when sending direct mail to those who had donated to the fundraising organization at least once are significantly greater than those when sending direct mail to a random sample. From the perspective of the fundraising organizations, the results from the selected sample could be more attractive and relevant. However, I still believe that the sample should be, whenever possible, selected from a more general population because the ultimate goal of conducting this type of natural field experiment is to better understand the social preferences of the general public. In retrospect, it turned out that random sampling from the entire population is risky because it does not guarantee responses, to some degree. One who plans to conduct a similar field experiment may want to look for the internal validity of the research project, rather than the external validity.

In this study, I did not find any significant evidence that the coin attachment could bring more responses. The key aspects of this experiment were to make people feel involuntarily indebted while neither making them happier nor urging them to make certain active choices. The natural field experiment was a primary data generation methodology because observations from controlled laboratory experiments or existing data cannot be generated under the proper situation satisfying all of the aspects described above. Since the results did not answer the question about which of either the overshooting response to the feeling of involuntary indebtedness or the response to the happier mood produced by an unexpected favor from others is a main driving force to make people behave pro-socially, one may look for a possibility of continuing this research project with another sample set.

Still there are at least two contributions of this study. First, it confirms the coin strategy appeals to mail recipients' inequity aversion. A significantly larger proportion of those who received a letter with 100 won returned the letter than that of those without any attachment. Some recipients who received 100 won were reluctant to keep 100 won, because keeping the coin marginally exacerbates the inequity between the potentially benefited person and the mail recipient, but at the same time it does not increase their utility from the negligible monetary payoff. Since such reluctance decreases when the monetary payoff increased fivefold, this methodology may provide a clearer idea of measuring inequity aversion in general situations. In this particular context, I could claim that the disutility from the recognition that they may exacerbate the inequity is greater than keeping 100 won, but smaller than keeping 500 won. Second, with considering the project expenses of more than $10,000, charities would have been better off by examining other cost-effective solicitation strategies. If this inefficiency of direct marketing could be applied to a large body of start-up charities which do not have a list of potential donors, it may call our attention about the choice between the private provision and the public provision of public goods. On top of the project expenses, many returned letters raised some social costs that were defrayed by the Korea Postal Service. It would be interesting if further studies can provide evidence about whether the private provision of public goods works well in charitable giving, even after taking the overhead expenses into account.

This project was conducted in South Korea, so we do not know if the surprisingly low donation rate might be mainly due to the unique attributes of Korea, or if it might be due to the random sampling. I initially believed that the data collection from South Korea would be relatively free from other possible interpretations because a number of endogeneity problems were cleared in the experimental design by itself. The project would have been less risky if it had been conducted in another developed country which has a well developed culture of giving.

Appendix A

Images of the solicitation letters are shown below. The solicitation letters are written in Korean, so some supplementary notes are provided.

Figure 3.5: The Solicitation Letter

휴먼인러브

귀하의 나눔은
빈곤의 고통을 겪고 있는 분들에게
한 줄기 희망이 됩니다.

편지를 읽어보시는 귀하께

안녕하십니까.

인류애를 바탕으로 국내, 외 빈곤취약계층을 지원하고 있는 비영리단체 '휴먼인러브'입니다.

과학 기술이 발달하면서 세상은 10년 전, 5년 전보다 풍요로워졌지만 역설적으로 서민들의 삶은 점점 더 어려워지고 있고, 빈곤취약계층에 해당하는 사람들의 수는 늘어나고 있습니다.

외부의 지원이 절실함에도 불구하고 복지 혜택의 사각지대에 있어서 아무런 지원을 받지 못하고 있는 저소득 가정, 자녀가 정신적 장애를 가지고 있어서 자녀와 잠시도 떨어질 수 없는 상황이라 경제활동을 할래야 할 수 없는 장애 아동 부모, 열악한 가정 형편 때문에 학원은커녕 학교 수업료조차 낼 수 없는 고등학생들은 바로 우리의 친척, 친구, 이웃의 이야기입니다. 또한, 최저개발국의 수많은 어린이와 청소년들은 공부를 하고 싶어도 교재가 없거나 학비를 납부할 수 있는 경제적 여력이 없어서 제대로 된 교육을 받지 못해 빈곤의 굴레를 벗어나지 못하고 있습니다.

열 사람이 밥 한 술씩을 보태어 한 사람이 먹을 분량을 만들 수 있다는 '십시일반'은 이 시대를 살아가는 우리에게 꼭 필요한 마음 씀씀이일 것입니다.

당신의 작은 나눔이 어떤 이에게는 세상을 살아가는 힘이 됩니다.

이제, 국내, 외 빈곤취약계층을 위해 나눔에 참여해주십시오.

거스름돈을 모아서, 밥 한 끼 혹은 용돈을 아껴서 보내주시는 작은 나눔은 빈곤으로 고통 받고 있는 주위의 이웃들에게 세상을 살아가는 큰 힘이 됩니다.

휴먼인러브 이사장 김 영 후 드림

당신의 나눔은 이렇게 전해집니다.

국내 저소득가정 청소년 지원

경제적인 이유로 학비를 미납하는 고등학생들에게 학비를 지원하여 안정적으로 학업을 지속할 수 있도록 돕는 한편, 학습멘토링과 진로멘토링을 제공하여 학생들이 현실의 어려움으로 인해 좌절하지 않고 자신의 꿈을 마음껏 펼칠 수 있도록 돕습니다.

국내 저소득가정 장애아동 지원

정신적 장애 아동을 키우고 있는 한부모 가정, 부모도 장애가 있는 경우, 중증 장애로 인해 치료비가 많이 드는 경우 등 휴먼인러브는 정신지체 특수학교로부터 빈곤취약계층 가정을 추천받아 방문실사 후 형편을 고려하여 매월 소정의 보조금을 지원함으로써 해당 가정의 생활안정을 돕고 있습니다.

아프리카 르완다, 부룬디, 우간다
빈곤가정 청소년 교육 지원

UN에서 발표한 최저개발국의 고아와 내전 피해자 등 빈곤취약계층 청소년들이 학업을 지속할 수 있도록 지원합니다.

빈곤국가 아동 도서 지원

창작동화, 전래동화, 위인전 등.. 어린이들은 책을 보며 자연스럽게 언어와 사고하는 법을 배우고 인성과 꿈을 키웁니다. 하지만 최저개발국의 어린이들은 열악한 환경으로 인해 책이 몹시 부족한 실정입니다.

후원금으로 할 수 있는 일들

5,000원 빈곤국가 어린이의 동화책 1권

10,000원 아프리카 르완다 학생 학용품 1셋트

30,000원 아프리카 부룬디 학생 교복 1벌

월 30,000원 아프리카 청소년 1명의 학비, 교보재, 방학교실

월 150,000원 국내 저소득가정 청소년 1명 학비

휴먼인러브 일시후원 계좌
• 국민은행 206037-04-004378
• 하나은행 583-910007-81904

휴먼인러브

휴먼인러브는 인류애를 바탕으로 재난과 빈곤이 극복되고 인간의 존엄성이 존중되며 지속가능하게 발전하는 세상을 만들어가기 위해 설립된 국제구호개발 NGO입니다.

www.hil.or.kr 02-6080-8654 enquiry@hil.or.kr

(Left: Front page) On the top of the front page, it shows images of coins to emphasize that the amount of the coins may not be of worth to the readers but could significantly matter to those in need. (Right: back page) It shows how the charity used the funds raised by individual donations, with relevant photos.

Appendix B (Not for publication)

The purpose of Appendix B is to log every procedure I have gone through in a detailed manner. I hope that this detailed description could work as a potential reference for field experiments with a similar methodology.

B.1. Timeline

From the proposal stage (August 2013) to the data collection (April 2015), it took about two years. The log of the actual timeline may help to identify where there were some unexpected delays and how one could have minimized

Figure 3.6: The Application Form

(Left: Inside) The form also provided information on how to donate online or by phone. (Right: Outside) The form by itself works as a self-sealing return envelope. Since a postage stamp is not required, one who wants to donate can simply fill out the form, fold it, and put it into the mailbox.

Figure 3.7: Four Types of Letters: No Visible Differences

Clockwise from top left: Letters with 100 won, with 500 won, without an attachment and with the medallion

Figure 3.8: Four Types of Letters: What's Inside

Clockwise from top left: Letters with 100 won, with 500 won, without an attachment and with the medallion. (Images duplicated by the author.)

them. Per each item, I also recorded the actual time spent, excluding preparation periods.

- Approval of the Internal Review Board Exemption: 5 days

  - Application on October 21, 2013. Approved on October 26, 2013.

  - Note: Since I didn't intend to collect personal identification information, I requested the IRB Exemption. The process time varies by institution, but it is known that the full review takes much more time than the approval of an exemption.

- Research grant (1): 305 days

  - Grant proposal submitted on October 23, 2013 under the auspices of Cornell University. Awarded on March 10, 2014. Funds available on August 14, 2014.

- Note: Funds were not immediately available at the time they were awarded. Legal issues between the University and the funding institution needed be cleared. One who plans to receive external funds may expect this delay.

- Research grant (2): 35 days

  - Grant proposal submitted on August 21, 2014 as a single researcher. Awarded on September 25, 2014. Funds available on September 25, 2014.

  - Note: For some small external grants which directly fund the research projects of single researchers (not through the university or the associated organization), the funds can be available immediately.

- Research grant (3): 28 days

  - Grant proposal submitted on February 3, 2015 under the auspices of Cornell University. Awarded on February 26, 2015. Funds available on March 3, 2015.

- Purchase Order (Medallions): 70 days

  - Received a quote on October 1, 2014. The sample design of the medallion was approved by the charity on November 3, 2014. Received an invoice on November 4, 2014. Product delivered on December 10, 2014.

- Purchase Order (Production of letters and envelopes): 37 days

  - Received a quote on October 13, 2014. Received a completed Form 8-BEN-E and an invoice on October 20, 2013. Payment completed on November 19, 2014

  - Note: If the products or the services can be provided by other suppliers preferred by the University Procurement Services, all the quotes from the supplier and the preferred suppliers should be provided to prove that there is a particular reason for choosing a supplier not on the list.

- Purchase Order (Postage stamps): 51 days

  -Received a quote and completed Form 8-BEN-E on February 15, 2015. Received an invoice on March 25. Payment completed on April 7, 2015.

  - Note: Purchasing postage stamps and sending mail can take less than an hour, but the whole purchase order process took two months.

B.2. Practical Challenges

B.2.1. Finding a cooperating charity

For almost a year I struggled to find a cooperating charity. I offered to conduct a solicitation project with no costs charged to the charity hoping that they share their response rates and returns with respect to the project. By the time I wrote the research proposal, I contacted two charities which currently adopt the coin strategy and made substantial progress with them. They turned down my offer ultimately. I then expended my scope of contacts to renowned US-based charities which do not use the coin strategy, but it turned out to be a futile struggle. For those which already use the coin strategy, my proposal was not attractive enough to share their internal information. For those which do not use the coin strategy, though recognize that there are some charities doing so, my proposal was not strong enough to change their decisions which had already been made internally. After that, I contacted Korea-based charities which do neither use nor recognize the coin strategy. Many charities turned down my proposal because some conservative charities did not want to try new solicitation strategies which have not proven to work. One charity turned down my proposal because they believed it may bring a negative reputation to the charity if those being solicited believe that they use the revenue, which mostly comes from donations, for marketing expenses instead of project expenses.

B.2.2. Prohibition of sending money by regular mail

In the United States, it is not illegal to send money by regular mail,[35] though it is not recommended. Therefore it is possible to make the coin attachment visible from the outside using the envelope with an additional window. (See Figure 3.2.) Most countries, including South Korea, prohibit sending money according to the final protocols of the Uni (2013).[36] It is therefore not allowed to make the coin attachment visible, though the whole purpose of the coin attachment is to appeal to the potential donors, not to deliver money. However, if the coin or medal attachment on a letter is invisible from the outside, there is no way for the post office to refuse to send it. Though there is no regulation regarding attaching a medallion with no real value, the Korean Post Office allowed the charity to make the medal attachment visible, but I and the charity decided not to make the medallion visible because it creates a different condition that may hamper interpreting the effect of the coin attachment properly.

[35] "Sending cash through the U.S. mail is illegal. False" snopes.com. http://snopes.com/legal/postal/sendcash.asp Access: May 1, 2015

[36] Section H. Article 18. Items not admitted. Prohibitions. 6.1 "It shall be prohibited to insert coins, bank notes, currency notes or securities of any kind payable to bearer, travelers' checks, platinum, gold or silver, whether manufactured or not, precious stones, jewels or other valuable articles;"

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