ABSTRACT

Title of Thesis:	USING TONTINES TO FINANCE PUBLIC GOODS: EXPERIMENTAL EVIDENCE
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Relying upon voluntary contributions for public goods provision generally results in the under-provision of the good relative to first-best levels due to the free-rider problem. Taxation/allocation schemes have been designed which solve the free-rider problem, but are too complex to implement. Lotteries and auctions are frequently used to fund public goods, as they diminish the incentive to free-ride. This thesis examines the use of a tontine to finance public goods. I will demonstrate that the tontine, a life-contingent annuity with survivorship benefits, maintains many of the properties of the single fixed-prize lottery. Additionally, I propose that the tontine outperforms the single fixed-prize lottery with symmetric, risk averse agents via some analogue of the Rothschild/Stiglitz effect. Laboratory experiments lend support to both of these conjectures. The results suggest that the tontine can be a more effective mechanism than the single fixed-prize lottery for increasing public goods provisions above voluntary levels.

USING TONTINES TO FINANCE PUBLIC GOODS: EXPERIMENTAL EVIDENCE

by

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I. Introduction

It is well established in the literature that relying on voluntary contributions for the provision of a public good generally results in the under-provision of the public good relative to first-best levels. Known as the free-rider problem, the under-provision stems from individuals' failure to internalize the social benefits of the public good. A number of mechanisms have been suggested to alleviate the free-rider problem. Early mechanisms by Groves and Ledyard (1971) and Walker (1981) rely upon government taxation-allocation schemes to generate first-best allocations of the public good. These schemes are subject to criticism as they rely on a strong central government, the decision rules are complex, and the equilibrium conditions rely on restrictive assumptions. In laboratory examinations, Chen and Tang (1998) found that taxation-allocation schemes generally fail to generate first-best allocations of the public good, except in situations where there is high punishment. Falkinger, et al. (2000) proposed a relatively simple mechanism for financing public goods. The mechanism relies on a subsidy-penalty scheme in which bids above the average contribution receive a subsidy and bids below the average contribution are penalized. In laboratory experiments, this mechanism has performed quite well. This method cannot be enforced without a central government, however, and thus is not applicable to many situations.

More recently, there have been a number of studies that examine the use of lotteries and/or charitable auctions as a means to finance a public good. For example, Engers and McManus (2002) extend the work of Andreoni (1990) by examining bidder behavior in a charity auction. Andreoni found that those who contribute to public goods receive a "warm glow" type feeling from their own contributions. Engers and

McManus find that a "warm glow" can increase auction revenue as well. The charity auction differs from voluntary contribution mechanisms for providing public goods in that bidders have a private gain from winning (and thus participating in) the auction. In addition, the authors show that the "all-pay" auction generates the greatest revenue as the number of participants in the auction tends towards infinity.

Morgan (2000) proposes the use of a single fixed-prize lottery to obtain higher levels of public good provision. The lottery introduces a compensating externality to ease the free-rider problem, thus increasing equilibrium contributions. In the case of voluntary contributions, positive externalities from the public good are not considered. That is, individuals only consider their personal benefits from the public good, and not the total benefits to society. Thus, their contributions are below the social optimum. The lottery introduces a negative externality to compensate for the positive externality, thus reducing the gap between private and social marginal benefit of contributions. The negative externality occurs as an increase in the number of lottery tickets purchased by one individual decreases all others' chance of winning the fixed prize. Thus, individuals buy more tickets to increase their chance of winning the prize, which results in an increase in contributions to the public good. Experimental work by Morgan and Sefton (2000) lends support to Morgan's theory: relative to the standard voluntary contribution mechanisms, lotteries increase the provision of the public good, are welfare improving, and provide levels of the public good close to first-best as the size of the lottery prize increases.

Morgan's work has been criticized because the lottery does not ensure an efficient allocation of the prize when individuals' valuations are asymmetric (Engers and

McManus 2002; Goeree and Turner 2002). The individual who purchases the most tickets, and thus has the highest expected value, is not guaranteed to win the prize. Thus, individual investments are suppressed and revenues remain finite even as the value of the prize tends towards infinity. Goeree and Turner address this concern by using a $(k+1)^{th}$-price all-pay auction to raise funds for a public good. The authors demonstrate that winner-pay auctions are suboptimal fund-raising mechanisms due to the positive externality bidders forgo when they outbid other bidders. In all-pay auction formats, the incentive to lower bids is eliminated, resulting in a higher contribution level. The authors find that revenue in an all-pay auction is increasing in the marginal return from the public good but decreasing in the number of bidders participating. As the number of participants increases, there is no externality in placing a low bid, because those bids do not factor into the price the winner pays. Thus the low value bids start resembling voluntary contributions. Low-value bidders may suppress their bids in order to "free-ride" on the contributions of the high-value bidders. Hence, contributions to the public good could actually decrease with large number of bidders in the $(k+1)^{th}$-price all-pay auction.

In this thesis, I propose an alternative mechanism for public goods provision: the tontine. The tontine, which was used in France and England in the 17^{th} and 18^{th} centuries, is a life contingent annuity with survivorship benefits. While there are various types of tontines, the general spirit is as follows: (i) Individuals contribute to a fund and split a fixed annual payout that is divided amongst participants according to a predetermined sharing rule; (ii) When a cohort dies, his share is split among the remaining group members according to the share rule.

Assuming financial market equilibrium, a tontine is outcome equivalent to a fixed-prize lottery over a distribution of prizes. In the symmetric, risk-neutral case, therefore, the general intuition from Morgan for the single fixed-prize lottery necessarily holds for the tontine. The introduction of a compensating lottery linked to provision of the public good will generate outcomes that approach the first-best as the value of the prizes increase. Theoretically, symmetric risk-neutral agents should contribute more under the single fixed-prize lottery than they would under an equivalent value multiple prize lottery. However, these differences disappear in the limit as the value of the first prize in the tontine approaches infinity and/or as the difference between the first and lower order prizes increases.

Yet there are a number of theoretical reasons why this rank-order need not hold in all instances. First, the tontine has a lower variance in expected final wealth, thus there could be differences in contribution levels related to risk preferences, similar to what occurs in the Rothschild/Stiglitz effect. Second, the tontine could induce participation from low-valuation agents that would not participate in the Morgan single fixed-prize lottery or the Goeree and Turner $(k+1)^{th}$-price all pay auction. Individuals that would typically place zero probability on winning the single fixed-prize or auctioned item, may place some positive probability on winning one of the smaller prizes and thus participate. Instead of making what would be considered a voluntary contribution, the individuals are contributing to win a prize of real expected economic value.

In this thesis, I will provide a conceptual model of contributions to a public good under a tontine. In modeling the tontine, I will rely upon an assumption of financial market equilibrium. This assumption permits the modeling of the tontine as a lottery over a distribution of prizes. This result is illustrated with a simple thought experiment and permits direct comparison between the tontine, an equivalent valued single fixed-prize lottery, and a voluntary contribution mechanism. I will demonstrate that in the case of symmetric, risk-neutral agents the tontine maintains many of the theoretical properties set forth in Morgan (2000) for the single fixed-prize lottery. In particular, contributions to the public good increase in the value of the prizes and will always dominate those generated under a voluntary contributions game.

Experiments are run to compare the outcomes of the voluntary contribution mechanism (VCM), the single fixed-prize lottery (FPL) and the tontine. Empirical results suggest that contribution levels for the VCM average 40% of endowments, consistent with previous efforts (Morgan and Sefton 2000, Andreoni 1995, List 2003). Subjects contribute, on average, 53.5% of endowments in the FPL, and 56.8% of endowments in the tontine treatment. After accounting for provision of the prize, contributions in the FPL and Tontine treatments result in an increase in the public good provision relative to the VCM.

The data suggest that there is no statistically significant difference between mean contribution levels in the FPL and Tontine. Given that the risk postures of experimental participants vary, this result is to be expected. Somewhat surprising, however, is that I find no significant difference between the Tontine treatment and FPL treatment for risk neutral agents as theory would predict. To a large degree this may be explained by the fact that in equilibrium contribution levels are only predicted to be a small percentage higher in the later treatment. However, consistent with my initial intuition, risk averse subjects in the Tontine treatment contributed 55.0% of their endowment which is greater than the average contribution of 48.5% for risk averse subjects in the FPL treatment.

The remainder of this thesis is set up as follows. Chapter II provides a history of the tontine as used in France and England. Tontine theory is derived in Chapter III. Chapter IV describes the experiment design. The results are discussed in Chapter VI. Chapter VII concludes.

II. History of the Tontine

The idea of the tontine is believed to have originated in 1652, when an expatriate banker, Lorenzo Tonti, proposed a new mechanism for raising public funds to the Cardinal Mazarin of France. He proposed a form of a life contingent annuity with survivorship benefits. Under Tonti's plan, subscribers would each pay a one-time lump-sum payment of 300 livres to the government. The subscribers would be grouped into ten age classes of seven years each. Each year, the government would make a payment to each group equaling five percent of the total capital contributed by each respective group. The payment would be distributed among the surviving subscribers based on individual shares of the group's total contribution. The government's obligation would end at the death of the last survivor of the class. Additionally, 1250 livres would be paid to one member of each class to handle payments and verifications of survivorship. The Parlement of Paris rejected Tonti's plan for two reasons: (i) it was difficult to calculate the actual costs to the government, and (ii) the initial interest rate was too low in comparison with rates on life annuities (Weir, 1989).

Tontines were used in France and Britain from 1689 to 1789 to finance wars and several other municipal projects.[1] Throughout the hundred years of tontine use, France had ten separate national tontine offerings, while Britain had just five. The tontine plans evolved throughout the period, and differed greatly between the two countries, leading to various levels of success. France and Britain's tontine policies reflected their different approaches to public finance: market orientation in Britain, and market avoidance and political coalition-building in France.

[1] This summary of the history of the tontine is based primarily on the work of David Weir (1989).

The tontine is structured such that there are three roles, which may or may not be played by the same person, plus the government. The subscriber is the person providing the initial capital, the person entitled to receive the annual income is the shareholder, and the person on whose life the contract is contingent is the nominee. Most often, the same person holds all three roles. Also common is the situation when an adult (parent) acts as the subscriber and shareholder with the nominee being a child. Often the shareholder rights would pass on to the nominee (the child) on the death of the subscriber.

In addition, all French tontines shared two important features. To appeal to those distrustful of the royal administration, there was a definite separation of the tontines' administration from the royal treasury and a guarantee that the payments would not be violated by even the most extreme royal necessities. Additionally, they used a complicated set of mechanisms to verify the age of the nominee on whose life the revenues depended and the dates of their ensuing deaths. To receive their annual payments, subscribers were required to show proof of survival by means of an annual notarized stamp. There were penalties for fraudulent receipt of payment, and heirs were allowed to collect payments for the year in which the nominee died if the death was reported in a timely manner. Subscribers were responsible for upholding the verification system, as they had more to lose from fraudulent claims than the government. The government made the same annual payment regardless of how many survivors remained, whereas the subscribers' payments were dependent on the number of remaining living members in the group.

The first national tontine was offered in France in 1689. The scheme was similar to Tonti's original proposal. French tontine offerings coincided with the peaks in resource demand during times of war. Tontines were generally successful in raising the capital sought by the government. During France's four major wars of the time period: the War of the Grand Alliance, the War of the Polish Succession, the War of the Austrian Succession, and the Seven Years' War, tontines were used to raise approximately $110 million livres from about 110,000 individuals.

Contrary to France's success, English tontines often failed to raise the desired capital. England's first tontine in 1693 raised barely a tenth of the million pounds the government had set as its goal. During the Seven Years' War when France raised almost 47 million livres to finance its military campaign, England was forced to cancel a proposed tontine for lack of support. The differences in success rates for the French and English tontines may be attributed to several factors regarding consumer preferences and government behavior.

While they were not the main reason for the different success rates, consumer preferences did play a role in the popularity of tontines, a role that France failed to take advantage of. Tontines differ from life contingent annuities in that income rises rapidly at older ages when mortality is high, whereas life annuity income is constant. From the shareholder's point of view, tontine income depended on two factors that are unique to tontines: the life expectancy of other subscribers and the percentage of shares one holds. If other subscribers have a higher life expectancy than a potential contributor, then that individual's probability of survival will fall at a faster rate than his income will rise. If no other group members die, the tontine becomes a life annuity. For those with high life expectancies, tontines become more attractive as they can use the income to supplement their retirement.

During the time that tontines were used, the French had a greater preference for old age security over intergenerational transfers. In France, children were already taken care of through partible inheritance. England, on the other hand, was much more concerned with providing for future generations, so life contingent investment plans such as the tontine did not appeal to the English as much as it did the French. This difference can be seen in the average age of the nominees across the two countries. In France, the majority of nominees were adults. In England, most of the nominees were children. The English preferred to purchase tontines on their children's heads.

While the differences in consumer preferences help explain why tontines were more popular in France, one may argue that the more likely reason for the difference in success rates was economic (Weir 1989). France offered tontines at much more attractive rates than England. For example, all the French tontines were split into separate age classes and offered above market rates of return. England's first tontine did not separate age classes, so that the younger subscribers received a much higher rate of return than the older ones. After the first tontine offering failed, England began to use separate age classes and learned to calculate the cost of the tontine more accurately. While the expected returns were high, the English tontines still did not have the same success level as the French. Part of the reason could be attributed to the English's desire to provide for the future generations as discussed above. However, the most likely reason is that England always offered their tontines with an alternative plan, usually an annuity with a higher rate of return. Thus the basic difference in success levels of French and English tontines boils down to simple economics. The French tontines offered a considerable premium over alternatives, especially for older investors. In contrast, the English tontines were barely fair even to the youngest nominees.

Despite the success in raising capital, France failed to consider the high long run costs of the tontines. The tontines were offered at above market rates, so the costs to the government ran very high. It is not clear if there was a system to tontine pricing. Tontine prices were always based on mark ups of the price of life annuities. France was essentially offering subsidized loans to the shareholders. These were very popular among the middle class, as the government strongly emphasized the stability of the tontine.

The stability was short-lived, however. In 1763, a royal edict banned any future tontines in France. In 1770, as part of a general reform of French finances, all tontines were frozen at 1769 levels and converted to life annuities. If France had paid more attention to the preferences of the population, there may not have been a need to cancel the tontines. Had the government taken advantage of the citizens' desire for old-age security, they could have offered tontines at market rates of return. It is possible that the government would have had similar success in raising funds, but at a lower long run cost.

The idea of the tontine also made it across the Atlantic to the newly formed United States. In an effort to reduce the principal on the national debt, Alexander Hamilton proposed a tontine in his 1790 Report Relative to a Provision for the Support of Public Credit (Jennings, et al., 1988). Hamilton's goal was to reduce the principle on the national debt by converting old debt with principle repayable at the pleasure of the government into debt demanding no return of principle at all. Hamilton's idea was correct, but the tontine he proposed, modeled after William Pitt's 1789 tontine, was not well thought out. Hence, Congress rejected the idea.

Hamilton's tontine, inspired by the English tontine, was not well developed. Hamilton proposed a tontine consisting of six age classes. Each share would cost two hundred dollars with no limit on the number of shares available in each class. Individuals could subscribe on their own lives, or on those of others nominated by them. Following the proposal by Pitt, Hamilton proposed a freeze component. The annuities of those who die would be divided among the survivors until just twenty percent of survivors remain. At that point, the survivors' payments would be frozen at that level for the remainder of their payments (Dunbar, 1888). Hamilton's plan was unclear on some issues. He never specified if the principle reverts to the government. The freeze component that he borrows from Pitt's tontine demonstrates that he may not have understood present values. Savings in future years are not worth much. He would have been better off taking a portion of earnings in the early years. Other issues with the Hamilton proposal was that it was not clear if shares could only be purchased with old debt instruments or if they could be purchased by other means. In addition, the interest rates he proposed only had a 2.2% rate difference across age groups. It was not clear how he calculated the rates, but it appears he based them on Pitt's tontine rates (Jennings, et al. (1988)). While Hamilton had good intentions for trying to reduce the principle on the national debt, he would have been better off modeling his plan off the more successful French tontine than that of the less successful English tontine.

Although tontines were not used after the eighteenth century, an adaptation of the tontine was implemented in the United States life insurance market in 1868. Tontine insurance was introduced in 1868 by the Equitable Life Assurance Society of the United States (Ransom and Sutch, 1987). The insurance premiums served two distinct purposes, to provide standard life insurance and to create an investment fund. With tontine insurance, policyholders defer receipt of the dividends received in the standard level premium insurance. The deferred dividends are pooled and invested by the insurance company on behalf of the policyholders for a specified period, usually 20 years. At the end of the period, the fund plus the investment earnings are divided proportionally among the entire active, surviving policyholders. The payment can be received in cash or as a fully paid life annuity. Beneficiaries of policyholders who died before the end of the tontine period still receive the specified standard death benefits, but have no claim on the tontine fund money (Ransom and Sutch, 1987).

Tontine insurance had several advantages. Policyholders were able to secure life insurance plus create a retirement fund for old age. Survivors could receive a very generous rate of return if many of the policyholders in their group died or let their policies lapse. The tontine insurance helped young Americans save for retirement by providing an efficient, low risk, high yield investment available on an installment plan. Unfortunately, corruption in the insurance companies led to the prohibition of sales of tontine insurance in 1906. The New York State Legislature led the 1905 "Armstrong Investigation" into the insurance company corruption (Ransom and Sutch, 1987). The insurance companies had discretionary control of the funds and the industry leaders often misused them to enhance social status, political influence and personal wealth. Tontine insurance was a victim of this corruption, and despite its being a successful financial innovation, an actuarially sound insurance option, and a "fair bet" gamble, was ultimately prohibited (Ransom and Sutch, 1987).

III. Tontine Theory

Basic Model

Consider an economy with N = {1, 2,…, *n*} agents with quasi-linear utility functions of the form

$$U_i = y_i + f_i(G)$$

where y_i is a numeraire good that denotes the income of consumer *i*, and $G \in \Re_+$, denotes the level of the public good provided. Utility is assumed concave in the public good so that, $f'(.) > 0$ and $f''(.) < 0$ for all individuals *i*. The public good is generated by converting income into G on a one-for-one basis and consumers are assumed utility maximizers.

The social planner's problem is to select the level of income to be converted into the public good so as to maximize aggregate surplus in the economy. Formally, the planner selects $G \leq \sum_{i=1}^{n} y_i$ to maximize

$$Y = \sum_{i=1}^{n} (y_i + f_i(G)) - G$$

where Y is the wealth of the economy. At an interior solution, the optimal level of the public good, G* > 0 is given by the solution to

$$\sum_{i=1}^{n} f_i'(G^*) = 1 \qquad (1)$$

which is the Samuelson Criterion for welfare maximization. Note that, if

$$\sum_{i=1}^{n} f_i'(0) < 1$$

then it is not optimal to provide positive levels of the public good so G* = 0.

Voluntary Contributions

Consider a government agency or charity that relies upon voluntary contributions for public good provision. Let w_i denote the amount of wealth contributed by agent *i*, and let $w(S)$ denote the sum of contributions from some set $S \subseteq N$ of agents. Thus, $w(N)$ gives the total level of contributions to the public good in the economy. Given the actions of all other individuals, agent *i* selects $w_i \in [0, y_i]$ to maximize utility. Formally, the agent's problem is given by

$$\max_{w_i} U_i = y_i - w_i + f_i\big(w(N)\big)$$

A Nash equilibrium to the above game is given by an *n-tuple* $\left(w_1^{VC}, w_2^{VC}, \ldots, w_n^{VC}\right)$ of contribution levels. In equilibrium public goods provision is given by $G^{VC} = w^{VC}(N)$. In the voluntary contributions game with quasi-linear preferences, the following result characterizes equilibrium contributions (see Morgan (2000) for details):

Proposition 1. *With quasi-linear preferences, voluntary contributions under-provide the public good relative to first-best levels.*

In this game, agents fail to internalize the benefits conferred on all other agents when deciding how much to invest in the public good. Thus, each agent tends to contribute less to the public good than is socially optimal. In the extreme, each individual may contribute zero to the public good despite the fact that such actions are socially desirable.[2]

[2] For an example of this situation, see Morgan, pp. 767.

Tontines and Public Goods Provision

Little is known about the theoretical underpinnings and actual performance of tontines to efficiently provide public goods when participants purchase shares in a fund whose proceeds are awarded to the participants based on survivorship. As aforementioned, assuming equilibrium in financial markets, the tontine can be thought of as a fixed-prize lottery over a distribution of prizes (LDP) or an m-prize game. Consider a tontine with the following assumption: each agent has an independent and identically distributed random probability distribution over death. If this assumption holds then the rank order of *ex ante* contribution levels need not correspond to *ex post* rank order of payments received. In other words, the person who contributes the most may not necessarily receive the highest payoff. Additionally, the highest contributor has the greatest expected value of payments; i.e. the ranking of expected values corresponds directly to the rank of contributions. These same properties hold for a fixed-prize lottery over a distribution of prizes. Thus, the tontine is outcome equivalent to the fixed-prize lottery over a distribution of prizes.

To understand the link more clearly, consider the following situation. The person who draws last prize in the LDP is equivalent to the first person to die in the tontine. The relation stems from the fact that the expected payouts for the two are functions of both a random component and the contribution level. In the LDP, the person's probability of "winning" any lottery prize is dependent on the contribution level and a random ticket draw. Contributing the most (buying the most lottery tickets) does not guarantee that one of that person's tickets will be drawn. Similarly, the person's probability of earning a certain payout in the tontine is dependent upon the contribution level and a random draw of death. Buying the most shares in the tontine does not guarantee the person will earn the highest return because that person could be the first group member to die. To see this more clearly, consider the case when there are 2 asymmetric agents investing in a tontine with exogenously determined share prices and rates of return. Agent 1 buys two shares in the tontine, while Agent 2 buys just one. Suppose Agent 1 dies after the first period, then the payouts for the two agents are as follows:

Agent 1: P= 2/3 X + 0 = 2/3X

Agent 2: P= 1/3X +X = 4/3X

Even though Agent 1 purchased twice as many shares in the tontine, Agent 2 earns 2/3X more than Agent 1, simply by living longer. Thus, in both the LDP and the tontine, the *ex ante* expectation is dependent on the contribution level.

Formally, the tontine can be modeled as follows. Assume that there is a group of n-symmetric agents in an economy. Each player *i* can contribute to a public good by buying b_i tickets for a lottery which pays 2 prizes $R_1 \geq R_2$. The player's payoff is determined by $x_i - b_i + hB$ where $x_i \in \{R_1, R_2, 0\}$ denotes the payoff from the lottery, b_i is player's contribution to the public good, and $0 \leq h \leq 1$ denotes the agent's MPCR. Under this structure, agent 1's expected utility is given by:

$$EU_1 = y_1 - b_1 + \frac{b_1}{b(N)} R_1 + \left(\frac{b_2}{b(N)} * \frac{b_1}{b_1 + b_3} \right) R_2 + \left(\frac{b_3}{b(N)} * \frac{b_1}{b_1 + b_2} \right) R_2 + f\left(b(N) - R_1 - R_2\right)$$

where y_1 is agent 1's wealth, b_1 is agent 1's contribution, R_1 is first prize, R_2 is the second prize, $b(N)$ is the sum of each agents contribution to the public good, and

$\left(b(N)-R_1-R_2\right)$ is the amount of public good provided (G). The above expression shows that expected utility is equal to:

- initial wealth minus investment in the lottery,
- plus the probability of winning first prize times the value of first prize,
- plus the sum of the probabilities of winning second prize conditioned on each other agent having won first prize, times second prize,
- plus the utility derived from the public good.

In the case of symmetric agents, the probability of winning any given prize is given by 1/n.

To formally derive a solution to the agent's maximization problem, denote the probability of winning a given prize as:

$$\pi_{1i}=\frac{b_i}{\sum_j b_j}$$

$$\pi_{2i}=\sum_{d_1\neq i}\left[\frac{b_{d_1}}{\sum_j b_j}\frac{b_i}{\sum_{j\neq d_1} b_j}\right]=\frac{b_i}{\sum_j b_j}\sum_{d_1\neq i}\frac{b_{d_1}}{\sum_{j\neq d_1} b_j}$$

Hence, each player maximizes:

$$\pi_{1i}R_1+\pi_{2i}R_2-b_i+hB$$

The first order conditions defining an optimal level of contributions in this game are given:

$$\frac{B-b_i}{B^2}V_1+\left(\frac{B-b_i}{B^2}\sum_{d_1\neq i}\frac{b_{d_1}}{\sum_{j\neq d_1} b_j}-\frac{b_i}{B}\sum_{d_1\neq i}\frac{b_{d_1}}{(\sum_{j\neq d_1} b_j)^2}\right)V_2=1-h$$

Given our assumption of an economy comprised of n symmetric agents, in equilibrium we have that for all agents *i* and *j*, $b_i = b_j = \frac{1}{n}B$. Total contributions to the public good are thus given by:

$$B = \frac{1}{1-h}\frac{n-1}{n}\left(R_1 + R_2 - \frac{n}{(n-1)^2}R_2\right)$$

It should be noted that for any fixed sum of $R_1 + R_2$, total contributions are a decreasing function of the lower order prize value, R_2. Hence, for symmetric risk-neutral agents contributions are greater in a single rather than multi-prize lottery. However, since the compensating externality of the lottery persists in the multi-prize case, the following theorems/propositions from Morgan (2000) hold for the tontine.

- Theorem 1: When preferences are quasi-linear, the tontine provides more of the public good than the voluntary contributions mechanism.
- Theorem 2: When preferences are quasi-linear, for any given $\varepsilon>0$, there exists an economy of size $\sum_{i=1}^{n} b_i^*$ and a tontine with payment stream R such that the public goods provision induced by the tontine lies within ε of the first-best outcome.
- Theorem 3: When preferences are quasi-linear, the tontine provides positive amounts of the public good iff the good is socially desirable.
- Proposition 5: When the public goods allocation decision can be separated from the distribution decision, the tontine increases public goods provision over voluntary contributions. Moreover, as the prize grows large, public goods provision in the tontine converges to first-best from below.

There are several situations where differences in the single fixed-prize lottery and the tontine can occur. First, if the agents are not symmetric in valuations for the public good, there is the potential for differences in contributions across the two methods. Second, if there are asymmetric risk preferences, the equilibrium contributions could differ across the single fixed-prize lottery and tontine. A tontine that has the same expected wealth as a single fixed-prize lottery will have a lower variance in the expected wealth, thus there could be differences in contribution levels associated with individual risk preferences. These differences would be similar to the Rothschild/Stiglitz effect, but are not a direct analog due to the endogeneity of choice probabilities and the associated moments of the distribution over expected wealth. The Rothschild/Stiglitz effect tells us that with exogenous probabilities over lottery choice, risk averse people invest more in the tontine, or the choice with the lower variance. For example, if an individual had to choose between two lotteries, A or B, where the probabilities of winning either A or B are predetermined, the expected values are equal, and the variance of A is less than the variance of B, the individual would contribute more to A in accordance with the Rothschild/Stigliz effect.

When the probabilities are endogenous over lottery choice, it is no longer possible to make a direct comparison between lotteries, but intuitively it makes sense that a similar situation will occur as in the case of exogenous probabilities. Consider the situation where an individual must choose between two lotteries, A or B, where the probabilities of winning either A or B are not predetermined, the expected values are equal and the variance of A is less than the variance of B. Initially, the individual will contribute more to A, which is the direct effect, but as the contribution to A increases, the odds change and thus the expected value of lottery A changes, which is the indirect effect. Thus, the expected values of A and B are no longer comparable. That being said, intuition suggests that the direct effect should dominate the indirect effect, and thus the tontine should dominate the single fixed-prize lottery for all agents demonstrating a given level of risk aversion. The theory behind this intuition is still being worked out and goes beyond the scope of this paper. In this paper, the intuition will be tested empirically in the lab. The general procedure followed herein is to use multiple treatments to first elicit risk preferences, and then examine whether the risk preferences are associated with contribution levels predicted by theory. These tests will be conducted by eliciting risk preferences in one game and using those risk postures to test for different contribution levels for each risk category across the two mechanisms.

IV. Experimental Design

The experiment was conducted at the University of Maryland—College Park during the second Summer Session of 2003. The experiment consisted of three sessions held on separate days with different subjects. Each of the three sessions tested a different mechanism. Each session consisted of two parts, the first to test how contribution levels in the tontine compared to contribution levels in the single fixed-prize lottery and the voluntary contribution mechanism. The second part was included to test the theoretical prediction that risk averse individuals would contribute more to the tontine than to either of the other two mechanisms. Each part of the experiment will be described below.

Part 1:

The first part of the experiment was designed to compare contribution levels across the tontine, the single fixed-prize lottery, and the voluntary contribution mechanism. In the lab, the tontine was simulated by using a fixed-prize lottery over a distribution of prizes. The voluntary contribution mechanism treatment and the single fixed-prize lottery treatment followed the instructions from Morgan and Sefton (2000) to enable direct comparison. One treatment of each mechanism was run using University of Maryland students. Subjects were recruited on campus using posters and emails that advertised subjects could "earn extra cash by participating in an experiment in economic decision-making." The message stated that students would be paid in cash at the end of the session and that sessions generally take less than an hour and a half. The same protocol was used to ensure that each session was run identically.

Each session took place in the same computer lab using 24 different subjects. Each subject was seated at linked computer terminals that were used to transmit all decision and payoff information. The sessions each consisted of 17 rounds, the first two being practice. The subjects were instructed that the practice rounds would not affect earnings. Once the individuals were seated and logged into the terminals, a set of instructions and a record sheet were handed out. The subjects were asked to follow along as the instructions (included in Appendix A) were read aloud. After the instructions were read and the subjects' questions were answered the first practice round began.

At the beginning of each round subjects were randomly assigned to groups of four. The subjects were not aware of whom they were grouped with, but they did know that the groups changed every round. Each round the subjects were endowed with 10 tokens. Their task was simple: decide how many tokens to place in the group account and how many to keep in their private account. The decision was entered in the computer and also recorded on the record sheet. When all subjects had made their choice, the computer would inform them of the total number of tokens placed in their group account, the number of points from the group account and the private account, as well as any bonus points that were earned. The payoff for the round was determined by summing the points from the group account, points from the private account, and any bonus points received. Once each of the subjects had recorded all of this information on their record sheets, the next round would begin.

The points for each round were determined as follows. For all sessions, subjects received 100 points for each token placed in their private account. They were awarded 75 points for each token placed in the group account by themselves and the other members of their group. Additionally, each session had a different method for earning bonus points. In the voluntary contribution mechanism session, all subjects, regardless of their contributions to the group account, earned 600 bonus points. The 600 bonus points represent 8 tokens placed in the group accounts. The bonus was used to make the VCM treatment comparable to the FPL and Tontine treatments. In the theoretical model, the total donation to the public good equals the sum of the individual contributions minus the cost of the prize. In the experiment, instead of subtracting the cost of the prize from the group account in the FPL and Tontine treatments, the cost of the prize was added to the group account in the VCM, which allows for comparison of contributions across treatments. In the single fixed-prize lottery session, group members competed for a lottery prize of 800 points. Each subject's chance of winning the prize was based on his or her contribution to the group account compared to the aggregate number of tokens placed in the group account by all group members. For the tontine session, group members competed for three lottery prizes of values 500, 200, and 100 points. As in the single fixed-prize lottery session, subjects' chance of winning the first prize was based on his or her share of group contributions. The three prizes were awarded in order of value, and without replacement, meaning that in each round, 3 of the 4 group members would receive some bonus points.

At the end of the last round, one of the final 15 rounds was chosen at random as the one that would determine earnings. Subjects were paid 50 cents for every 100 points earned. They recorded their earnings for *Part 1* of the session and prepared for *Part 2*.

Part 2

The second part of the experiment was designed to determine subjects' risk preferences. In this part of the session, the low-payoff treatment of Holt and Laury (2002) was replicated (see Appendix A for instructions). In each of the three sessions this part was conducted in an identical manner. The treatment is based on ten choices between paired lotteries. The paired choices are included in the appendix. The payoff possibilities for Option A, $2.00 or $1.60, are much less variable than those for Option B, $3.85 or $0.10, which was considered the risky option. The odds of winning the higher payoff for each of the options increase with each decision. In the first decision, there is only a 1/10 chance of winning the higher payoff, so only the most risk-loving individuals should choose Option B. The expected payoff difference for choosing Option A is $1.17. As the probabilities of winning the higher payoff increase, individuals should cross over to Option B. The paired choices are designed such that a risk-neutral individual should choose Option A for the first four decisions and then switch to Option B for the remaining six decisions. The paired choices are also designed to determine degrees of risk aversion. A risk-averse individual should choose Option A six times before switching to Option B, while a highly risk averse individual should choose Option A 8 times before making the switch to Option B. In the last decision, the higher payoff is won with certainty; so all individuals should choose Option B regardless of risk preferences. Holt and Laury (p.1649) provide a table that will be used to categorize subjects' risk preference levels based on their ten decision choices.

Upon completion of Part 1 of the session, instructions and a decision sheet were handed out. After the directions were read and questions were answered, the subjects were asked to complete their decision sheets by choosing either A or B for each of the ten decisions. The subjects were instructed that one of the decisions would be randomly selected *ex post* and used to determine their payoffs. Part of a deck of cards was used to determine payoffs, cards 2-10 and the Ace to represent "1". After each subject completed his or her decision sheet, a monitor would approach the desk and randomly draw a card twice, once to select which of the ten decisions to use, and a second time to determine what the payoff was for the option chosen, A or B, for the particular decision selected. After the first card was selected, it was placed back in the pile, the deck was reshuffled, and the second card was drawn. For example, if the first draw were an Ace, then the first decision choice would be used, and the subject's decision, A or B would be circled. Suppose the subject selected A for the first decision. The second draw would then be made. If the Ace were drawn, the subject would win $2.00. If cards 2-10 were drawn the subject would win $1.60. The subjects were aware that each decision had an equal chance of being selected.

After all the subjects' payoffs were determined, they combined their payoff from Part 1 with that of Part 2 to compute their final earnings. The final payoffs were then verified against the computer records, and subjects were paid privately in cash for their earnings. Each of the sessions took approximately 75 minutes.

V. Results

The average individual contributions and average total group contributions for each treatment are presented in Table 1. On average, subjects in the VCM treatment contributed 40% of their endowments, for an average group contribution of 16 tokens. Subjects in the FPL treatment contributed, on average, 53.6% of their endowments, for an average group contribution of 21.4 tokens. Consistent with the model and Morgan and Sefton (2000), subjects in the FPL treatment contributed approximately 5.5 more tokens to the public good than subjects in the VCM treatment. In the Tontine treatment, subjects contributed an average of 56.8% of their endowment, resulting in an average group contribution of 22.7 tokens. Similar to the FPL treatment, subjects in the Tontine treatment provide almost 7 more tokens to the public good than subjects in the VCM.

Unlike results of some previous experiments (e.g. Morgan and Sefton 2000, Andreoni 1995, List 2003), VCM contributions herein do not converge towards zero in later periods.[3] Examining contributions in 3 groups of 5 periods each, mean contributions begin at 4.3 tokens in the first group (periods 1-5), decrease to 3.7 tokens in the second group (periods 6-10) then increase again in the last group (periods 11-15). This is inconsistent with the previous findings that contributions in the VCM converge towards zero in later rounds but may be related to the high MPCR employed in this study. Also interesting to note, (see Figure 1), is that the mean total group contributions for VCM follow a similar pattern as the FPL and Tontine treatments.

[3] I am unable to reject the null hypothesis that contributions in the first period are greater than those of the final period using a matched pairs t-test. The t-statistic for this test is 0.376 which is not significant at any meaningful level. However, the data demonstrate a decline in contributions across periods that is directionally consistent with Nash predictions.

Although the trend across periods follows a similar pattern in all three treatments, the individual mean contributions differ across treatments. Table 2 provides the differences in mean contribution levels across treatments. In the table, each entry reports the mean difference between column and row treatments for the respective performance measure. All statistical tests evaluate the null hypothesis that the column treatment is no larger than the row treatment (when the difference is positive) or that the row treatment is no larger than the column treatment (when the difference is negative). A Wilcoxon test was used to determine if the differences in means are statistically significant at conventional levels. As compared with the VCM, individual contribution levels in the Tontine were 1.67 tokens higher with this difference statistically significant at the $p<0.05$ level. For the FPL, individual contribution levels were 1.35 tokens higher than the VCM with this difference significant at the $p<0.10$ level. Individual contributions in the Tontine and FPL treatments are not significantly different.

Individual contributions were also analyzed based on subjects' risk preferences. Risk preferences were assigned based on the table given by Holt and Laury (2002, pp. 1649). Table 3 demonstrates mean contributions by each risk level. The risk levels were grouped into three risk categories: risk loving, risk neutral, and risk averse. Table 4 shows mean contributions for each of these risk categories. Based on the table, in the VCM treatment, 4 subjects were risk loving, 6 subjects were risk neutral, and 14 subjects were risk averse. In the FPL treatment, 2 subjects were risk loving, 7 subjects were risk neutral, and 15 subjects were risk averse. In the Tontine treatment, 7 subjects were risk neutral, 17 subjects were risk averse, and there were no risk-loving individuals. Thus it will only be possible to compare risk-loving behavior across the VCM and FPL treatments. Table 4 and Figure 2 show mean contributions by risk preference level. Contributions in the VCM treatment are lower than those in the other two treatments across all risk levels. In the VCM, risk-neutral individuals contributed the highest percentage (46.9%) of their endowments.

As expected, in the FPL risk-loving individuals contributed the highest percentage of their endowments (68.3%). Additionally, in the FPL, risk-averse individuals contribute the fewest tokens (48.4%). This level of contributing is close to the contribution levels of risk-neutral agents in the VCM. Since risk-averse individuals should avoid risky propositions, *ceteris paribus*, it makes sense that the individuals are contributing what they would donate to the public good in the absence of a lottery. Thus, their contributions, though still higher, start to resemble those from a VCM. In other words, risk averse individuals may not purchase lottery tickets to “compete” for the prize. Instead, they view the ticket purchase solely as contributing to the provision of the public good at a level that is individually optimal. For risk averse individuals, the lack of a desire to compete for the prize eliminates the compensating externality. This will result in contribution levels closer to those of a VCM.

The Tontine treatment results can only be compared for the risk-neutral and risk-averse cases. The average contribution by risk-neutral individuals is 61.3%. Risk-averse individuals contribute 55% of their tokens, which is almost 7 tokens more than in the FPL treatment. This makes sense because there is a distribution of prizes in the tontine, thus risk-averse individuals may be motivated to contribute more to compete for one of the lesser prizes.

Figure 2 visually depicts the mean contribution levels by treatment for each risk category. If preferences of individuals are known, fund-raisers can select the optimal method for raising money. If most of the participants are risk-averse, the tontine is the superior method for funding public goods. For risk-averse individuals, the tontine is the superior mechanism for funding public goods. The Tontine treatment contributes more to the public good than the single fixed-prize lottery. This result indicates that an effect similar to the Rothschild/Stiglitz effect is present despite the endogeneity of choice probabilities. If the participants are risk-neutral, either the single fixed-prize lottery or the tontine could be used. Due to the lack of risk-loving subjects in the Tontine treatment, one cannot say with certainty whether the single fixed-prize lottery is superior to the tontine for raising money from risk-loving individuals. However, intuitively, it makes sense that the FPL will be the superior method.

Econometric Analysis of Contribution Levels

While the above results indicate significant differences in individual contribution levels across treatments, the Wilcoxon test statistics do not condition behavior on unobserved individual characteristics or the history of the game. The unit of observation for the Wilcoxon test is the average contribution levels for each individual agent. The data, however, are sufficiently rich to enable such conditioning. A problem in estimating such a relationship is that the data are censored by design at the zero and ten token contribution levels. This situation is handled by employing a random-effects Tobit model with censoring from both above (at the ten token level) and below (at the zero token level).

In estimating individual contribution levels, the primary relationship of interest is the underlying latent structure:

$$C_{it}^{*} = X_{it}\beta + e_{it} \tag{2}$$

However, this latent structure is not directly observed since the data are censored from above (at 10 tokens) and below (at zero tokens). Rather, the relationship observed is given by:

$$C_{it} = 0 \qquad \text{if } C_{it}^{*} \leq 0$$

$$C_{it} = C_{it}^{*} \qquad \text{if } 0 < C_{it}^{*} < 10$$

$$C_{it} = 10 \qquad \text{if } C_{it}^{*} \geq 10$$

for all individuals $i = 1, 2, \ldots, N$ and all periods $t = 1, 2, \ldots, T$. In estimating 2, it is assumed that $e_{it} = u_{it} + \alpha_i$ where the two components are individually and normally distributed with mean zero. It follows that the variance of the disturbance term e_{it} is $Var(e_{it}) = \sigma_u^2 + \sigma_\alpha^2$. By construction, the individual random effects, α_i, capture important unobserved heterogeneities across individuals that would be left uncontrolled in standard cross-sectional analysis. The vector X_{it} includes treatment dummies, the interaction of treatment dummies and individual risk preference, and lagged performance measures. Specifically, the vector X_{it} is comprised of the following:

- fpl – is a treatment dummy=1 if the observation comes from the FPL treatment
- tontine – is a treatment dummy=1 if the observation comes from the Tontine treatment
- loving – is a dummy=1 if the observation comes from a risk loving individual
- averse – is a dummy=1 if the observation comes from a risk averse individual

- loving_fpl – is a dummy=1 if the observation comes from a risk loving individual in the FPL treatment
- averse_fpl – is a dummy =1 if the observation comes from a risk averse individual in the FPL treatment
- averse_tont – is a dummy=1 if the observation comes from a risk averse individual in the Tontine treatment
- lagdon – is a one-period lagged donation level for the i^{th} agent
- lagtotdon – is a one-period lagged donation level for the group that the i^{th} individual was in the previous period
- lagtotprof – is a one-period lagged profit level for the i^{th} individual
- loving_mid – is a dummy=1 if the midpoint of the interval defining the first and last switchpoints for agents in the Holt/Laury experiment falls in the risk loving range[4]
- averse_mid – is a dummy=1 if the midpoint of the interval defining the first and last switchpoints for agents in the Holt/Laury experiment falls in the risk averse range
- averse_mid_fpl – is a dummy=1 if the midpoint of the interval defining the first and last switchpoints for agents in the Holt/Laury experiment falls in the risk averse range for in the FPL treatment.

[4] Following suggestions from Glenn Harrison in measuring risk posture based upon responses from the Holt/Laury design I use the midpoint of an interval defining a range of indifference between choice (i.e., a range over which agents switch choice between Option A and Option B) as a measure of individual risk posture rather than the number of “safe” choices.

- Averse_mid_tont – is a dummy=1 if the midpoint of the interval defining the first and last switchpoints for agents in the Holt/Laury experiment falls in the risk averse range for in the Tontine treatment
- _cons – is the intercept representing the mean contribution level for a risk-neutral agent in the VCM treatment

In estimating equation 2, observations for the first period must be dropped when the one-period lagged variables are included. Thus the total number of observations for those specifications is 1008.

Table 5 and Table 6 provide parameter estimates for equation 2. From Table 5, we see that when accounting for censoring of the data, contribution levels for risk-neutral agents in both the single fixed-prize lottery and tontine are significantly greater than those of the risk-neutral agent in the VCM. These results support the non-parametric analysis reported in the prior section and conform to theoretical predictions. Results from the random effects Tobit model from Table 5 suggest the importance of including dynamics for determining donation levels. The coefficients on both lagged profit and lagged donations are positive and significant, suggesting that agents do respond to the history of play. For example, if a player earned greater profits in one period, he tends to contribute more in the following period. Conversely, if individuals earn less in a given period, on average they tend to reduce their contribution in the following periods. To the extent that profits are determined by the donations of all group members in a given period, this suggests players adhere to some form of a “tit for tat” strategy when determining their contribution levels.

Furthermore, estimates from the tables suggest important differences in the contribution levels of agents with differing risk preference across the various treatments. For example, based upon model specification (f) contributions by risk-averse agents in the Tontine are approximately 0.98 token greater than those made by risk-averse agents in the FPL. This approximation is generated by examining the difference in differences between the relevant treatment dummy and the interaction of the treatment dummy and the dummy for risk averse agents—which provide comparisons with contribution levels for risk-neutral agents in the VCM treatment. Additionally, results from the tables provide general support for the non-parametric results indicating significant treatment effects. Across all but a single model specification (g), the estimated coefficient on the dummy variable for the FPL treatment is significant at the $p<0.10$ level indicating significant differences in the contribution levels of risk-neutral (or all) agents in this treatment relative to the VCM. Similar results hold for the Tontine treatment dummy which is significant across all model specifications except (a) at the $p<0.10$ or higher.

VI. Conclusions

Both theoretically and empirically, history has shown that when left to voluntary contributions, the funding of public goods is less than the social optimum. Numerous mechanisms have been designed to elicit socially optimal levels of public goods contributions by discouraging free-riders. Theoretically, complex taxation/allocations schemes have been designed that solve the free-rider problem. However, in practice these schemes fail to achieve socially optimal contribution levels. In recent years, the effectiveness of auctions and lotteries in raising funds for public goods has been studied. These mechanisms have been found to diminish the free-rider effect, but do not completely eliminate it. To a large degree, these shortcomings are related to asymmetries across agents' preferences and risk postures.

In this thesis I set out to examine the performance of a new "old" mechanism for the financing of public goods: the tontine. The tontine may alleviate many of the asymmetries mentioned above by creating opportunities for agents to compete over various levels of prizes. Tontines were introduced in France several hundred years ago as a method for financing wars and other public projects. The tontine was used for approximately one hundred years in France and England. Although it never came to fruition, Alexander Hamilton proposed a tontine in the newly formed United States to help reduce the principle on the national debt. From the mid-19th to the early 20th century, a variation of the tontine was implemented in the United States life insurance market. Despite its promise as an effective investment option, corruption in the life insurance market eventually led to the prohibition of tontine insurance.

Tontines, which are life contingent annuities with survivorship benefits, are in many regards conceptually equivalent to Morgan's fixed-prize lottery over a distribution of prizes. In fact, for symmetric, risk neutral agents, the tontine maintains the relevant properties of the single fixed-prize lottery. Namely, the tontine outperforms voluntary contribution mechanism. Additionally, while it has not been shown theoretically, intuitively, one would expect the tontine to outperform the single fixed-prize lottery for risk averse agents via some analogue of the Rothschild/Stiglitz effect. Experimentally, I test these conjectures by running three sessions consisting of two games: a standard public goods game testing one of the three mechanisms (voluntary contribution mechanism, single fixed-prize lottery, and tontine) and a game to determine subjects' risk preferences.

Empirical results support the theoretical predictions suggesting that contribution levels to the public good under both the tontine and single fixed-prize lottery will dominate those of the VCM. Nonparametric results suggest that there is no significant difference in the performances of the tontine and single fixed-prize lottery for symmetric, risk-neutral agents. The results also suggest that risk averse agents will contribute more in the tontine than in the single fixed-prize lottery. Additionally, the total group contribution to the public good was higher using the tontine mechanism when risk preferences were not taken into account. Thus, in the absence of information on risk preferences, using the tontine mechanism should lead to the highest provision of the public good.

To extend the work of this thesis, more treatments need to be run to explore the range of situations where the tontine is the superior method of funding public goods. A

Tontine session that includes risk loving individuals needs to be run to complete the comparison with the FPL and VCM treatments. Additionally, I would like to examine if the results found in this analysis hold for different returns to the public good, namely if the tontine is still the superior method for funding a less desirable good. Experiments should also be run looking at outcomes when individuals are asymmetric in marginal utility for the public good. In such situations, will either mechanism for providing public goods be superior?

The analysis in this thesis assumes symmetric marginal utilities of the public good. If the agents' marginal utilities of the public good are asymmetric, equilibrium contribution levels in the tontine and single fixed-prize lottery will differ. Conceptually, under given ranges of heterogeneous preferences, contributions from risk neutral agents in the Tontine should rank-order dominate those from risk neutral agents in an equivalently valued FPL. For example, if a group of four agents have symmetric valuations for a public good given by 0.3 then the FPL should generate relatively more contributions than the Tontine. However, if preferences in this same group were given by the set (0.9, 0.1, 0.1, 0.1) then contributions under the Tontine should strictly dominate those from the FPL. Given the very real possibility that some agents do value the public good differently, this situation should be examined in future research.

The tontine mechanism has been shown to be just as effective, and in some cases superior, to the single fixed-prize lottery in funding public goods in the lab. Private fund-raisers should find this mechanism appealing because, as with lotteries, the tontine can be implemented in a real world setting without the need of a central government. If the tontine performs as well in a real world application as it did in the laboratory, in most cases it should replace the single fixed-prize lottery as the more effective method for increasing public goods provision. Considering the ongoing need to finance public goods, these results should prove to be highly beneficial for improving public goods provision.

APPENDIX A

Instructions—Part 1

General Rules

This is an experiment in economic decision making. If you follow the instructions carefully and make good decisions you can earn a considerable amount of money. You will be paid in private and in cash at the end of the session.

It is important that you do not talk, or in any way try to communicate, with other people during the session. If you have a question, raise your hand and a monitor will come over to where you are sitting and answer your question in private.

The experiment will consist of 17 rounds. The first 2 rounds will be practice. In each round, you will be randomly assigned to a group of 4 people. These groups will change each round. You will not know which of the other people in the room are in your group and the other people in the session will not know with whom they are grouped, in any round.

In each round, you will have the opportunity to earn points. At the end of the session, one of the non-practice rounds will be randomly selected and you will be paid in cash an amount that will be determined by the number of points you earn during the randomly selected round.

Description of each round

At the beginning of the first trial a subject number will be given on your terminal. Record that number on your record sheet. Each round you will be given an endowment of 10 tokens. At the beginning of each round, the computer will prompt you to enter the number of tokens you want to contribute to the group account. Enter a whole number between 0-10, record the number in column (b) on your record sheet, and click continue. Any tokens you do not place in your group account are placed in your private account. Once your decision is recorded, it cannot be changed. After everyone in your group has recorded their decisions, a screen will appear informing you of the number of tokens contributed to the group account by all group members, whether any bonus points have been earned, and your profit for the round. Record the information from that screen onto your record sheet as follows:

Tokens in Private Account:	Column A
Your Contribution to Group Account:	Column B
Total Tokens in Group Account:	Column C
Private Account Points:	Column D
Group Account Points:	Column E
Bonus Points:	Column F
Profit for Round:	Column G

Once everyone has recorded his or her information, the next round will begin.

How earnings are determined

VCM:

The number of points you earn in the round will be determined as follows. For each token placed in your private account you will earn 100 points. This amount is recorded in column (d) on your record sheet. You will receive 75 points for each token placed in your group account by you and the other people in your group. The group account points are recorded in column (e) on your record sheet. In addition, in each round you will also receive 600 bonus points regardless of how you and the other people in your group place your tokens. This amount is recorded in column (f). Your profit for the round is computed by summing the private account points, the group account points and the bonus points. This total is recorded in column (g) on the record sheet.

FPL:

The number of points you earn in the round will be determined as follows. For each token placed in your private account you will earn 100 points. This amount is recorded in column (d) on your record sheet.

You will receive 75 points for each token placed in your group account by you and the other people in your group. The group account points are recorded in column (e) of the record sheet.
In addition, in each round you have the chance to win 800 bonus points. At the end of each round a lottery will be drawn. Your odds of winning the lottery are determined by how much you contributed to the group account in that round. Specifically, your chances of winning the bonus points will be equal to the number of tokens you place in the group account, divided by the total number of tokens placed in the group account by you and the other people in your group. For example, if the group account contains 12 tokens of which 3 were placed by you, you will have a 3 in 12 chance of winning the bonus. If no tokens are placed in the group account, each member of the group will have an equal chance of winning the bonus. Record any bonus points earned in column (f) on your record sheet. Your profit for the round is computed by summing the private account points, the group account points and the bonus points. This total is recorded in column (g) on the record sheet.

Tontine:
The number of points you earn in the round will be determined as follows. For each token placed in your private account you will earn 100 points. This amount is recorded in column (d) on your record sheet. You will receive 75 points for each token placed in your group account by you and the other people in your group. The group account points are recorded in column (e) of the record sheet.
In addition, in each round you have the chance to win one of three bonus prizes. First prize is 500 points, second prize is 200 points, and third prize is 100 points. After all group members enter their contribution, a lottery will be drawn and bonus points will be awarded. Your odds of winning first prize are determined by how much you contributed to the group account in that round. Specifically, your chances of winning the 500 points will be equal to the number of tokens you place in the group account, divided by the total number of tokens placed in the group account by you and the other people in your group. This process is repeated for the two remaining prizes without replacement. For example, if each of the four players contributes the same number of tokens to the group account, each player will have a 1 in 4 chance of winning first prize. After first prize is drawn, the remaining three players will then each have a 1 in 3 chance of winning second prize. The last two players will then have a 1 in 2 chance of winning third prize. If no tokens are placed in the group account, each member of the group will have an equal chance of winning first prize. Bonus points are recorded in column (f) on your record sheet. Your profit for the round is computed by summing the private account points, the group account points and the bonus points. This total is recorded in column (g) on the record sheet.

At the end of the session we will draw a ticket from the box. In the box there is a numbered ticket for each round played (1-15). The number on the ticket that is drawn will determine the round for which you will be paid. Record the selected round and then your profit for that round in the space provided at the bottom of the record sheet. You will receive 50 cents in cash at the end of the session for every 100 points you earn in that round. This amount is recorded in the space titled earnings.

INSTRUCTIONS—Risk Aversion

Record your subject number from the previous part on your decision sheet. Your decision sheet shows ten decisions listed on the left. Each decision is a paired choice between OPTION A and OPTION B. You will make ten choices and record these in the final column, but only one of them will be used in the end to determine your earnings. Before you start making your ten choices, please let me explain how these choices will affect your earnings for this part of the experiment.

We will use part of a deck of cards to determine payoffs; cards 2-10 and the Ace will represent "1". After you have made all of your choices, we will randomly select a card twice, once to select one of the ten decisions to be used, and a second time to determine what your payoff is for the option you chose, A or B, for the particular decision selected. (After the first card is selected, it will be put back in the pile, the deck will be reshuffled, and the second card will be drawn). Even though you will make ten decisions, only one of these will end up affecting your earnings, but you will not know in advance which decision will be used. Obviously, each decision has an equal chance of being used in the end.

Now, please look at Decision 1 at the top. OPTION A pays $2.00 if the Ace is selected, and it pays $1.60 if the card selected is 2-10. OPTION B yields $3.85 if the Ace is selected, and it pays $0.10 if the card selected is 2-10. The other Decisions are similar, except that as you move down the table, the chances of the higher payoff for each option increase. In fact, for Decision 10 in the bottom row, the cards will not be needed since each option pays the highest payoff for sure, so your choice here is between $2.00 or $3.85.

To summarize, you will make ten choices: for each decision row you will have to choose between OPTION A and OPTION B. You may choose A for some decision rows and B for other rows, and you may change your decisions and make them in any order. When you are finished, we will come to your desk and pick a card to determine which of the ten Decisions will be used. Then we will put the card back in the deck, shuffle, and select a card again to determine your money earnings for the OPTION you chose for that Decision. Earnings for this choice will be added to your previous earnings, and you will be paid all earnings in cash when we finish.

So now please look at the empty boxes on the right side of the record sheet. You will have to write a decision, A or B in each of these boxes, and then the card selection will determine which one is going to count. We will look at the decision that you made for the choice that counts, and circle it, before selecting a card again to determine your earnings for this part. Then you will write your earnings in the blank at the bottom of the page.

Are there any questions? Now you may begin making your choices. Please do not talk with anyone else while we are doing this; raise your hand if you have a question.

Decision Sheet

OPTION A	OPTION B	DECISION
1/10 of $2.00, 9/10 of $1.60	1/10 of $3.85, 9/10 of $0.10	
2/10 of $2.00, 8/10 of $1.60	2/10 of $3.85, 8/10 of $0.10	
3/10 of $2.00, 7/10 of $1.60	3/10 of $3.85, 7/10 of $0.10	
4/10 of $2.00, 6/10 of $1.60	4/10 of $3.85, 6/10 of $0.10	
5/10 of $2.00, 5/10 of $1.60	5/10 of $3.85, 5/10 of $0.10	
6/10 of $2.00, 4/10 of $1.60	6/10 of $3.85, 4/10 of $0.10	
7/10 of $2.00, 3/10 of $1.60	7/10 of $3.85, 3/10 of $0.10	
8/10 of $2.00, 2/10 of $1.60	8/10 of $3.85, 2/10 of $0.10	
9/10 of $2.00, 1/10 of $1.60	9/10 of $3.85, 1/10 of $0.10	
10/10 of $2.00, 0/10 of $1.60	10/10 of $3.85, 0/10 of $0.10	

APPENDIX B

Table 1. Mean Performance Levels

		OVERALL	*PERIODS 1-5*	*PERIODS 6-10*	*PERIODS 11-15*
VCM	Individual Contribution	4.01 (3.40)	4.29 (3.38)	3.70 (3.35)	4.05 (3.46)
	Total Group Contribution	16.06 (6.95)	17.17 (7.90)	14.8 (6.41)	16.2 (6.30)
FPL	Individual Contribution	5.36 (3.39)	5.21 (3.33)	5.05 (3.32)	5.81 (3.51)
	Total Group Contribution	21.43 (6.88)	20.83 (6.70)	20.23 (6.10)	23.23 (7.45)
Tontine	Individual Contribution	5.68 (3.18)	5.71 (3.11)	5.47 (3.24)	5.88 (3.21)
	Total Group Contribution	22.73 (6.03)	22.83 (5.02)	21.87 (6.77)	23.5 (6.11)

Note: Figures in the table represent the average contribution levels (tokens) for each of the three treatments. Summary statistics by period are provided for both individual and total group contributions along with respective standard deviations (in parenthesis). For example, in the VCM treatment, average overall individual contribution was 4.01 tokens across all periods with a standard deviation of 3.40 tokens. Total overall group contributions for the VCM treatment averaged 16.06 tokens with a standard deviation of 6.95 tokens.

Table 2. Mean Differences in Performance Measures Across Treatments[a]

	(1) Fixed Prize Lottery	(2) Tontine
Overall Individual Contribution		
VCM	1.344*	1.669**
FPL		0.325

[a] Cell entries report the mean difference between column and row treatments for the respective performance measure. All statistical tests evaluate the null hypothesis that the column treatment is no larger than the row treatment (when the difference is positive) or that the row treatment is no smaller than the column treatment (when the difference is negative). For example, overall individual contribution levels are 1.344 tokens greater in the fixed prize lottery than in the VCM.

*reject H_0 at a 90% confidence level using a one-tailed nonparametric Wilcoxon test.

**reject H0 at a 95% confidence level using a one-tailed nonparametric Wilcoxon test.

Table 3. Mean Individual Contributions by Risk Level

RISK	*VCM*	*FPL*	*TONTINE*
0	3.33 (3.96) N=1		
3	2.49 (3.23) N=3	6.83 (3.04) N=2	
4	4.69 (2.86) N=6	6.03 (3.59) N=7	6.13 (3.33) N=7
5	5.10 (1.95) N=2	4.34 (3.42) N=6	6.21 (2.81) N=9
6	2.08 (2.57) N=4	4.95 (2.80) N=7	3.76 (3.59) N=3
7	4.25 (2.89) N=5	3.20 (2.54) N=1	5.53 (3.75) N=2
8		8.80 (2.83) N=1	5.13 (2.25) N=2
9	4.70 (5.04) N=2		5.0 (2.10) N=1
10	8.20 (3.59) N=1		

Note: This table depicts the mean contribution levels in tokens for individuals by treatment for each risk level as determined by Holt and Laury (2002). Standard deviations are in parentheses, and N= the number of individuals in that risk level. For example, in the FPL treatment, there are 6 individuals whose risk level=5, and their mean contribution level is 4.34 tokens with a standard deviation of 3.42 tokens.

Table 4. Mean Contribution Levels by Risk Category

		RISK LOVING	*RISK NEUTRAL*	*RISK AVERSE*
VCM				
	Overall	2.70	4.69	4.10
		(3.41)	(2.86)	(3.51)
	Period 1-5	3.75	5.5	3.93
		(3.49)	(2.89)	(3.46)
	Period 6-10	1.15	4.23	4.2
		(2.21)	(2.49)	(3.63)
	Period 11-15	3.2	4.33	4.17
		(3.89)	(3.10)	(3.49)
	# Subjects	4	6	14
FPL				
	Overall	6.83	6.03	4.85
		(3.04)	(3.58)	(3.24)
	Period 1-5	4.9	6.2	4.79
		(3.07)	(3.73)	(3.10)
	Period 6-10	6.3	4.83	5.0
		(2.83)	(3.76)	(3.17)
	Period 11-15	9.3	7.06	4.76
		(1.06)	(2.94)	(3.49)
	# Subjects	2	7	15
Tontine				
	Overall		6.13	5.50
			(3.33)	(3.11)
	Period 1-5		6.31	5.46
			(3.08)	(3.10)
	Period 6-10		6.06	5.22
			(3.67)	(3.04)
	Period 11-15		6.03	5.81
			(3.29)	(3.19)
	# Subjects		7	17

Note: Figures in the table represent the average contributions by risk level for each of the three treatments. Summary statistics by period are provided for individual contributions along with its standard deviation. For example, in the VCM treatment average overall individual contributions were 2.70 tokens for the four risk loving agents with a standard deviation of 3.41 tokens. In periods 11-15, these agents gave an average of 3.2 tokens with a standard deviation of 3.89 tokens.

Table 5. Empirical Analysis of Individual Contribution Levels

Variable	*Random Effects Tobit*						
	(a)	(b)	(c)	(d)	(e)	(f)	(g)
Fpl	2.62*** (0.38)	1.01** (0.47)	3.30*** (0.56)	2.90*** (0.92)	2.93*** (0.62)	1.99*** (0.79)	1.57 (1.08)
Tontine	0.41 (0.48)	1.78*** (0.61)	2.04*** (0.67)	2.01** (0.90)	1.66** (0.72)	2.89*** (0.73)	2.92*** (0.96)
Loving		-1.90*** (0.63)	-0.96 (0.75)	-0.97 (1.24)	-0.99 (0.76)	-3.85*** (0.80)	-2.83*** (0.91)
Averse		-2.46*** (0.48)	-1.77*** (0.56)	-1.48* (0.89)	-1.77*** (0.56)	-0.41 (0.70)	0.14 (0.96)
Loving_fpl						4.50*** (1.12)	4.35*** (1.45)
Averse_fpl						-2.32*** (0.92)	-2.08* (1.25)
Averse_tont						-2.74*** (0.89)	-2.73** (1.27)
lagtotdon			0.06*** (0.02)		0.10*** (0.03)		-.090*** (0.03)
Lagdon				0.19*** (0.05)			
Lagtotprof					-0.0006 (0.0004)		-0.0006* (0.0004)
_cons	4.11*** (0.32)	5.43*** (0.60)	3.55*** (0.74)	3.72*** (1.07)	4.56*** (0.97)	4.63*** (0.60)	3.84*** (0.97)
sigma_u	3.27	3.04	2.98	2.64	2.88	3.27	2.99
sigma_e	3.14	3.14	3.16	3.18	3.16	3.13	3.15
Log-likelihood	-2349.33	-2348.45	-2186.99	-2184.92	-2185.68	-2344.54	-2182.00
Observations	1080	1080	1008	1008	1008	1080	1008
Trunc_0	146	146	139	139	139	146	139
Trunc_10	147	147	140	140	140	147	140
ρ	0.52	0.48	0.47	0.41	0.45	0.52	0.47

Note: Cell entries report marginal effects on contribution levels for the model covariates. Each column reports parameter estimates for a RE tobit model accounting for censoring of the data. For example, in model specification (a), when accounting for censoring in the data, contributions in the FPL treatment are 2.62 tokens greater than those from the baseline VCM treatment with this difference significant at the $p < 0.01$ level.

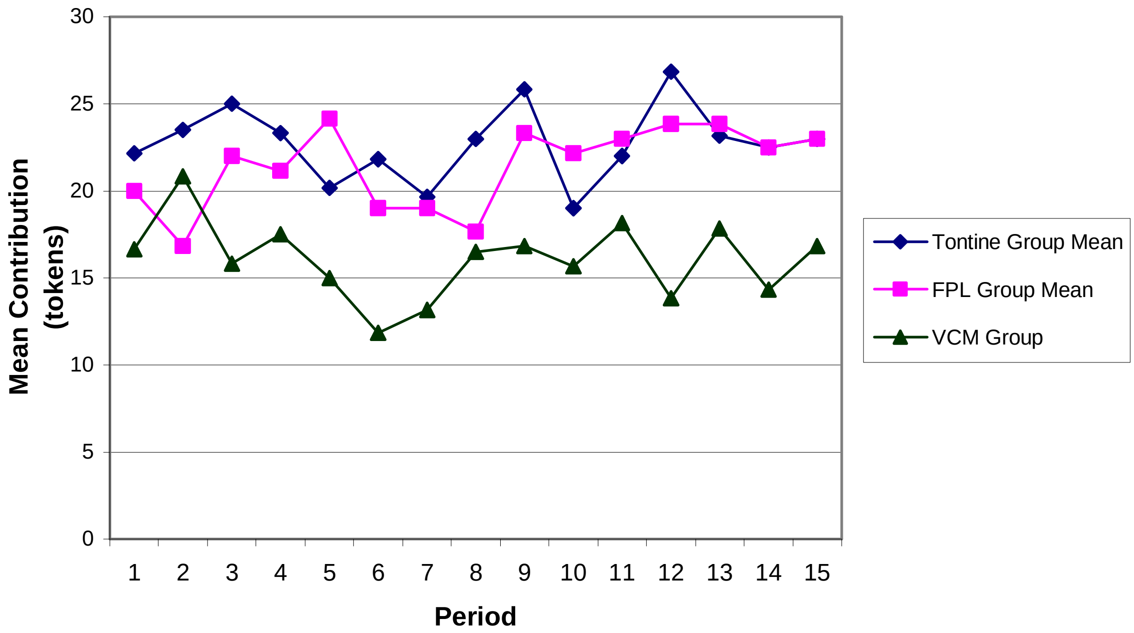
*** denotes significance at the 99% level; ** denotes significance at the 95% level; * denotes significance at the 90% level

Table 6. Parameter Estimates Using Mid-Point of HL Design

Variable	*Random Effects Tobit* (1)	(2)	(3)
fpl	2.15***	2.07***	4.08***
	(0.42)	(0.61)	(0.86)
tontine	0.99*	0.93	3.62***
	(0.55)	(0.64)	(0.84)
Loving_mid	-2.57***	-4.77***	-3.08***
	(0.82)	(0.92)	(0.87)
Averse_mid	-1.81***	-1.98***	0.51
	(0.50)	(0.49)	(0.76)
Averse_mid_fpl			-1.81*
			(0.95)
Averse_mid_tont			-3.52***
			(0.95)
Lagdon		0.18***	
		(0.05)	
_cons	6.19***	5.19***	3.86***
	(0.62)	(0.73)	(0.69)
sigma_u	3.26	2.85	3.30
sigma_e	3.14	3.17	3.12
Log-likelihood	-2347.21	-2181.52	-2344.26
Observations	1080	1008	1080
Trunc_0	146	139	146
Trunc_10	147	140	147
ρ	0.52	0.45	0.53

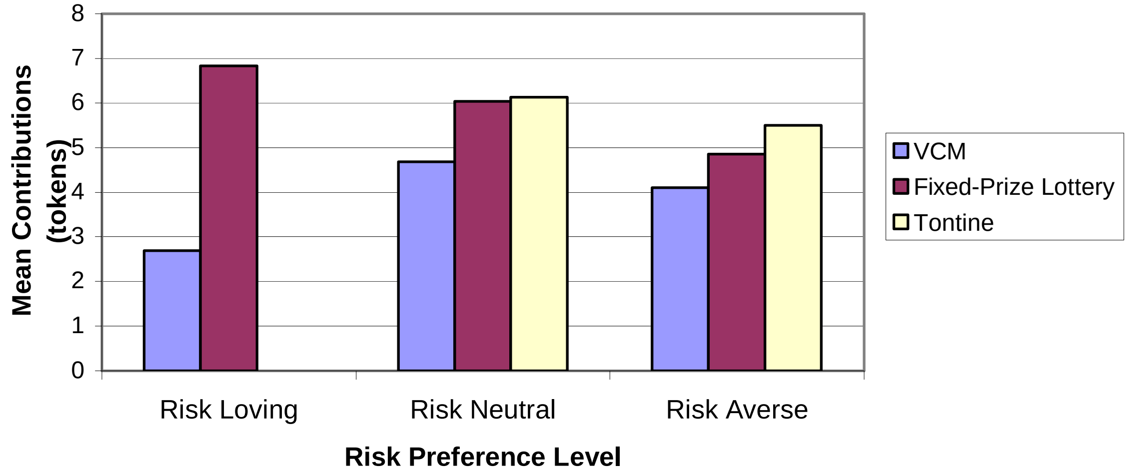
Note: Cell entries report marginal effects from a RE tobit regression of contribution levels on a number of assumed relevant covariates. For example, in column 1 the parameter estimate for fpl suggests that individuals in the FPL treatment contribute approximately 2.15 tokens more than do agents in the VCM with this difference significant at the $p<0.01$ level of significance.
*** denotes significance at the 99% level; ** denotes significance at the 95% level; and * denotes significance at the 90% level.

Figure 1. Mean Group Contributions



Note: This figure represents the mean group contributions by treatment level for each period. For example, in period 1, the group mean for the FPL treatment is 20 tokens.

Figure 2. Mean Contributions by Risk Levels



Note: This chart depicts individual mean contributions by risk levels for each treatment. For example, risk loving individuals in the VCM treatment contributed an average of 2.7 tokens in each period. Note that there were no risk loving individuals in the Tontine treatment.

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