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Lotteries as a Funding Tool for Financing Public Goods

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In the Review of Economic Studies, Morgan (2000) proposed that targeted self-funding lotteries could be used as a method of increasing voluntary contributions to public goods. In the same issue, Morgan and Sefton (2000) tested the theoretical predictions in a laboratory experiment and found support for the theory. The theory, and consequently the experiment, both assumed a quasi-linear utility function with one private good and one representative public good. This current research asks the question, does such a lottery work when there are two public goods? In the original case, expected utility maximization causes agents to divert funding away from the private good and towards the public good. Enough resources are diverted to not only fund the lottery prize but also to lead to an overall increase in public good provision thereby increasing social welfare. However, when two public goods are involved, funds are diverted from both the private good and from any out-of-equilibrium voluntary contributions made to the public good that does not involve the lottery. This paper presents the theory and an initial experiment run at CEEL in Trento using PGLottery software designed at McEEL (McMaster) and CEEL. There are two key findings. First, behaviour in a multiple public good experiment seems to differ from behaviour in traditional single public good experiments. Second, opposite to the findings of Morgan and Sefton (2000), the introduction of the lottery decreases efficiency, adding evidence to the argument that lotteries decrease social welfare.

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Lotteries as a Funding Tool for Financing Public Goods

1. Introduction

Providing for the public good has long-plagued economists and policy-makers alike. Adam Smith clearly wrote of the problems associated with expecting private provision of public goods and the consequent duty of the state.

The third and last duty of the sovereign or commonwealth is that of erecting and maintaining those public institutions and those public works, which, though they may be in the highest degree advantageous to a great society, are, however, of such a nature that the profit could never repay the expense to any individual or small number of individuals, and which it therefore cannot be expected that any individual or small number of individuals should erect or maintain.

– *The Wealth of Nations, Book 5, Chapter 1, Part 3*

Indeed, when agents can voluntarily contribute to the public good, under-provision is the predicted theoretical outcome. Warr (1983) showed that the equilibrium level of voluntary contributions would remain unchanged if income was redistributed. Bergstrom, Blume, and Varian (1986) extended this neutrality result to the case in which income redistribution is large enough to change the set of contributors. They also extended the analysis to more than one public good. Experiments using the voluntary contribution mechanism have shown that free-riding is not as extensive as theorists predict (e.g., Isaac and Walker (1988) with linear payoffs; Ledyard (1995) for survey of mostly linear payoff experiments, and Chan, Mestelman, Moir, and Muller (1996) with nonlinear payoffs).

Other theoretical research has promoted mechanisms for helping agents achieve the social optimum. These include, the Lindahl mechanism (1919), the Groves-Ledyard mechanism (1977), the Tideman-Tullock mechanism (1976), and Walker's (1981) variant of the Lindahl mechanism. Experimental evidence suggests that in many cases the mechanisms do not live up to their theoretical potential (Smith, 1979). Other mechanisms seem to show promise both theoretically and in the laboratory. Loehman and Rassenti (1997) have designed and tested a cost sharing mechanism which shows some promise. Moir (1998a, 1998b) implemented a lottery in contributions which significantly increased aggregate contributions. Falkinger (1996) proposed a very simple tax-subsidy scheme which was later tested in Falkinger, Fehr, Gächter, and Winter-Ebmer (2000). Again, the results were quite promising. However, in each case, the role of the government as the mechanism enforcer and data gatherer is assumed to be costless.

The use of lotteries as a method of raising revenues has a long history. Early lotteries held in the Republic of Venice (mid-February, 1552) were largely private ventures run by profit-seeking individuals (Seville, 1999). By late February the government had banned all private lotteries. "The motive was simple: the state had recognized an easy source of revenue" (p. 18). The Republic needed the funds to support its many wars so it collected profits from the lottery and taxed the winnings. It was not until 1569 that an English lottery was conducted to raise funds for the " 'reparations of the havens and the strength of the realme and towards such other public good works' " (p. 20).

In a time of fiscal restraint, it seems that governments and private charities around the world are increasingly turning to lotteries as a means of generating revenues without imposing new taxes or raising existing ones. In Canada, households have, on average increased their expenses on games of chance. As Figure 1 shows, the overall increase arises because of a dramatic increase in spending at casinos, video lottery terminals, and slot machines. Lottery expenditures have fallen for government lotteries and remained relatively stable (slight increase) for non-government lotteries and raffles. Still lottery expenditures are the single largest form of household expense on games of chance. **{AT SOME POINT LOOK AT ADDING CONTRIBUTIONS TO CHARITIES}**

While there may be sound reasons for increasing lottery (and other games of chance) adoption by states (Mixon, Jr., Caudill, Ford, and Peng, 1997), it is not clear that lotteries are a cost efficient method of generating revenues (Mikesell and Zorn, 1988), and they are generally considered to be a regressive tax (Mikesell and Zorn, 1988; Farrell and Walker, 1999; Borg and Mason, 1988). Moreover, social costs associated with gambling – criminal activity, gambling addiction leading to social and family problems, lost productivity, etc. – can be significant, although such social costs tend to be low in the case of lotteries.¹ While there may be problems associated with lotteries (and gambling in general) from a normative viewpoint, I will not be addressing those issues here.

Morgan (2000) shows that with risk-neutral profit-maximizing agents, a lottery used to fund a public good can be self-financing. Indeed, it can raise the level of public good provision beyond amount that would be voluntarily contributed in equilibrium. Morgan and Sefton (2000) show that not only does the lottery increase public good contribution beyond the levels voluntarily provided, but that this gap grows through repetition. Davis et al. (2003), compare lotteries to English auctions in a Morgan environment with heterogeneous preferences. Not only do they confirm the Morgan and Sefton results, their data reveal that lotteries generally outperform auctions in terms of revenue generation for the public good (despite the fact that revenues were predicted to be equal). Spraggon and Apinunmahakul (2004) are conducting experiments to see if a two-part tariff as suggested by Apinunmahakul and Barham (2003) – agents pay to be involved in the lottery and then buy lottery tickets – increases efficiency beyond even the levels suggested by Morgan.

The only other lottery-like public goods experiment (of which I am aware) involves homogeneous subjects selecting an amount that they would like to see contributed to the public good (Moir, 1998a and 1998b). These amounts are then distributed randomly across the group (i.e., drawn from a hat). The incentives of such a contribution lottery are such that individuals should select the socially optimal as a Nash equilibrium strategy. While the contribution lottery is effective in increasing contributions (Moir, 1998a), a certain amount of ‘shirking’ leads to subjects selecting an over-contribution which they hope someone else will have to make (Moir, 1998b). Moreover, it is difficult to see how a government could enforce such a contribution lottery.

The goal of this paper is to expand the theory in Morgan (2000) and the behavioural

¹ Walker and Barnett (1999) argue that many studies over-estimate the social costs of gambling if one strictly adheres to the economic definition of social costs.

results in Morgan and Sefton (2000) to look at the case of two public goods as opposed to a single generic public good. While the utility/payoff function simple – it is linear in both the private and public goods – the results, both theoretical and behavioural, have important implications. Specifically, a lottery can be used to fund the ‘wrong’ public good from a social perspective and this can have important equity and social welfare implications.

2. Lotteries as a Fund-raising Tool

Morgan (2000) shows that with quasi-linear preferences for a public good, a self-funding fixed-prize lottery can be used as a method of increasing contributions to a public good beyond those voluntarily provided at the non-cooperative Nash equilibrium.² Moreover, Morgan and Sefton (2000) show that these theoretical results are exhibited in the laboratory (in the case of a linear specification of preferences). This experimental confirmation is especially important. Morgan’s (2000) theoretical predictions are based upon Nash behaviour in the absence of a lottery (i.e., free-riding). However, experimental evidence to date suggests that agents voluntarily contribute more than that predicted at the non-cooperative Nash equilibrium (Isaac and Walker, 1988; Chan, et al., 1996). Indeed, it is not clear that agents use information in a Nash-like manner in a repeated-game public good environment (Moir, 2001).

One problem with the Morgan (2000) study, and indeed with a significant portion of public good research involving mechanism design, is that there is only one generic public good. We know that this is certainly not the case. In addition to religious institutions, Canadians can immediately think of the United Way, Big Brothers/Sisters, the Red Cross, the Cancer Society, the Heart and Stroke Foundation, the World Wildlife Federation, and any number of local charities and environmental groups. This list ignores larger-scale public goods that are funded by governments through general revenues, including government proceeds from national and provincial/regional lottery corporations. As we will see, the addition of a second public good raises significant implications in a Morgan (2000) environment.

2.1 A Lottery in a Linear Public Good Environment

First we examine the simple case of a lottery in an environment with only one public good and linear-homogeneous preferences. Most of these results can be found in Morgan (2000) and Morgan and Sefton (2000) but are repeated here for clarity and for the purpose of comparison.

Suppose N individuals with a wealth endowment of w face a lottery with a fixed prize of

² Indeed, Morgan (2000) further shows that these “results are robust to a specification of preferences where income effects are present, but where the public goods allocation decision is separate from distributional assumptions.” (p. 776)

P .³ To simplify the argument, further suppose that if insufficient wagers are gathered to cover the cost of the fixed-prize, P , then the lottery provides negative amounts of the public good.⁴ Each individual i , chooses a wager (effectively a contribution) in order to maximize expected payoff

$$(1) \quad \pi_i^e = (w - g_i) + (g_i/(g_i+G_{-i}))P + m(g_i+G_{-i}-P),$$

where g_i is i 's wager (or voluntary contribution in the absence of a lottery), $G_{-i} = (\sum g_i) - g_i$ is the aggregate contribution made by others (and is taken as given when i makes her decision), and m is the marginal per capita return (MPCR) as identified by Isaac and Walker (1988). Private consumption, $w-g_i$, is augmented by an expected return of P won with probability $(g_i/(g_i+G_{-i}))$. Wagers determine the probability of winning and funds in excess of the fixed-prize pays for the public good (i.e., $(g_i+G_{-i}-P)$). When $P=0$, (1) reduces to the standard linear voluntary contribution mechanism (VCM) payoff structure used in Isaac and Walker (1988) and elsewhere, where payoff is no longer uncertain.

Throughout this work, we assume that $0 < m < 1$ and that $Nm > 1$. This ensures that the dominant solution in the absence of a lottery (i.e., when $P=0$) is for each agent to set $g_i=0$, yet the social optimum involves setting $g_i=w$ for all i .⁵

A risk-neutral agent facing an exogenously determines fixed prize (P) and taking others' wages as given (i.e., G_{-i} is fixed), chooses a wager, g_i , to maximize (1), resulting in the following first-order condition

$$(2) \quad (G_{-i}/G^2)P = 1-m,$$

where $G = \sum g_i$ is the aggregate wager. Recalling the assumed symmetry in payoffs and in wealth endowments, then $G_{-i} = (n-1)g_i$ and $G = Ng_i$, and we solve for a Nash equilibrium wager of

$$(3) \quad g_i^N = [(N-1)/N^2 \cdot P] \cdot [1/(1-m)].$$

Summing these N equilibrium wagers and rearranging, we get

$$(4) \quad G^N - P = (Nm-1)/(N-Nm) \cdot P,$$

³ While I use the term lottery, technically this is a fixed-prize raffle where the prize is known with certainty and the probability of winning is simply calculated as an individual's wager divided by the sum of all wagers.

⁴ While this assumption is unrealistic, the results remain unchanged if in this situation the raffle is cancelled and wagers (contributions) are returned to individuals (see Morgan (2000) for details). Another option involves scaling back the prizes if revenues are not sufficient to cover the lottery prize. For instance, in 2003 the Canada Winter Games were held in Bathurst and Campbellton in New Brunswick and the Canada Winter Games Million Dollar Lottery was used to raise funds. The official rules state that if sufficient sales are not reached by the morning of the lottery, the million dollar prize would be reduced to "50% of the gross proceeds (sales) and the remaining prizes remain the same." In fact, the 'million dollar' prize was only \$660,780. How such a rule influences the theory remains to be studied.

⁵ If, however, $Nm < 1$, then the public good is not socially desirable. Morgan (2000; pp.771-772, 783) shows that a lottery (fixed-prize raffle) will not generate wagers in excess of the fixed prize, so it will not fund socially undesirable goods.

which ensures that the funds raised through the lottery will exceed the prize only when the public good is socially desirable (i.e., $Nm > 1$).⁶

Recall that the VCM equilibrium condition (i.e., $P=0$), involves $g_i^N=0$ thus $G^N=0$, so individual payoff is $\pi_i^N = w$ and aggregate payoff is $\Pi^N = Nw$. Complete free-riding is the dominant solution and ensures that agents keep their wealth for private consumption. When $P > 0$ and the good is socially desirable, then $G^N - P > 0$, so a positive level of the public good is provided in equilibrium. In equilibrium, expected payoff can be written as

$$(5) \quad \pi_i^e = w - [(N-1)/N^2 \cdot P] \cdot [1/(1-m)] + (1/N)P + m((Nm-1)/(N-Nm) \cdot P) \\ = w + \{[-(N-1)/N^2] \cdot [1/(1-m)] + (1/N) + m[(Nm-1)/(N-Nm)]\} \cdot P$$

which is greater than w as long $\{\cdot\} > 0$. When $Nm > 1$ (the good is socially desirable) then $\{\cdot\} > 0$. Thus, the introduction of a lottery in this environment increases *expected per capita* payoff and is welfare improving. The negative externality associated with the lottery (an individual purchasing an extra ticket decreases the expected payoff to others) offsets the positive externality associated with the public good thereby offsetting agents' tendencies to free-ride.⁷

Suppose a social planner were to maximize aggregate payoff. Without a lottery, the social planner would set $g_i^S = w$ so that aggregate payoff would be $\Pi^S = N \cdot Nm w$. $\Pi^S > \Pi^N$ when $Nm > 1$. The government may be able to implement such a scheme (in this highly stylized economy), by setting a lump sum tax equal to w , but this is generally politically infeasible. One option then is for the government to resort to a lottery. Realizing aggregate payoff always increases when the net level of public good increases and that $\partial(G^N - P)/\partial P = (Nm-1)/(N-Nm)$ is always positive (under our assumptions), then the government is forced to a corner solution in which the prize is just large enough so wages equal wealth.⁸ Substituting $w = g_i^N$ and solving (3) for P^* we get

$$(6) \quad P^* = w(1-m) \cdot N^2/(N-1).$$

In this case, aggregate payoff is $\Pi^{SL} = Nm(G^N - P^*) + P^*$. Recall that at P^* , $G^N = Nw$ so $\Pi^{SL} = N \cdot Nm w + (1-Nm) \cdot P^* = \Pi^S + (1-Nm) \cdot P^*$. Given our assumptions of $Nm > 1$, then $1-Nm < 0$ so $\Pi^N < \Pi^{SL} < \Pi^S$ – while the introduction of a lottery is welfare improving, it is not a first-best solution. While the lottery increases the aggregate level of public good, it comes at the cost of funding a prize.

⁶ Realizing that the Nash equilibrium with the lottery, someone will win the prize, then we can write $\Pi^{NL} = Nw + (Nm-1)/(N-Nm) \cdot P = \Pi^N + (Nm-1)/(N-Nm) \cdot P$. In other words, with a positive prize and a socially desirable public good, the Nash equilibrium under the lottery will lead to higher aggregate payoff than when we rely solely upon voluntary contributions.

⁷ For a broader theoretical discussion on how lotteries, taxes and other mechanisms create a negative externality which (partially) offsets the positive externality associated with a public good, see Amegashie (2003).

⁸ By extension, a charity fund manager, interested in raising the largest possible funds for her charity would likewise select P^* to maximize the net level of public good. The problem of setting an optimal lottery prize is much more difficult if agents are heterogeneous in either wealth or preferences (e.g., MPCR).

This work, which so far conforms to the work of Morgan (2000) and Morgan and Sefton (2000), suggests that lotteries may be an important tool for both the private and public sector to raise the funds necessary to provide public goods. Agents' involvement in the lottery is not based on risk-loving preferences, warm-glow towards the public good, or interdependent utility, but rather is a function of the lottery funds being attached to the public good.

Others have further developed Morgan's (2000) seminal work to look at different lottery structures which can increase efficiency. Amegashie and Myers (2000) consider intense lottos and raffles, where the purchase of g_i tickets puts g_i^τ , $\tau > 1$, tickets into the raffle and Amegashie and Myers (2003) consider a two-stage lottery in which lottery contestants are selected from a larger set of all individuals who want to participate in the lottery. In both cases, efficiency is increased beyond that predicted by Morgan (2000). Apinunmahakul and Barham (2003) show that with a properly structured two-part tariff, the Pareto efficient level of public good will be provided. None of these papers address the concerns raised in section 2.2.

One important caveat should be added to Morgan and Sefton (2000). They note that the lottery merely redistributes wealth among individuals, "so the negative externality has no direct welfare implications" but it does increase the variance of income levels across individuals (p.788). In fact, for certain levels of MPCR, individuals who lose the lottery are actually worse-off than if the lottery had never been introduced. Recall that without a lottery and at the equilibrium, an agent sets $g_i^N=0$ and thus earns a payoff $\pi_i=w$. With a lottery in place, then in equilibrium each agent sets $g_i^N=[(N-1)/N^2 \cdot P] \cdot [1/(1-m)]$. The payoff to the -1 losers is then

$$(7) \quad \pi_i^{LOSE} = w - \{[(N-1)/N^2] \cdot [1/(1-m)] + m((Nm-1)/(N-Nm))\} \cdot P.$$

If the term $\{\cdot\} > 0$, then $\pi_i^{LOSE} < \pi_i^N$. If we set the term $\{\cdot\} = 0$ and solve for the positive root of m , we get

$$(8) \quad m = [1/2 + 1/2 (-3 + 4N)^{1/2}]/N.$$

Thus if $1/N < m < [1/2 + 1/2 (-3 + 4N)^{1/2}]/N$ then the lottery losers are actually hurt by the introduction of the lottery. For instance, if $N=3$ then for values of MPCR between $1/3$ and $2/3$, lottery losers are actually worse-off in equilibrium because of the lottery. Moreover, given the likelihood that a government or a charity fund manager will maximize the net level of public good provided, the gap between the winner's and losers' payoffs can be quite large.

This income variance can be offset by having multiple smaller prizes. However, according to the Atlantic Lottery Corporation:

Player reaction to large jackpots indicates they prefer to try for big jackpots. ... We tried a special draw of 10 prizes of \$1 million each. Players did not respond with the enthusiasm they show when a jackpot grows.

<http://www.alc.ca/English/AboutUs/FAQs/index.shtml> accessed 21 May 2003

The income distribution effect is quite separate from the abundant evidence of the regressive nature of lotteries and more generally gambling – it exacerbates the issue. Assuming the Atlantic Lottery Corporation reflects the general views of lottery managers, it is not an issue likely to be addressed voluntarily by those running lotteries.

2.2 A Lottery in a Linear Public Goods Environment

Now suppose that we modify (1) to allow for two public goods, G and H , and further suppose that a lottery, P_H , is instituted to fund only good H . Then agent i 's expected payoff function can be written as

$$(9) \quad \pi_i^e = x_i + (h_i/(h_i+H_{-i}))P_H + m(g_i+G_{-i}) + k(h_i+H_{-i}-P_H),$$

where x_i is private consumption. This expected payoff is maximized subject to the constraints that $w_i = x_i + g_i + h_i$, $g_i \geq 0$ and $h_i \geq 0$. We assume $m < 1$, $Nm > 1$, $k < 1$, and $Nk > 1$ (both G and H are socially desirable public goods with a dominant solution involving free-riding). If we further assume that $m > k$, then it follows that $Nm > Nk$. In other words, while both G and H are socially desirable public goods, G is *more* socially desirable.

If $P_H = 0$, and agents maximize payoffs choosing g_i and h_i , then the dominant solution of complete free riding holds and $g_i^N = h_i^N = 0$ so $\Pi^N = Nw$ and $\pi_i^N = w$. A social planner seeking to maximize aggregate payoff, would plan to have agents contribute to the public good that is most socially desirable. In this simple linear environment, the social planner would set $g_i^S = w$ for all i so $\Pi^S = N \cdot Nm w$ and $\pi_i^S = Nm w$.

However, if $P_H > 0$ then all of the results developed in section 2.1 hold. Moreover, if P_H is chosen to maximize the net level of H provided, then $(\Pi^{SL}|P_H=P_H^*) = N \cdot Nkw + (1-Nk)P_H^*$. Given $m > k$, then we know that in equilibrium $(\Pi^N|P_G=P_H=0) < (\Pi^{SL}|P_H=P_H^*) < (\Pi^{SL}|P_G=P_G^*) < \Pi^S$.⁹ In other words, while the lottery is an improvement upon complete free-riding, it can lead people to wager on (and hence contribute to) the “wrong” public good – while a socially desirable public good is provided because of the lottery, it is not the *most* socially desirable public good.

It is immediately evident in the field that an economy has a number of public goods (not just one generic public good). Likewise, we see a number of charities and other public good providers turning to lotteries as one method of fund-raising. Though the right to run charitable lotteries is monitored by many governments through the issuing of lottery identification numbers, there is no method of ensuring that the right to run a lottery is restricted to charities providing only the most socially desirable public good. Indeed, ranking the social desirability of public goods is likely an impossible task. **{DO I WANT TO MENTION DEMAND REVELATION IN AN FOOTNOTE - IF SO, NEED CITATION}**

My current research in progress suggests that the problem identified above for the simple linear two public goods payoff is not trivial. For instance, if charities providing both G and H are privately run by fund-raising managers both interested in maximizing the net level of their

⁹ From (6) we know $\partial P^*/\partial m < 0$ suggesting that the prize which extracts all wealth in a lottery environment, decreases as the MPCR increases. A smaller prize is necessary to elicit complete wealth extraction towards a raffle when the good is more socially desirable. For fixed wealth then, the net contribution to a public good (wagers less prize) will be higher for the public good with a higher MPCR. While the prize is returned to the winner as a private good in both cases, the net contribution, which is higher for the good with the higher MPCR, is more highly valued by society for the good with a higher MPCR. This is similar to Cornes and Itaya (2003) who point out that in a multiple public goods environment it is possible to have the wrong mix of public goods in equilibrium.

particular public good provided, then setting $P_G=P_G^*$ and $P_H=0$ is not a Nash equilibrium. Intuitively, if the fund-raiser for G institutes a lottery with a prize designed to extract all wealth towards her cause, the fund-raiser for H need only institute a lottery with a small prize to cause some people purchase tickets in his raffle. In other words, a second-best solution in which a lottery is instituted for the public good which is *most* socially desirable, is not a Nash equilibrium if there are competing fund managers.

So far, the problems identified have been restricted to linear payoff public goods environments. Instituting a lottery causes agents to substitute from private consumption towards public good provision. In a linear payoff environment in which complete free-riding is the dominant solution, any substitution away from private consumption and towards public good provision necessarily improves aggregate payoffs and is thus welfare-improving. Suppose instead, that agents had Cobb-Douglas payoffs. With one public good, the optimal prize would not extract all wealth. However, with two public goods instituting a lottery for one public good has quite complex effects. While inducing substitution away from private consumption and towards one public good increases social welfare, people also substitute away from the other public good in order to purchase lottery tickets. My current research in progress suggests that even small prizes can reduce expected payoffs below Nash levels.

3. Experiments

Public good experiments reveal that while the Nash equilibrium is a pretty good predictor of behaviour in a repeated game framework, it is not perfect. Subjects regularly over-contribute relative to the Nash equilibrium in a linear payoff VCM environment (e.g., Isaac & Walker, 1988; see Ledyard, 1995 for a survey). Over-contribution is strongest in the first period in a multi-period session and seems to decline steadily towards the Nash equilibrium with repetition. However, a non-trivial level of over-contribution exists even in the last period of such sessions, and even if subjects are randomly rematched throughout the session. Free-riding is not as extensive as traditional non-cooperative game theoretic models predict yet the theoretical predictions outlined in section 2 are based on the assumption of free-riding. While a zero conjectural variations Nash equilibrium model was used to develop the theory in section 2, many of the results will hold in a qualitative sense if subjects have homegrown utility functions based on the experimentally induced payoff function. However, it is not clear that subjects use Nash-like behaviour in public goods environments (Moir, 2001). Experimental analysis is necessary to see if theory extends to behavioural reality.

Experimental analysis is also necessary because of the increasing tendency for charities and even the government to turn to lotteries as a fund-raising device. The perceived effectiveness of lotteries to generate more funds than a VCM (the theoretical result in Morgan (2000) and behavioural result in Morgan and Sefton (2000)), and hence improve social welfare, may in part be a result of observing their ability to generate funds independent of observing the effects on other charities and other public good providers.

Finally, experimental analysis is warranted as very few papers have considered multiple public goods. Bergstrom et al. (1986) cite Kemp (1984) when they derive neutrality properties for wealth redistributions in the case of multiple public goods, but their note is really an afterthought to the main thesis of their paper. Cornes and Schweinberger (1996) discuss

different definitions of free-riding which are only meaningful when there are multiple public goods. They mention that at the Nash equilibrium, the mix of public goods may be a source of inefficiency, in addition to the well-known under-provision result. Kanbur and Clark (2002) point out that in many societies and for many goods, we have the choice as to whether to make them private or public. They postulate a ‘Samuelson machine’ which turns a private good into a public good and discuss the efficiency implications of the costs of the Samuelson machine as opposed to the costs of ensuring efficiency once a good becomes public. Cornes and Itaya (2003) summarize the little research that exists regarding the theory or provision of multiple public goods and derive the result that “[n]ot only will aggregate public good provision be ‘too low’, but the mix of public goods will generally be ‘wrong’”.^{10,11} I have seen no experiments involving multiple public goods.¹²

3.1 Design

In order to see if a lottery can be used to fund the ‘wrong’ public good, I use an across subjects design. Sessions consist of 15 subjects each and subjects are informed that they are connected by computer to 2 other individuals in the room. Thus, while subjects are partnered throughout the session their partners are anonymous.

Subjects are jointly read instructions detailing the particular payoff structure, the use of the computer as a smart scenario calculator¹³, how to enter their decisions, and how to read the

¹⁰ Cornes and Itaya (2003) show that equilibrium contributions in a multiple public goods environment are often internally Pareto inferior – “starting from a Nash equilibrium, it will generally be possible to find a Pareto superior allocation without increasing the aggregate level of resources devoted to the provision of public goods”. This is before any lottery is introduced.

¹¹ This point highlights the issue raised here – that a lottery can be implemented that causes people to invest in the less socially preferred public good. While the theoretical results here suggest the lottery is Pareto-improving as compared to the Nash equilibrium of zero contributions, this artefact exists only because of the linear utility function used. In current research, I show that lotteries introduced when utility is non-linear (e.g., Cobb-Douglas) can quickly reduce welfare below Nash levels.

¹² Andreoni and Petrie (2004) reports results from an experiment in which one public good is split into two components – contributions to the public good can either be announced or remain anonymous. The return from the two public goods is identical as it is really the same public good.

¹³ A “Payoff Wizard” was provided to help subjects make decisions. With three possible goods to contribute to, the payoff table normally provided to subjects – which they find complicated enough – would be a payoff cube. The Payoff Wizard allowed subjects to select allocation possibilities for themselves and others, see if the lottery would be run, and produces the resulting expected, winning and losing payoff (or just payoff in the event of no lottery or a

results at the end of a period. Subjects are also informed of the exchange rate for that session (from lab dollars to local currency), that there are 15 periods in a session, and that they will be paid privately at the end of the session.

The expected payoff function for the entire experiment is

$$(10) \quad \pi_i^e = x_i + (h_i/(h_i+H_{-i}))P_H + 0.75(g_i+G_{-i}) + 0.50(h_i+H_{-i}-P_H).$$

Subjects must select g_i and h_i subject to the constraints that $w=x_i+g_i+h_i$, $g_i \geq 0$ and $h_i \geq 0$. The constraints are enforced by the computer software both in the smart scenario calculator and in the decision box. Here, (10) is just a particular case of (9) so following the work in section 2.1 and recalling that $N=3$, (3) reduces to

$$(11) \quad h_i^N = 4/9 \cdot P_H.$$

To avoid negative levels of public good H (i.e., $H-P_H < 0$), Morgan and Sefton (2000) modified the subject payoff function such that an exogenous level of public good was provided each period. They argue that “[s]ince MPCR is constant for all levels of public good provision, then level effects (such as the exogenous provision of prize amounts) have no effect on *marginal* incentives” (emphasis theirs, p.789 footnote 9). This claim depends upon equilibrium behaviour, but by the authors’ own admission, equilibrium behaviour only approximates subject behaviour in public good experiments. Moreover, from a policy perspective, the government and private charities cannot be expected to exogenously fund lotteries which regularly lose money.

One option is to simply allow for negative levels of the public good, but this is an unreasonable solution. Alternatively, one can announce a fixed prize of P_H as long as H^* wagers are received. In the event that $H < H^*$, then P_H is a fraction of H .¹⁴ Such a scheme would introduce a large number of equilibria. Finally, the solution I have adopted is to return wagers in the event that $H < P_H$. Morgan (2000) shows that while this introduces an extra equilibrium point – if all agents believe the lottery will be called off, bettors contribute zero – other theoretical results are not changed.

Table 1 summarizes the experimental treatments and sets out the key theoretical predictions. In the baseline sessions, $P_H=0$ and the dominant solution is to free-ride on others’ contributions to both public goods. Accordingly, at the Nash equilibrium all agents keep their wealth for private consumption and aggregate profit is $\Pi^N=Nw=60$. A social planner would have all agents contribute to public good G – the *more* socially desirable public good – leading to an aggregate payoff of $\Pi^S=N^2mw=135$. Thus, at the Nash equilibrium with $P_H=0$ the efficiency is 44.4%. As the fixed-prize for public good H increases, the efficiency increases but at a slow rate. In fact, when $P_H=P_H^*=45$ so that people contribute all of their wealth as a wager, the efficiency at the Nash equilibrium is only 50%.

The last row in Table 1 is included for information purposes only. In this case, I calculate the efficiency of the same lottery as indicated in the first row of the table had it been

lottery that is cancelled).

¹⁴ This was the solution adopted by the Atlantic Lottery Corporation when it ran its ‘Million Dollar Lottery’ to fund the 2003 Canada Winter Games in Bathurst, New Brunswick. The million dollar top prize actually turned out to be closer to \$660,000.

applied to public good G . A social planner who has decided to use a lottery as a means of financing public good provision would always want to run the lottery for the good which is *more* socially desirable – the efficiency is always higher for the same prize.

In summary, three baseline sessions ($P_H=0$) will be run with 5 groups of 3 subjects each. A baseline session will be run at each of 3 different sites – Saint John, Nottingham, and Trento. This will provide enough data to test the Nash prediction of complete free-riding in an environment with two public goods – a experimental test not yet conducted. It also allows for cross-country comparisons. One of the three treatment session will be conducted at each site. With a baseline and treatment session at each site, meaningful comparisons can be made as to the effectiveness of each treatment. Moreover, with the use of dummy variables, I can test for the effect of increasing the lottery prize.

3.2 Predictions

Following from the results in section 2 and summarized in Table 1 a number of predictions consistent with a zero conjectural variations Nash equilibrium model can be made. A preliminary prediction can be made based on actions within the baseline sessions.

Prediction 0a: With a lottery prize set to zero, subjects' behaviour conforms to the Nash equilibrium prediction of complete free riding so that $g_i=0$ and $h_i=0$.

$$H_0: g_i=0$$

$$H_0: h_i=0$$

$$H_A: g_i>0$$

$$H_A: h_i>0$$

This is a pretty strict interpretation of the Nash equilibrium. Distribution-free tests (e.g., Moir, 1998c) are used for analysis as they impose the fewest assumptions on the data.¹⁵

As past experiments have shown subject behaviour does not necessarily correspond to Nash equilibrium predictions. In fact, Isaac and Walker (1988) show that higher MPCR values are associated with larger contributions. While there are no experiments with two public goods, it is reasonable to assume that the public good with a higher MPCR (good G in this case) might have higher contributions.

Prediction 0b: In the event that strong free-riding does not characterize the control sessions' data, it is expected that within each session, $g_i>h_i$.

While there is past empirical evidence to suggest that subject behaviour may not correspond with the Nash equilibrium there is no *a priori* reason to expect that subject behaviour will differ across cultures.

Prediction 0c: With a lottery prize set to zero, subjects' behaviour is indistinguishable

¹⁵ Where possible, Tobit analysis is used for regressions (as subjects decisions are restricted to $g_i \geq 0$ and $h_i \geq 0$) but these results are provided only to further support conclusions from exact randomization tests.

across the three sessions so that $g_i^{SJ} = g_i^{NH} = g_i^{TR}$ and $h_i^{SJ} = h_i^{NH} = h_i^{TR}$.

If there is no difference between behaviour in the baseline sessions, then the data from the three baseline sessions can be used jointly when I test for treatment effects.

The following predictions relate specifically to the introduction of the lottery for good H . The introduction of a lottery is predicted to increase wagers to good H .

Prediction 1: When a lottery prize is offered, contributions increase for the good in which the lottery is offered. For instance, when $P_H > 0$, $h_i^T > h_i^B$ (where superscripts T and B stand for treatment and baseline respectively).

Theory further predicts that wagers will increase along with increases in the prize.

Prediction 2: Larger lottery prizes are associated with larger values for h_i .

The theory also predicts that not only will contributions increase when a lottery is introduced but more importantly, net contributions (total wagers less the lottery prize) will increase. This is an especially important prediction, as the introduction of the lottery is meant to increase the amount of public good provided (or equivalently the amount of funds raised to provide the public good). Recall, when $H < P_H$ all wagers are returned. Prediction 3 (below) provides a strong test of the efficacy of lotteries as a tool for increasing public good provision.

Prediction 3: When a lottery prize is offered, net contributions increase for the good in which the lottery is offered. For instance, when $P_H > 0$, $H^T - P_H^T > H^B$ (where superscripts T and B stand for treatment and baseline respectively).

Similarly, net contributions are predicted to increase with the size of the lottery prize.

Prediction 4: Larger lottery prizes are associated with more of the public good being provided; in other words, $H - P_H$ increases with P_H .

Based on the theoretical prediction of complete free-riding, the introduction of a lottery increases the overall contribution to the public good thus leading to an increase in efficiency. Moreover, increasing the size of the fixed lottery prize is predicted to increase efficiency. Denoting efficiency as ξ ($\xi = \Pi / \Pi^S$ where Π is aggregate payoff for a particular group) then predictions 5 and 6 follow directly.

Prediction 5: When a lottery prize is offered, efficiency increases. For instance, when $P_H > 0$, $\xi^T > \xi^B$ (where superscripts T and B stand for treatment and baseline respectively).

Prediction 6: Larger lottery prizes are associated with increases in efficiency.

Even if contributions to H increase, it is not clear that efficiency will increase for two reasons. First, suppose that in the baseline sessions subjects keep half of their wealth

endowment for private consumption (X) and split the remaining half of their wealth between public goods G and H . If the introduction of the lottery causes people to substitute from X to H , then efficiency will increase. If the lottery causes people to substitute from G to H , then efficiency will fall. Second, if in the absence of a lottery $H > 0$, and if people wager less than the equilibrium amount when a lottery is available, then it may be the case that $H - P_H \leq 0$ and good H is not provided for at all, thus lowering efficiency. By modifying their payoff function, Morgan and Sefton (2000) avoid this important issue.

From (7) and (8) in section 2.1 we see that when $N=3$ and the MPCR lies between the values of $1/3$ and $2/3$ – here it is 0.5 – then in equilibrium, income distribution becomes quite skewed. While expected and aggregate income increase with the introduction of the lottery, these gains come at the expense of the lottery losers.

Prediction 7: When a lottery is available, lottery losers earn a lower income as compared to when no lottery was available. Moreover, this effect is larger as the prize increases.

If this prediction holds, then there is important new evidence that such public good lotteries can make income distribution less equitable, further enhancing the regressive nature of lotteries.

4. Results

Two sessions were conducted in Trento, Italy, at the Computable and Experimental Economics Laboratory (CEEL) – *trento_nolottery* and *trento_lottery*. Each session was identical except that in *trento_lottery*, a prize of 22.5 lab dollars was used as an incentive to encourage wagers to be used towards good H .

In each session, 15 subjects were individually seated at computer terminals with privacy shields. Each computer was running PGLottery software with all screens and instructions in Italian.¹⁶ A laboratory assistant read the instructions, in Italian, while the subjects read an electronic version (the instructions were always available to subjects from the Decision page). Subjects were clearly informed that they were identical in terms of payoff, that they were connected with two other people in the room, that this connection would remain in place until the end of the session, and that the session would last 15 periods.¹⁷ Because of the complexity of this environment, a Payoff Wizard was available which allowed subjects to calculate payoffs under a variety of ‘what-if’ scenarios. When they supplied their allocation decision for X , G , and H , and potential values for X , G , and H made by the other two members of their group, the resulting payoff was displayed. When there was a lottery, the Payoff Wizard alerted them as to whether the lottery was on (i.e., if $H > P_H$) and calculated the appropriate payoff. In the event that

¹⁶ This software was created by Rob Moir, Neil Buckley of McEEL and Marco Tecilla of CEEL. The software operates in both English and Italian. For a copy of this open source software (covered by the GNU General Public License) which includes the instructions, please contact the author (rmoir@unbsj.ca).

¹⁷ While the subjects were ‘partnered’ this partnership was effectively anonymous.

the lottery was on, the Payoff Wizard displayed the expected payoff (based on the probability h/H), the payoff if they won and the payoff if they lost. At the end of each period, each subject was informed of his own actions, the aggregate actions of others, his own payoff, and his cumulative payoff. In the lottery treatment, subjects were told whether or not the lottery was cancelled. In the event that the lottery was not cancelled, subjects were informed whether they won or lost the raffle. This information was also summarized in the Decision History page.

During the Trento sessions, a supplementary experiment followed the lottery experiment. This experiment was run to establish subjects' risk preferences. I will not be discussing these results here. The sessions took approximately 1.5 hours. On average, subjects earned approximately €18 in the *trento_nolottery* session and €13 in the *trento_lottery* session. Subjects earned an additional €3 on average for the second experiment in both sessions.¹⁸

The results in Morgan and Sefton (2000) show that lotteries are an effective tool for raising funds for public goods. On average, net provision (aggregate wagers less the fixed prize) under a lottery exceeds the amounts voluntarily contributed when no lottery is present. By modifying the experimental payoff function to include an exogenous contribution to the public good in the voluntary contributions sessions and then devoting the amount to exogenously fund a fixed prize in the lottery sessions, the authors avoid negative funding for the public good. While this is a clever design feature, it is implausible to expect governments or private charities to come up with such a funding scheme. Moreover, it is difficult to tell if there were any instances when the funds raised fell short of the fixed prize which, in the current scenario would lead to a return of wagers and no public good provision. For the aforementioned reason, direct comparison between data from Morgan and Sefton (2000) and these data is difficult.

4.1 Summary and Graphical Results

The results are summarized in Figures 2 and 3 and in Table 2. As a general convention, I will use upper-case letters to indicate data aggregated within a group and lowercase letters to indicate individual data. Figure 2 presents aggregate voluntary contributions to goods G and H for the *trento_nolottery* session. Figure 3 presents aggregate voluntary contributions to good G and initial aggregate wagers for the H-Raffle for the *trento_lottery* session (more will be said later about initial versus final wagers). Likewise, Table 2 summarizes the data, aggregated by group, across different periods.¹⁹

The results are quite striking. In the absence of a lottery, we quickly see large voluntary contributions to good G, while voluntary contributions to good H are small and quickly fall to zero (even in aggregate). Voluntary contributions to G seem to remain stable (although with significant variation across groups and hysteresis within groups) and possibly grow, until the last

¹⁸ At the time, €1 \approx \$1.64 CDN, so the average total payoff for the *trento_nolottery* session was about \$34.65 and \$26.40 for the *trento_lottery* session.

¹⁹ These include all periods, periods 3-13, 1-5, 6-10, 11-15, and period 15 alone. Periods 3-13 were selected to avoid early learning about the environment and the significant end-game effects.

two or three periods when they sharply drop off. In Figure 2, note that aggregate G contributions are identified by group number in order to appreciate the group-specific nature of cooperation and to highlight the variation in aggregate contributions. Both groups 2 and 4 realize 100% cooperation during significant portions of the session. This cooperation is entirely tacit as subjects could not communicate, nor were they aware of the identity of other members in their group.

When a lottery to raise funds for good H is in place, the results are almost the mirror image to the *trento_nolottery* results. Now aggregate voluntary contributions to good G start low and decline – though not to zero – while aggregate wagers on the H-Raffle start higher and remain relatively high (see Figure 3 in which aggregate wagers on the H-Raffle are identified by group number). Aggregate wagers on the H-Raffle do not seem to appreciably change at the end of the session. The large drop in efficiency can in part be explained by this reallocation of voluntary contributions from good G to wagers for the H-Raffle. Also important are the lottery cancellations. Recall, when $H < P_H$ then tokens wagered are returned and allocated to good X. In Table 2, we see that the lottery was cancelled 33 (out of a possible 75) times. The drop in average H_f (final wagers to the H-Raffle which is 0 if the lottery is cancelled) as compared to H_s (starting wagers) also makes this point. Generally speaking the number of lotteries cancelled declines throughout the session, but this is a very weak relationship. The average net H exceeds the Nash equilibrium predicted value of 7.5, but only if we consider only those lotteries which were not cancelled due to insufficient funds. This value drops towards 7.5 over the course of the experiment (see Figure 4). In fact, the predicted value from a univariate linear regression on period falls below 7.5 by the end of the session.

As Figures 2 and 3 indicate, the results are quite striking. While the observed voluntary contributions to good G (especially in the *trento_nolottery* session) are not predicted by traditional game theory, the increase in wagers on the H-Raffle follows directly from the theory presented in Sections 2.1 and 2.2. Efficiency falls, as was hinted at in Prediction 5, because of a reallocation away from voluntary contributions to good G towards wagers on the H-Raffle. Given the glaring nature of the results, the most appropriate statistical test is the interocular trauma test – “Plot the data. If the result hits you between the eyes, then it's significant.” Where necessary, the results are further supported by (generally non-parametric) statistical tests.

4.2 Hypothesis Testing

Result 0 *These data from a linear-payoff with two public goods environment do not conform to traditional game theoretic predictions (based on backwards induction) of strong free-riding. The public good with the higher marginal per capita return (MPCR) receives significant voluntary contributions, while strong free-riding, indeed complete free-riding, characterizes subjects' actions towards the good with the lower MPCR.*

Figure 2 provides the necessary support for this result. The presence of a second public good with a higher MPCR quickly produces complete free-riding (i.e., both individually and in aggregate) in the less socially desirable public good. In Table 3 we see that every group makes a positive aggregate contribution to good H in the first period (although this value is quite small as

indicated in Figure 2). By the second period, only 3 groups make positive contributions to good H, and by period 4 only 2 groups make positive contributions. From period 9 until the end of the session free-riding is complete – individual contributions to good H are zero for everyone. It seems that all we need to do to generate complete free-riding in a linear public good environment is involve a second, less socially desirable public good.

According to Newton's Third Law, every action has an equal and opposite reaction. While we cannot say much about the equality of the reaction, we seem to see a reaction to the free-riding towards good H; voluntary contributions to good G significantly depart from theoretical predictions of free-riding. Consider Figure 5 which expresses aggregate voluntary contributions to good G as a percentage of total endowment. Recall, the social optimum involves each subject allocating 100% of their tokens to good G, while the Nash equilibrium using backwards induction predicts a voluntary contribution of 0%. Median aggregate contributions in the first period start near 50% and hover largely in the 50-70% range for most of the session. Groups 2 and 4 realize significant periods of full cooperation throughout the session. Group 3 remains largely cooperative throughout the session, while groups 1 and 5 conform more to the Nash prediction and typical results in linear-payoff single public good experiments. In the final periods, median aggregate contributions decline significantly towards the Nash equilibrium prediction although there is still significant variation in aggregate contributions.

Other than the presence of a second public good, what might explain these high contributions to good G? Are Italian subjects, and more specifically subjects recruited at CEEL in Trento, unique in their cooperative tendencies? Could it be the high value for the MPCR for good G or perhaps the low number of subjects per group? Data from other experiments can assist in answering these questions. Fortunately a few weeks before my session, Professor Luigi Mittone (co-director of CEEL) ran a linear public good experiment. Twenty subjects were divided into 4 matched-but-anonymous groups of 5 and made voluntary contribution decisions for 30 periods. Using notation developed earlier, subject payoff is described as $\pi_i = x_i + 0.4G = w_i - g_i + 0.4G$. Figure 6 presents the data from the Mittone experiment. Likewise, Isaac, Walker, and Williams (1994) conducted an experiment in which subjects were divided into matched-but-anonymous groups of 4 and made voluntary contribution decisions for 10 periods. In this experiment, subjects either faced an MPCR of 0.3 or 0.75 (i.e., $\pi_i = w_i - g_i + 0.3G$ or $\pi_i = w_i - g_i + 0.75G$; in either case all individuals within a group had identical MPCRs). Data from the Isaac, Walker, and Williams experiment is presented in Figure 7.

In comparing Figure 6 and the left graph (MPCR=0.3) from Figure 7 we get the impression that Italian subjects are slightly more cooperative than their American counterparts (*has this been said elsewhere?*). While data from both sets of subjects indicate that there are dramatic end-game effects, the data from the American experiment show a general decline throughout the session towards the Nash equilibrium prediction of complete free-riding whereas Italian subjects seem to be able to sustain a certain degree of cooperation throughout much of the session. The data from the current session (Figure 5) suggest similar dynamics to the Mittone session (Figure 6) albeit with a greater degree of cooperation.

Next compare Figure 5 (*trento_nolottery* session) to the right graph (MPCR=0.75) from Figure 7. Now the MPCRs are identical. In the *trento_nolottery* session, the median aggregate contribution rises from around 50% and hovers in the 50-70% range for most of the session,

whereas in the Isaac, Walker, and William (1994) session with MPCR=0.75, the median aggregate contribution starts at about 45% and hovers in the 45-55% range for most of the session.

There are five important design differences between each experiment that make comparison difficult: number of subjects per group, number of periods, MPCR, experiment location (cultural differences), and social return – defined as $SR = (n * MPCR) / (\text{return from the private good})$. These are summarized in Table 4. To properly test the effect of including a second public good with a lower MPCR, one would have to control for these many factors.²⁰ Still, I cautiously suggest that, in a linear payoff environment, adding a second public good with a lower MPCR alters subject behaviour making them more cooperative in the good with the higher MPCR. Furthermore, the extremely strong free-riding results towards good H in the *trento_nolottery* session suggests that it is not lack of understanding or error that causes subjects to stray from the dominant solution in traditional linear public good experiments (i.e., with a single public good). They know how to free-ride, but they strategically choose not to.

Result 1 Introducing a lottery for good H increases individual allocation towards good H.

As predicted, introducing a lottery to raise funds for good H increases aggregate wagers as compared to voluntary contributions to H in the absence of a lottery (Figure 8). Median individual wagers towards the H-Raffle in *trento_lottery* fluctuate between 5 and 12 tokens, generally falling below the individual Nash equilibrium prediction of 10 tokens. In the *trento_nolottery* session, the median individual contribution to good H starts at 2 tokens and quickly falls to zero. Mann-Whitney tests for equality in distribution all reject the null of equal distributions at the 1% level of significance (Table 5 column 2) suggesting that the distribution of the wagers in *trento_lottery* is to the right of the distribution of contributions in *trento_nolottery*. Mann-Whitney tests suggest that this result also holds in aggregate (Table 5 column 3) though with fewer observations, the p-values rise slightly.

Result 2 Awaiting further data.

Result 3 Net contributions to H are not always significantly higher when a lottery is in place.

To appreciate the significance of this result, it is important to recall how this lottery works as specified by Morgan (2000). A raffle for prize P_H takes place only if $H \geq P_H$, and then $net H = (H - P_H)$. In the event that $H < P_H$ all individual wagers for the H-Raffle are returned and allocated to good X, and $net H = 0$. Thus $net H$ can be zero if the lottery is cancelled or if wagers just cover the cost of the prize.

Figure 9 presents the results graphically while Table 5 uses Mann-Whitney tests to present statistical results. While Mann-Whitney tests indicate that there is an increase in $net H$

²⁰ A direct test would involve running 5 groups of 3 people in Trento with the payoff function $\pi_i = w_i - g_i + 0.75G$.

in general (see column 4 of Table 5, particularly the results for periods 6-10, periods 11-15, and periods 3-13), period-by-period test results and median *net H* values (Figure 9) suggest that this is not a strong relationship.

The statistical results are complicated by two factors. First, the extremely strong free-riding results towards good H in the *trento_nolottery* session (as predicted by theory) mean that any positive net contribution to H in the *trento_lottery* session is a significant departure from 0.²¹ In this light, it is surprising that we ever fail to reject the null of no treatment effect as it relates to *net H*. The failures to reject the null, however, are due to the large number of lottery cancellations (see column 5 of Table 5). Only in periods 11 and 15, is the lottery not cancelled for at least one of the five groups. On average, slightly more than 2 lotteries are cancelled each period. More disturbing, a regression of lottery cancellations upon period indicates no significant effect of time on lottery cancellations.²² This result runs quite contrary to the Morgan and Sefton (2000) result in which sufficient funds were always raised to cover the prize.²³ Equally disturbing, it seems that subjects are attempting to cover the raffle prize, but just barely (see Figure 4). If we run a simple linear regression for all of the data:

$$net_h_t = \alpha_0 + \alpha_1 * period + \epsilon_t.$$

With all 75 observations we get:

$$net_h = 6.24 (1.872) - 0.12 (0.2052) * period,$$

where values in parentheses are standard errors. We can reject the null of *net H* = 0 (p-value=0.001) but we cannot reject the null of a time effect (p-value=0.575). The value of 6.24 is less than the predicted net H value of 7.5, suggesting that on average, the lottery will fail to raise the predicted amount for the public good. If we consider only those lotteries which were

²¹ This is similar to the argument used to suggest that positive contributions in a linear public good environment are ‘over-represented’ because we do not allow for under-contribution (i.e., negative contributions are not allowed). Here however, the constraint is imposed by subject behaviour (complete free-riding in the *trento_nolottery* session) and not the institution.

²² A simple linear regression reveals *cancellations* = 2.97 (0.5597) - 0.096 (0.0616) * *period*, where values in parentheses are standard errors. We can reject the null of mean cancellations equals zero (p-value=0.000) but we fail to reject a time effect of zero (p-value=0.141). Low R² and adjusted-R² values support this claim, 0.1588 and 0.0940 respectively, but the low number of observations (15) means more data is necessary if we are to be sure of such a claim.

²³ Modification of the payoff function used in Morgan and Sefton makes it difficult to see if any lotteries might have been cancelled when wagers were less than prize. Moreover, it is unclear how subject behaviour might be affected when they are told that the lottery will be cancelled if wagers are less than prizes (as they were in the current experiment). Finally, with the exception of the BADLOT session (where MPCR=0), Morgan and Sefton always had an MPCR of 0.75. As noted in Table 1, the predicted efficiency properties with a high MPCR means that over-wagering in their environment is less costly than in mine. Only further research can determine the effect of MPCR upon the efficiency of self-funded lotteries to provide public goods.

successful, then:

$$net_h = 14.11 (2.717) - 0.537 (0.2813) * period.$$

We can reject the null of $net\ H = 0$ (p-value=0.000) **and** we reject the null of no time effect (p-value=0.064). Subjects seem to be hunting for a solution in which they jointly wager the value of the prize. If this is the case, then selection of an optimal prize rule (i.e., $prize = f(wagers)$) is extremely important.

Result 5 *When the lottery is introduced, efficiency decreases substantially.*

There are significant efficiency effects to introducing a lottery in this environment, but opposite to those predicted by traditional game theory. Figure 10 presents this result graphically, while Table 6 provides statistical support in terms of Mann-Whitney test results. In both panels of Figure 10, lines are placed at 44.4% and 47.2% which are the Nash equilibrium predicted efficiencies in the *trento_nolottery* and *trento_lottery* sessions respectively.²⁴ Figure 10 also shows that there is significantly less variation in efficiency in the *trento_lottery* session and shows a clear declining trend towards the Nash equilibrium prediction. While statistical support for the conclusion that efficiency is less in the *trento_lottery* session on a period-by-period basis is mixed, when period data is grouped we always reject a null hypothesis of equal distributions (at the 1% level of significance).

As hinted at in the discussion to Prediction 5, reduced efficiency in the *trento_lottery* session might be expected for two reasons: **(1)** if there were significant contributions to good G in the *trento_nolottery* session that were replaced in the *trento_lottery* session by wagers on the H-Raffle, and **(2)** if net H in the *trento_lottery* session was lower than in the *trento_nolottery* session because of lottery cancellations. Of these two explanations, the first is undoubtedly the main reason for the decline in efficiency. Figure 11 presents aggregate G contributions by treatment. The introduction of a lottery for good H crowds-out voluntary contributions to good G. Table 7 presents Mann-Whitney test results which show statistically that this result holds in all but a few periods, and certainly when periods are grouped. The second reason is a less plausible explanation for the efficiency reduction, not because there were not a significant number of lottery cancellations, but because there was complete free-riding towards good H in the *trento_nolottery* session so without a lottery, net H was already zero.

Result 6 *Awaiting further data*

Result 7 *Lottery losers are worse off than if there had been no lottery at all.*

Figure 12 shows this result graphically – the distribution of payoffs for the lottery losers is distinctly to the left of individual payoffs when there was no lottery. Table 8 presents t-test results for the same data. The lottery was cancelled 33 times in 75 periods of observation (i.e., 5

²⁴ Efficiency cannot fall below 44.4% as that is the efficiency when all subjects contribute zero to both public goods. This corresponds to the Nash equilibrium prediction in the *trento_nolottery* sessions.

groups times 15 periods). There were a total of 42 lotteries generating 42 winners and 84 losers. We can easily reject the null of equal pay between lottery losers and subjects who did not have the opportunity for a lottery in favour of the alternative that those without the lottery actually realized a higher pay (associated p-value=0.0000; see Table 8). While this is predicted by the theory in section 2.1, the result is strengthened by the out-of-equilibrium behaviour in the *trento_nolottery* session (i.e., very high contributions to G). Alternatively, we can compare the payoff losers receive to the predicted Nash payoff of 20 when no lottery is present. Of the 84 payoff observations for lottery losers, 55 are less than or equal to 20. We can reject the null of lottery loser payoff equals 20 in favour of the alternative that it is less than twenty with an associated p-value of 0.0007.

5. Conclusions

It seems that adding a second public good in ‘public goods’ experiments leads to some rather strange results. When we have two linear public goods, one with a lower MPCR, we simultaneously find tremendous support for the traditional game theoretic prediction based on backwards induction and significant rejection of the same theoretic prediction. The good with a lower MPCR is quickly subject to complete free-riding – every individual in every group contributes zero to this public good. No other public good experiment, to my knowledge, has produced such conclusive free-riding results. At the same time, for the good with the higher MPCR, we see what seems to be even greater cooperation than is normally found in similar single public good experiments with linear payoffs. This suggests that contrary to other hypotheses involving subject misunderstanding or errors (on the side of cooperation), subjects really do understand what it means to free-ride. Moreover, they willingly abandon free-riding when there is the possibility of payoff gains from cooperation. This suggests strategic behaviour or perhaps homegrown preferences (i.e., subject utility is not a homothetic transformation of experimenter-induced payoffs) on the part of subjects.²⁵

Introducing a lottery in this environment, with surplus funds beyond the prize used to provide the public good with the lower MPCR, works at least qualitatively if not always quantitatively. Positive wagers often generate an increase in the amount of the related public good provided. This is the job they were meant to do. However, there are important caveats to this conclusion. First, there were a significant number of lottery cancellations in my sessions (44% of the lotteries were cancelled). This is dramatically different from Morgan and Sefton (2000). Second, the introduction of a lottery in this environment significantly worsens the payoffs from lottery losers. *Ex ante* identical agents with identical endowments would vote to create a lottery and will wager in an existing lottery as it means an increase in expected payoff. *Ex post* however, lottery losers would prefer to live in a world with either voluntary contributions or even in a world with complete free-riding. Finally, the introduction of a lottery in this two public good environment leads to an overall decrease in efficiency – social welfare declines. This occurs primarily because wagers for the lottery supporting the less socially desirable public good crowd-out the out-of-equilibrium voluntary contributions to the more

²⁵ See Scatlet (2000) for a discussion of these issues from a philosophical perspective.

socially desirable public good in the absence of a lottery.

Does the lottery ‘work’? It increases public good contribution as predicted, but to the ‘wrong public’ good (see Cornes and Itaya, 2003 for this point in a theoretical context). Moreover, each of the three caveats above suggest a possible decrease in social welfare. Significant lottery cancellations would cost money and would mean that some public goods are not provided at all, or in amounts that are less than if no lottery existed. Second, a lottery has important income distribution effects which compound any distributional effects already associated with lotteries – as the saying goes, “lotteries are a tax on the poor and the stupid”. Finally, in this environment, the lottery induces people to invest in the ‘wrong’ public good and in doing so, reduces their voluntary contributions to the ‘right’ public good. This causes an overall decrease in efficiency. The results from this experiment lend support to the argument that lotteries are not entirely socially useful.

- **{Mention the publicity result as a link to the Andreoni & Petrie (2004, JPubE)?}**

One must ask then, why lotteries? Falkinger (1996), and Falkinger et al. (2000) provide convincing theoretical proof and experimental evidence for a very simple revenue-neutral tax-subsidy scheme based on deviations of own contributions from the average contribution of others in an income class. Intuitively each individual receives on average $1/N$ of the social benefit from the provision of a public good, and should pay a tax or receive a subsidy based upon how far their own contribution strays from others’ in their income class. While Falkinger et al. (2000) do not run an experiment with different income classes, they do run sessions with heterogeneous payoffs. Using the values stated in their paper for session M5 (see p. 253), in equilibrium, agents with relatively stronger preferences for the private good always pay a tax to subsidize those with relatively weaker preferences for the private good. While the value of the tax and subsidy is small relative to total income, it may seem unfair to individuals to perpetually pay a tax to subsidize others’ consumption.²⁶ While the results for this simple mechanism look promising, the cost of data gathering, performing calculations, and managing collections and transfers could be quite prohibitive.²⁷ Moreover, Falkinger’s theory is based upon the existence of a single generic public good whereas there are many public goods in our society.

There are a number of arguments for studying lotteries and their relationships to public goods. First, and foremost, they work at the job they were intended to do; they raise funds

²⁶ Using the values in Falkinger et al. (2000), agents who have a stronger (weaker) preference for the private good pay a tax (receive a subsidy) of 4 lab dollars. To those with a stronger (weaker) preference for the private good, this amounts to a tax of $4/221.84=1.8\%$ (a subsidy of $4/171.85=2.3\%$) of equilibrium income.

²⁷ Kanbur and Clark (2002) state, “Paradoxically, therefore, observing free riding in the supply of public goods does not necessarily indicate social inefficiency, *once the costs of the “efficient” outcome are taken into account*” (p.17, italics mine). In other words, we must include the transaction costs associated with improving efficiency in public good provision. A lottery likely has substantially lower transaction costs than the Falkinger mechanism.

beyond what would be contributed voluntarily. Moreover, this result is derived through willful actions by all participants – those who are to pay a tax in under the Falkinger mechanism *ex post*, are not likely to do so happily. Second, state-run and charitable lotteries are already in existence. As states mature, rent seeking groups are better able to organize and lobby legislators to implement lotteries as a tax-shifting device (Mixon, Jr., et al., 1997). In fact, in 2002 Alberta introduced “Breakaway to Win” tickets which are sold for \$10 each. Profits from these tickets are expected to raise \$2 million per year for the Calgary Flames and the Edmonton Oilers – teams in the National Hockey League.²⁸ Do such teams represent a public good to the entire province of Alberta? Third, because they ‘work’ and because they are ‘here’, lotteries need to be studied in a more realistic environment with more than one generic public good. Perhaps the lesson we should learn is that to raise money for public good provision, the government should be the sole operator of lotteries and collect wagers net of prizes. While giving monopoly power to the government may mean a loss in efficiency of the lottery, such a scheme would prevent rival charities from running lotteries in order to compete against each other for limited funds.

While this research has been revealing, there is still work to do. We need to explore more fully the nature of competition between rival charities interested in implementing lotteries to raise funds.²⁹ Early research in a linear-homogeneous environment suggests that in a two public good world, it is not an equilibrium for only one charity to institute a lottery. Thus, if a less socially desirable public good is funded with a lottery, the fund-raisers at the charity with the more socially desirable public good will also institute a lottery. This certainly mitigates, *but does not eradicate*, some of the efficiency loss if the charity with the ‘wrong’ public good is the one that institutes a lottery. Finally, lottery-funded public good provision needs to be analyzed in a richer environment with more complex payoff/utility functions. Preliminary analysis in a two public good environment with Cobb-Douglas payoffs suggests that even relatively small prizes can lead to aggregate payoffs lower than the Nash equilibrium payoff without lotteries.

In addition to the obvious direct application to lottery fund-raising for public goods, there is another unique application for this data. Under Sharia Law, interest can only be earned in certain cases. If an investment is used to generate profit, then ‘profit-sharing’ effectively allows for an interest rate to be charged (Aluko, 1999). However, money in a savings/deposit account is ‘sleeping’ and under strict application of Sharia Law, should not earn interest. Banks in Iran do not offer interest rates on such accounts. Instead they offer a depositor a chance to win a fixed prize based on the depositor’s share of total deposits. Thus, further research in this area may have direct implications for the financial sector under Sharia Law.

²⁸ See <http://calgary.cbc.ca/regional/servlet/View?filename=nhllotteryca020116> (accessed 8 October 2003) for details.

²⁹ The Ontario Early Years foundation for instance requires that groups accepting funding refrain from other fundraising activities.

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Appendix 1: TABLES

TABLE 1: Experimental Treatments and Theory Predictions

	$P_H=0$	$P_H=11.25$	$P_H=22.5$	$P_H=33.75$
Groups (Individuals)	15 (45)	5 (15)	5 (15)	5 (15)
g_i^N	0	0	0	0
h_i^N	0	5	10	15
g_i^S	20	20	20	20
$H^N - P_H$	0	$15 - 11.25 = 3.75$	$30 - 22.5 = 7.5$	$45 - 33.75 = 11.25$
$\Pi^N / \Pi^S (P_H \geq 0, P_G = 0)$	$60 / 135 = 0.444$	$61.875 / 135 = 0.458$	$63.75 / 135 = 0.472$	$65.625 / 135 = 0.486$
$\Pi^N / \Pi^S (P_H = 0, P_G \geq 0)$	$60 / 135 = 0.444$	$83.4375 / 135 = 0.618$	$106.875 / 135 = 0.792$	n/a ³⁰

³⁰ When $P_G=22.5$ then at the Nash equilibrium, all wealth is wagered in the G lottery. There is no reason to increase P_G beyond 22.5.

TABLE 2: Mean Aggregate Values (Standard Deviations) by Treatment

All Periods (Number of Observations = 75)

	G pred.=0,0	H_s pred.=0,30	H_f pred.=0,30	Net H pred.=0,7.5	Efficiency ($\Pi/135$) pred.=44.4,47.2	Number of Lottery Cancellations pred.=n/a,0
No Lottery	33.87 (18.650)	0.89 (2.403)	0.89 (2.403)	0.89 (2.403)	76.13 (17.223)	n/a
Lottery $P_H=22.5$	9.13 (7.221)	24.69 (10.809)	17.91 (17.080)	5.31 (7.669)	54.87 (5.982)	33

Periods 3-13 (Number of Observations = 55)

	G pred.=0,0	H_s pred.=0,30	H_f pred.=0,30	Net H pred.=0,7.5	Efficiency ($\Pi/135$) pred.=44.4,47.2	Number of Lottery Cancellations pred.=n/a,0
No Lottery	37.07 (18.932)	0.55 (2.124)	0.55 (2.124)	0.55 (2.124)	78.97 (17.516)	n/a
Lottery $P_H=22.5$	8.69 (6.831)	24.82 (11.304)	17.78 (17.561)	5.51 (8.111)	54.53 (5.637)	25

Periods 1-5 (Number of Observations = 25)

	G pred.=0,0	H_s pred.=0,30	H_f pred.=0,30	Net H pred.=0,7.5	Efficiency ($\Pi/135$) pred.=44.4,47.2	Number of Lottery Cancellations pred.=n/a,0
No Lottery	34.56 (15.278)	2.6 (3.629)	2.6 (3.629)	2.6 (3.629)	77.41 (13.885)	n/a
Lottery $P_H=22.5$	11.56 (7.805)	24.64 (12.793)	16.84 (19.154)	6.04 (9.383)	57.39 (6.112)	13

***** should average net H be calculated only in instances where $l_{cancel}=0$ (i.e., where the lottery is on)? If so: 9.48 (8.104); 10.10 (8.633); 12.58 (10.113); 8.88 (6.615); 7.74 (7.378); 7.5 (7.314).

Periods 6-10 (Number of Observations = 25)

	G pred.=0,0	H_s pred.=0,30	H_f pred.=0,30	Net H pred.=0,7.5	Efficiency ($\Pi/135$) pred.=44.4,47.2	Number of Lottery Cancellations pred.=n/a,0
No Lottery	38.88 (17.444)	0.08 (0.277)	0.08 (0.277)	0.08 (0.277)	80.474 (16.162)	n/a
Lottery <i>P_H</i> =22.5	10.24 (7.108)	23.28 (10.776)	16.32 (16.673)	4.62 (6.512)	55.64 (5.611)	12

Periods 11-15 (Number of Observations = 25)

	G pred.=0,0	H_s pred.=0,30	H_f pred.=0,30	Net H pred.=0,7.5	Efficiency ($\Pi/135$) pred.=44.4,47.2	Number of Lottery Cancellations pred.=n/a,0
No Lottery	28.16 (21.775)	0 (0)	0 (0)	0 (0)	70.52 (20.162)	n/a
Lottery <i>P_H</i> =22.5	5.6 (5.377)	26.16 (8.726)	20.56 (15.605)	5.26 (7.061)	51.58 (4.795)	8

Period 15 (Number of Observations = 5)

	G pred.=0,0	H_s pred.=0,30	H_f pred.=0,30	Net H pred.=0,7.5	Efficiency ($\Pi/135$) pred.=44.4,47.2	Number of Lottery Cancellations pred.=n/a,0
No Lottery	17 (17.436)	0 (0)	0 (0)	0 (0)	60.185 (16.144)	n/a
Lottery <i>P_H</i> =22.5	4 (4.183)	30 (7.314)	30 (7.314)	7.5 (7.314)	50.93 (3.593)	0

TABLE 3: Strong Aggregate Free-riding for Good H (No Lottery)

Period	Groups with	
	H > 0	H = 0
1	1,2,3,4,5	none
2	3,4,5	1,2
3	3,4,5	1,2
4	3,5	1,2,4
5	3,5	1,2,4
6	none	1,2,3,4,5
7	3	1,2,4,5
8	3	1,2,4,5
9-15	none	1,2,3,4,5

TABLE 4: Experimental Design Differences

Number of Groups	Subjects per Group	Periods	MPCR	SR	Location	Source
5	3	15	MPCR _H =0.5 MPCR _G =0.75	SR _H =1.5 SR _G =2.25	Italy	Moir (2004)
4	5	30	0.4	2.0	Italy	Mittone (2004)
17	4	10	0.3	1.2	USA	Isaac, Walker & Williams (1994)
10	4	10	0.75	3.0	USA	Isaac, Walker & Williams (1994)

**TABLE 5: Mann-Whitney Tests for Equality in Distribution
Individual H Wagers, Aggregate H Wagers, Net H**

Period	p-values (Nobs)			Lotteries Cancelled
	<i>h_s</i>	<i>H_s</i>	<i>net H</i>	
1	<i>0.0012 (15,15)</i>	<i>0.0088 (5,5)</i>	0.1693 (5,5)	3/5
2	<i>0.0016 (15,15)</i>	<i>0.0088 (5,5)</i>	0.5775 (5,5)	3/5
3	<i>0.0002 (15,15)</i>	<i>0.0160 (5,5)</i>	0.4506 (5,5)	2/5
4	<i>0.0001 (15,15)</i>	<i>0.0082 (5,5)</i>	0.6379 (5,5)	3/5
5	<i>0.0001 (15,15)</i>	<i>0.0080 (5,5)</i>	0.2188 (5,5)	2/5
6	<i>0.0000 (15,15)</i>	<i>0.0053 (5,5)</i>	0.1360 (5,5)	3/5
7	<i>0.0000 (15,15)</i>	<i>0.0071 (5,5)</i>	0.1261 (5,5)	2/5
8	<i>0.0000 (15,15)</i>	<i>0.0071 (5,5)</i>	0.1955 (5,5)	2/5
9	<i>0.0001 (15,15)</i>	<i>0.0053 (5,5)</i>	<i>0.0539 (5,5)</i>	2/5
10	<i>0.0000 (15,15)</i>	<i>0.0052 (5,5)</i>	0.1336 (5,5)	3/5
11	<i>0.0000 (15,15)</i>	<i>0.0053 (5,5)</i>	<i>0.0053 (5,5)</i>	0/5
12	<i>0.0001 (15,15)</i>	<i>0.0052 (5,5)</i>	<i>0.0528 (5,5)</i>	2/5
13	<i>0.0000 (15,15)</i>	<i>0.0053 (5,5)</i>	0.3173 (5,5)	4/5
14	<i>0.0000 (15,15)</i>	<i>0.0053 (5,5)</i>	0.0539 (5,5)	2/5
15	<i>0.0000 (15,15)</i>	<i>0.0052 (5,5)</i>	<i>0.0052 (5,5)</i>	0/5
1-5	<i>0.0000 (75,75)</i>	<i>0.0000 (25,25)</i>	0.7513 (25,25)	13/25
6-10	<i>0.0000 (75,75)</i>	<i>0.0000 (25,25)</i>	<i>0.0005 (25,25)</i>	12/25
11-15	<i>0.0000 (75,75)</i>	<i>0.0000 (25,25)</i>	<i>0.0000 (25,25)</i>	8/25
3-13	<i>0.0000 (165,165)</i>	<i>0.0000 (55,55)</i>	<i>0.0000 (55,55)</i>	25/55

Values in *italics* are significant at traditional levels of significance (i.e., 0.10 or less). Values in **bold** indicate distributions counter to theory (i.e., net H was actually higher when there was no lottery, despite theoretical predictions).

TABLE 6: Mann-Whitney Test for Equality in Distribution Efficiency

Period	p-value	Notes
1	0.0758	Nobs=5,5; *
2	0.0283	Nobs=5,5; **
3	0.0090	Nobs=5,5; ***
4	0.0758	Nobs=5,5; *
5	0.1172	Nobs=5,5
6	0.0163	Nobs=5,5; **
7	0.0088	Nobs=5,5; ***
8	0.0088	Nobs=5,5; ***
9	0.0472	Nobs=5,5; **
10	0.1745	Nobs=5,5
11	0.1745	Nobs=5,5
12	0.0749	Nobs=5,5; *
13	0.0937	Nobs=5,5; *
14	0.1425	Nobs=5,5
15	0.7540	Nobs=5,5
1-5	0.0000	Nobs=25,25; ***
6-10	0.0000	Nobs=25,25; ***
11-15	0.0016	Nobs=25,25; ***
3-13	0.0000	Nobs=55,55; ***

In all instances, the difference between the efficiency with no lottery and with the lottery was positive, suggesting that the environment without the lottery had a higher mean efficiency. Rejection of the null hypothesis of equal distributions at the 1%, 5% and 10% levels of significance are indicated by ***, **, and * respectively.

**TABLE 7: Mann-Whitney Test for Equality in Distribution
Aggregate G Contribution**

Period	p-value	Notes
1	0.0749	Nobs=5,5; *
2	0.0163	Nobs=5,5; **
3	0.0090	Nobs=5,5; ***
4	0.0283	Nobs=5,5; **
5	0.0758	Nobs=5,5; *
6	0.0163	Nobs=5,5; **
7	0.0090	Nobs=5,5; ***
8	0.0086	Nobs=5,5; ***
9	0.0472	Nobs=5,5; **
10	0.1172	Nobs=5,5
11	0.0278	Nobs=5,5; **
12	0.0740	Nobs=5,5; *
13	0.0937	Nobs=5,5; *
14	0.0593	Nobs=5,5; *
15	0.3443	Nobs=5,5
1-5	0.0000	Nobs=25,25; ***
6-10	0.0000	Nobs=25,25; ***
11-15	0.0001	Nobs=25,25; ***
3-13	0.0000	Nobs=55,55; ***

In all instances, the difference between the aggregate G contribution with no lottery and with the lottery was positive, suggesting that the environment without the lottery led to a higher mean aggregate contribution to G. Rejection of the null hypothesis of equal distributions at the 1%, 5% and 10% levels of significance are indicated by ***, **, and * respectively.

TABLE 8: Difference in Payoffs

	N	Mean Period Payoff (Stdev.)
No Lottery	225	34.26 (8.8113)
Lottery losers	84	17.78 (6.1901)
Difference (Sterr.)		16.48 (1.0467)
t-statistic		15.7454
p-value		0.0000

Appendix 2: FIGURES

Please note, the group figures are not visible on the following graphs (a Stata to WordPerfect conversion problem). Hopefully I will be able to correct this by the time I reach Toronto, and certainly for my presentation.

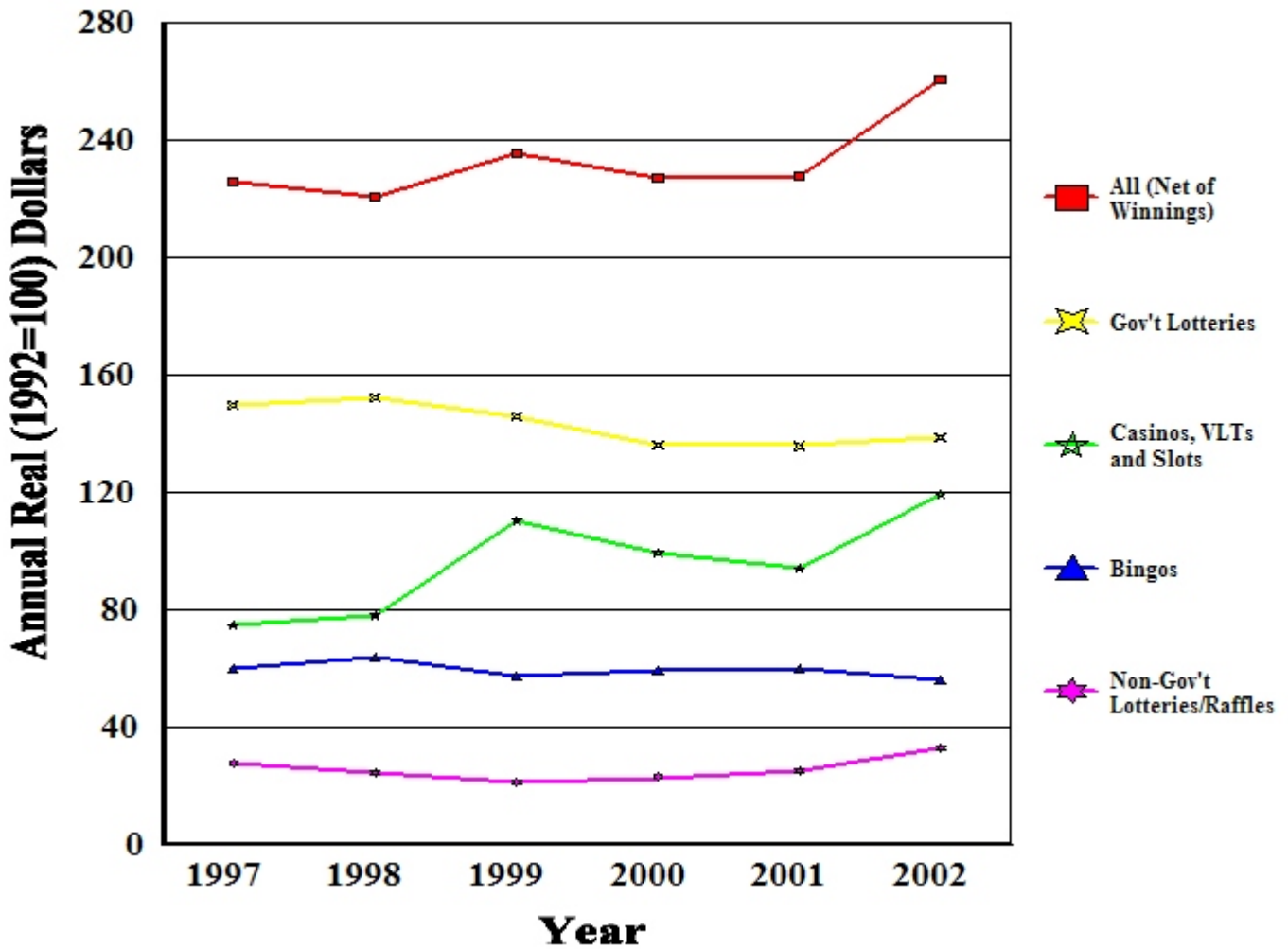


FIGURE 1: Average Annual Canadian Household Expenditure on Games of Chance³¹

³¹ These data were retrieved from CANSIM Table 2030014. They were converted to real values using CANSIM Series V18702622 which is the CPI (excluding its 8 most volatile components) using 1992 as a base year and the 2001 basket definition.

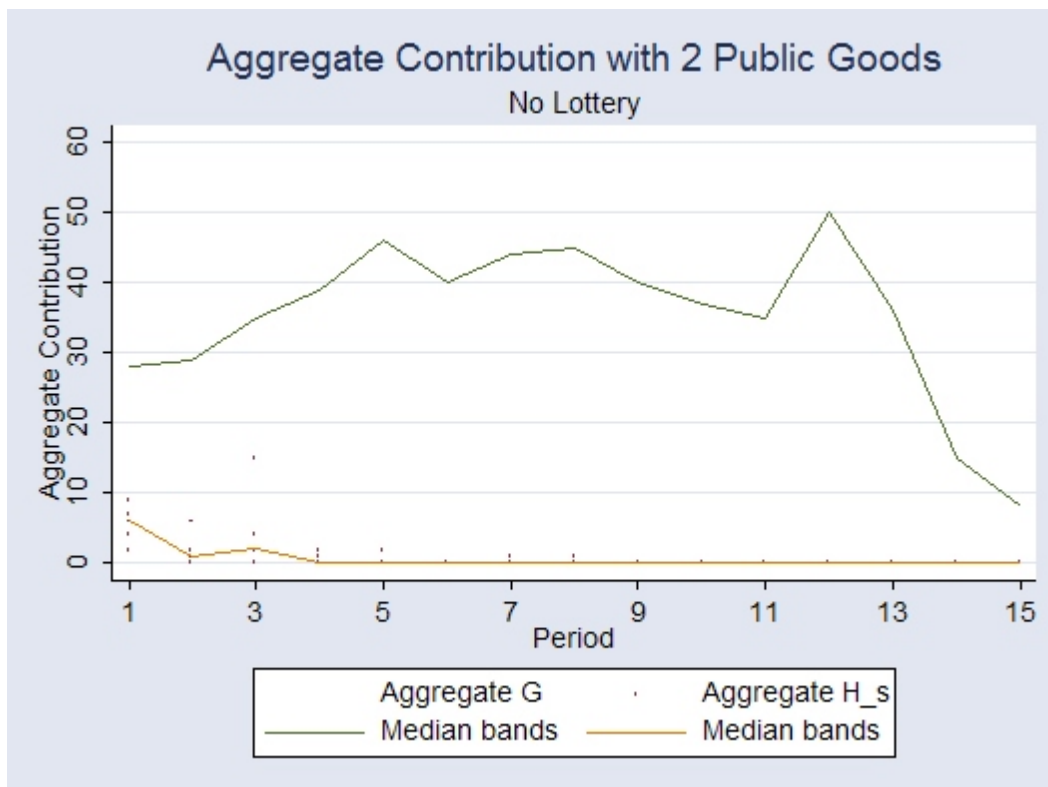


FIGURE 2

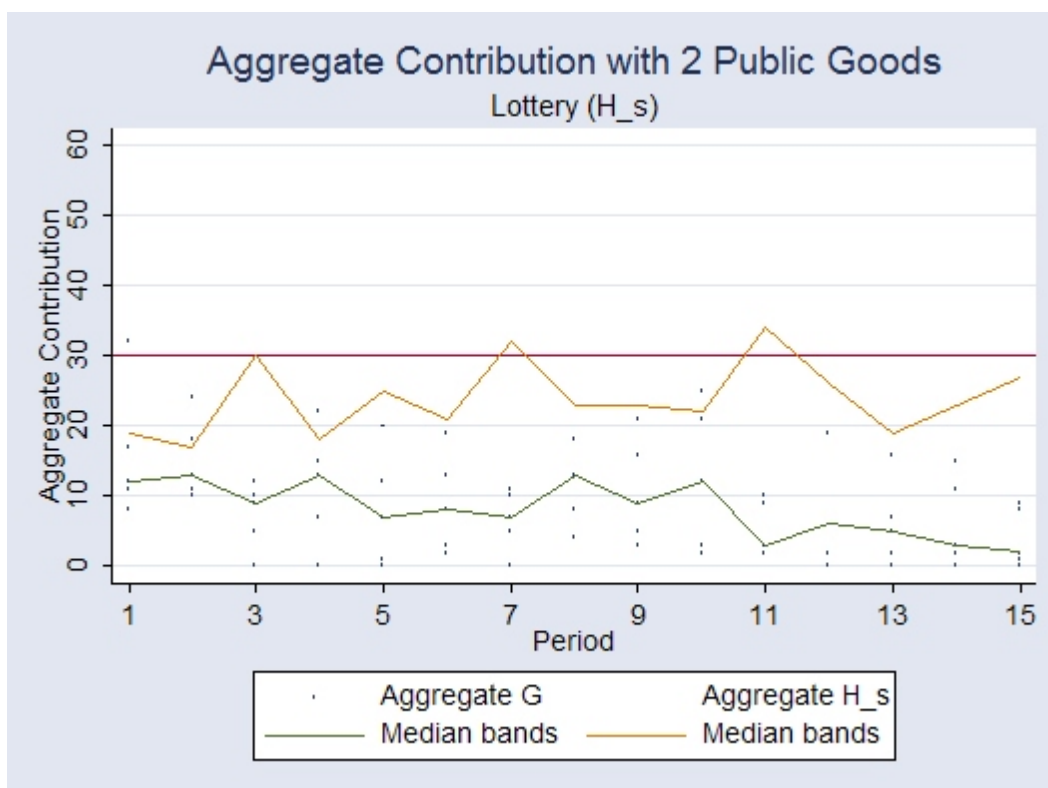


FIGURE 3

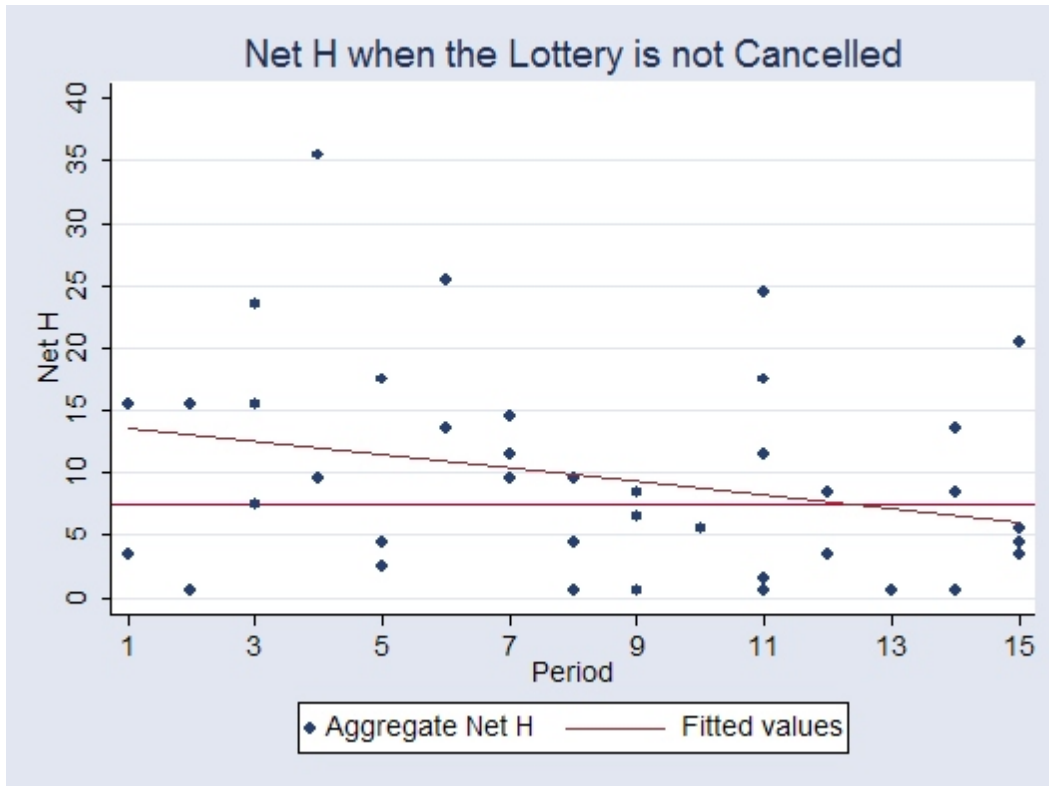


FIGURE 4

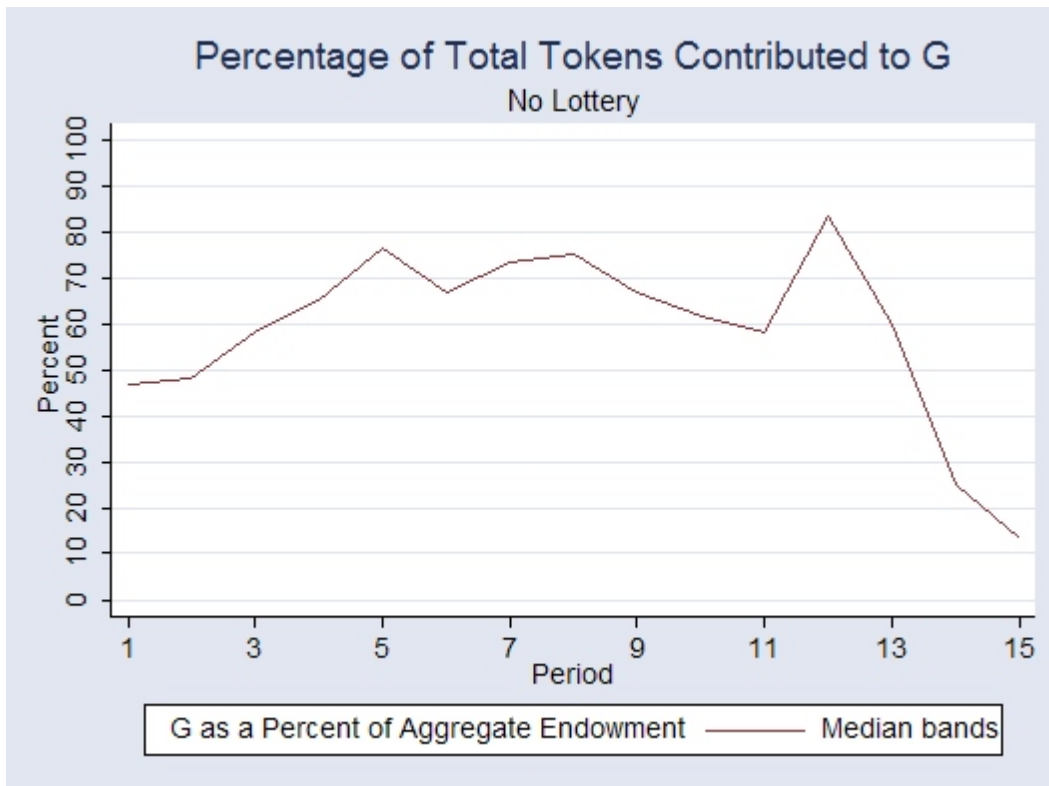


FIGURE 5

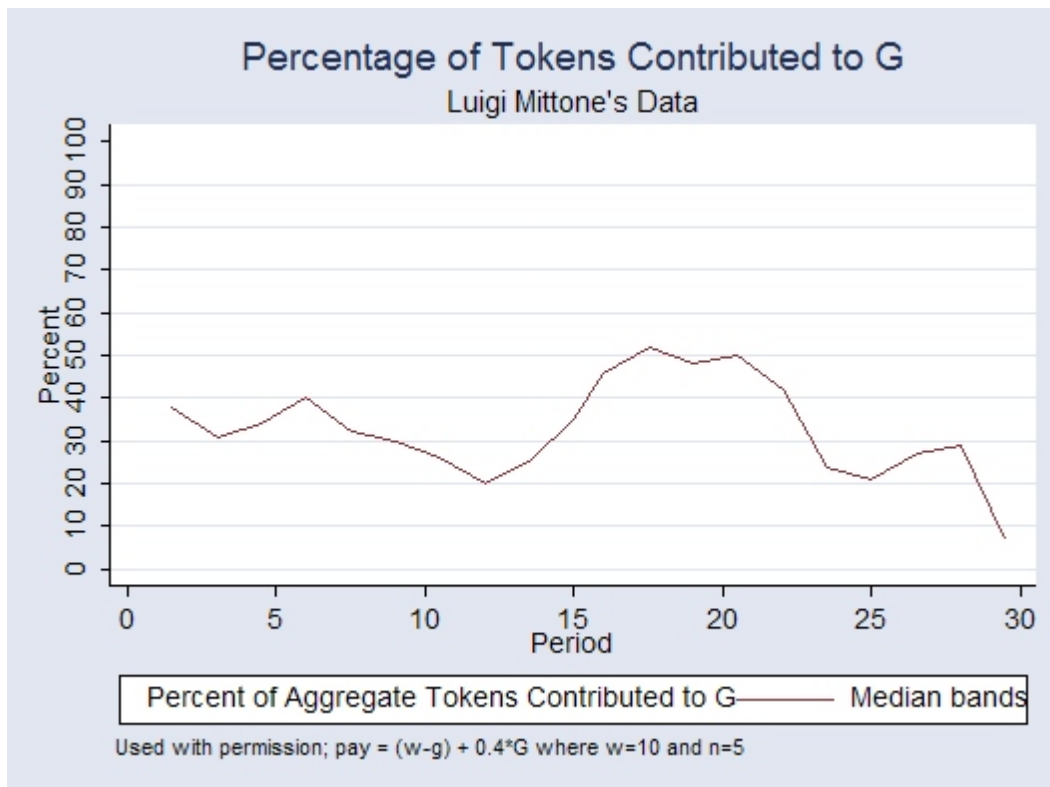


FIGURE 6

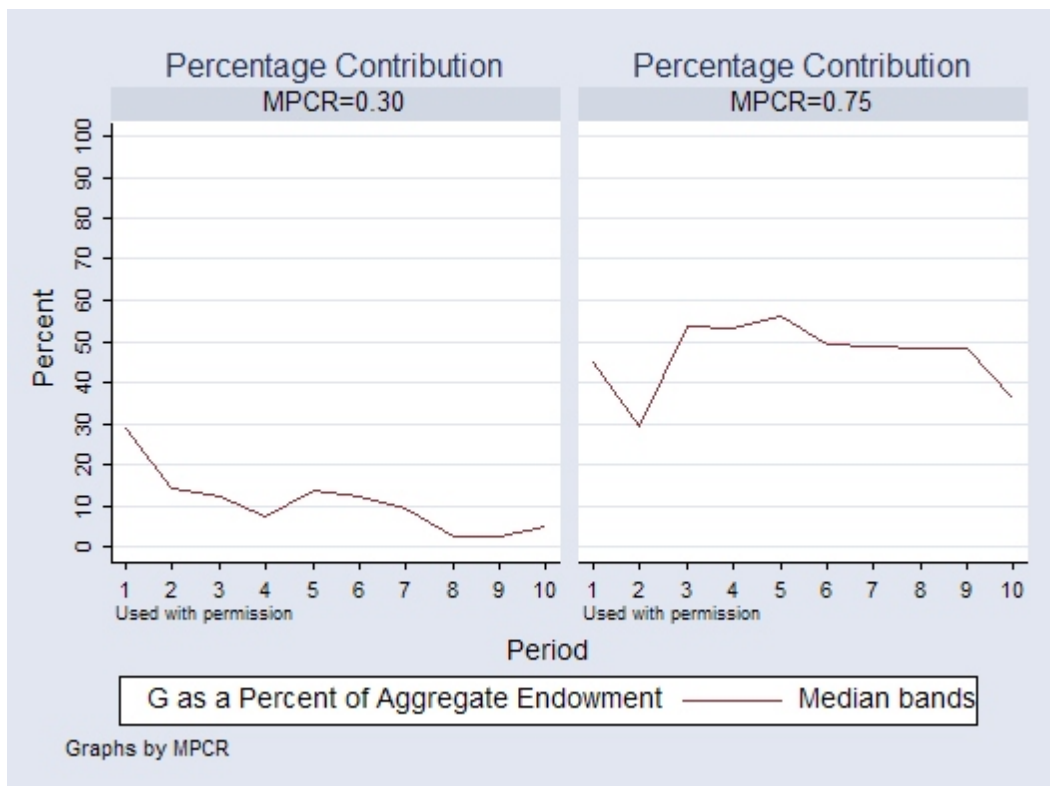


FIGURE 7

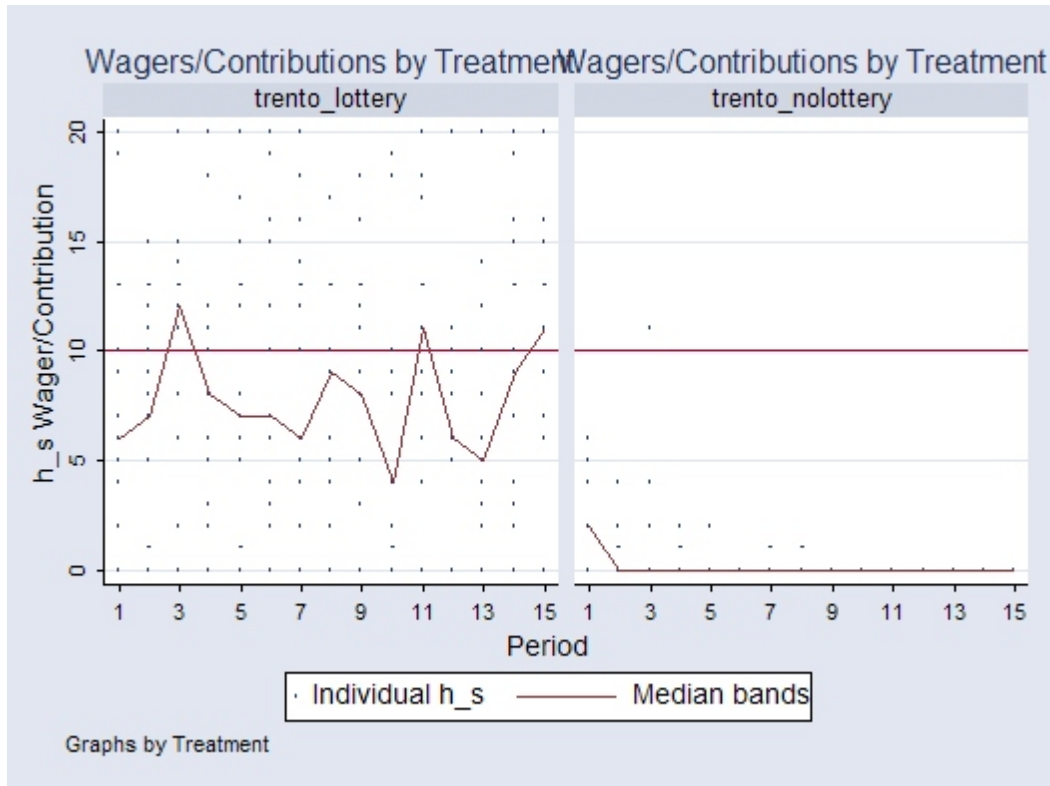


FIGURE 8

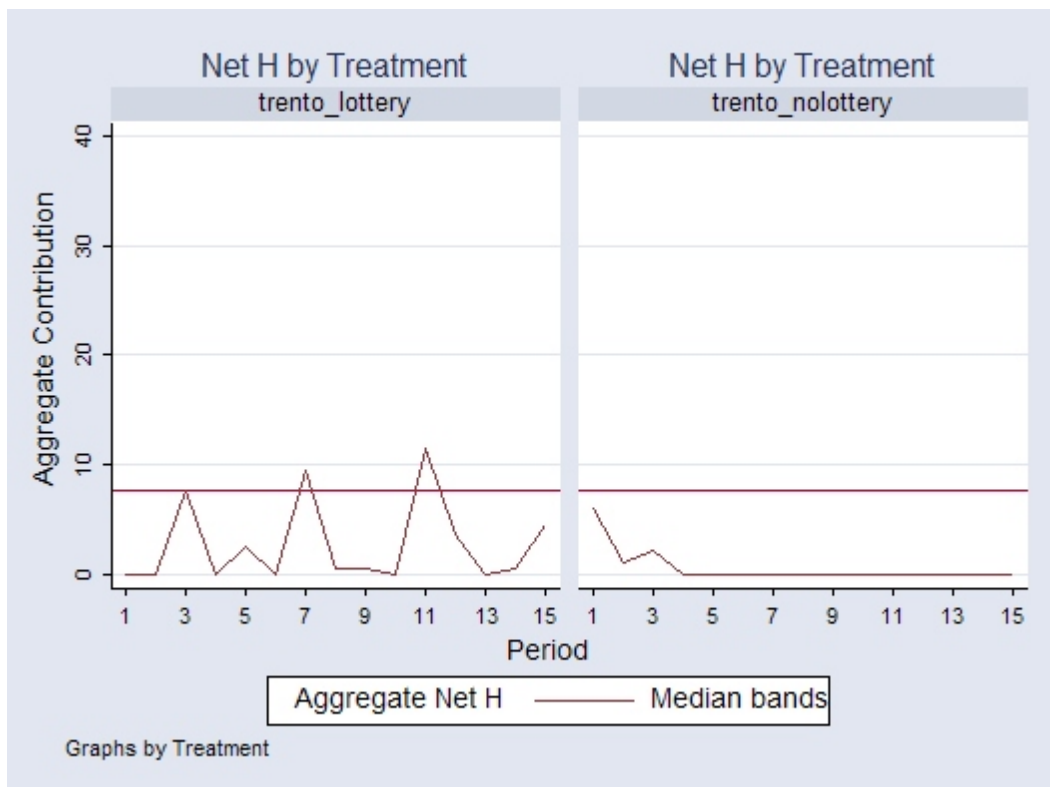


FIGURE 9

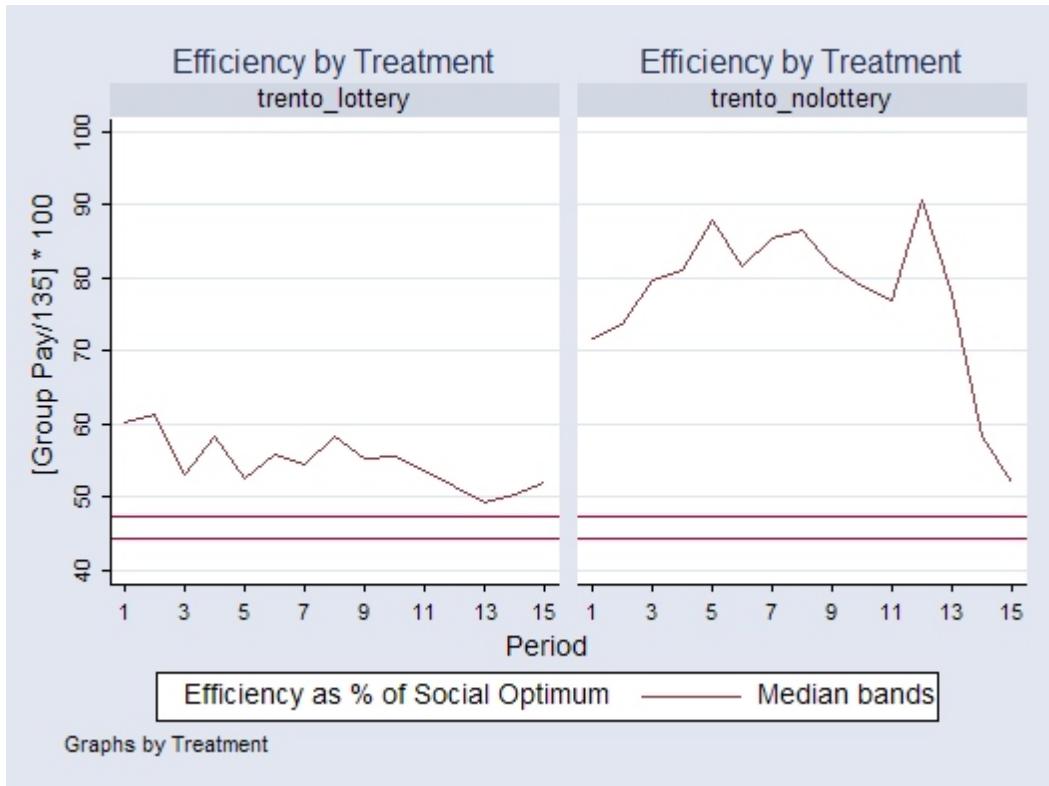


FIGURE 10

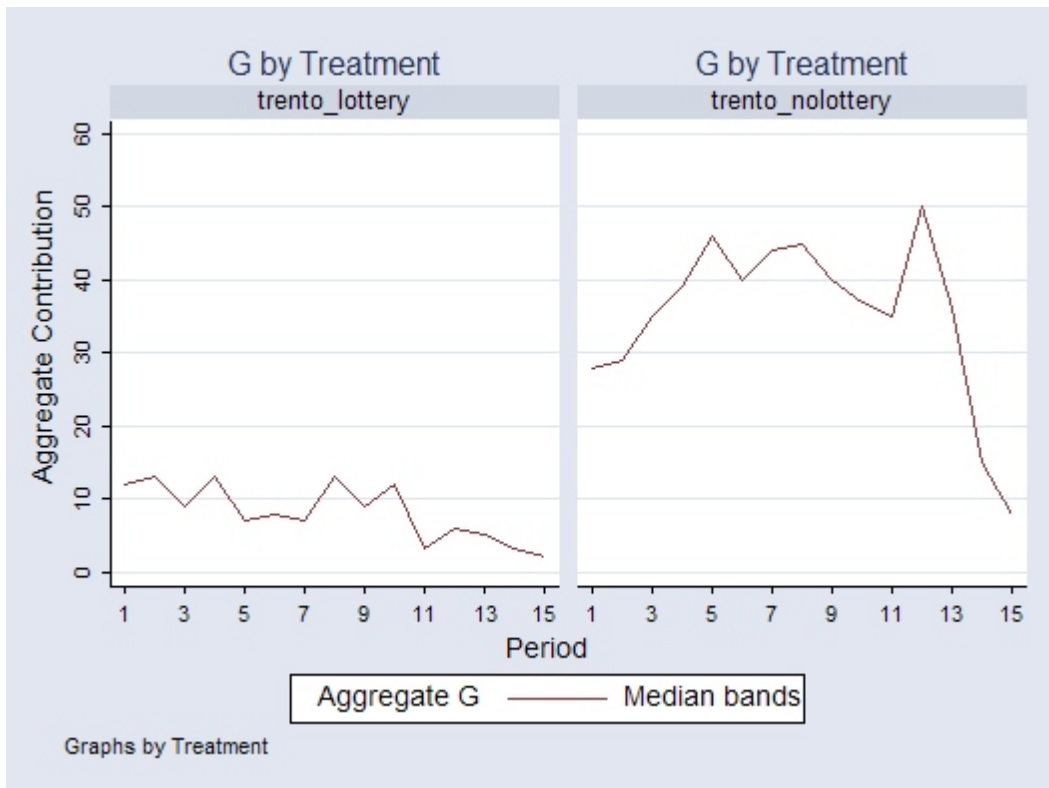


FIGURE 11

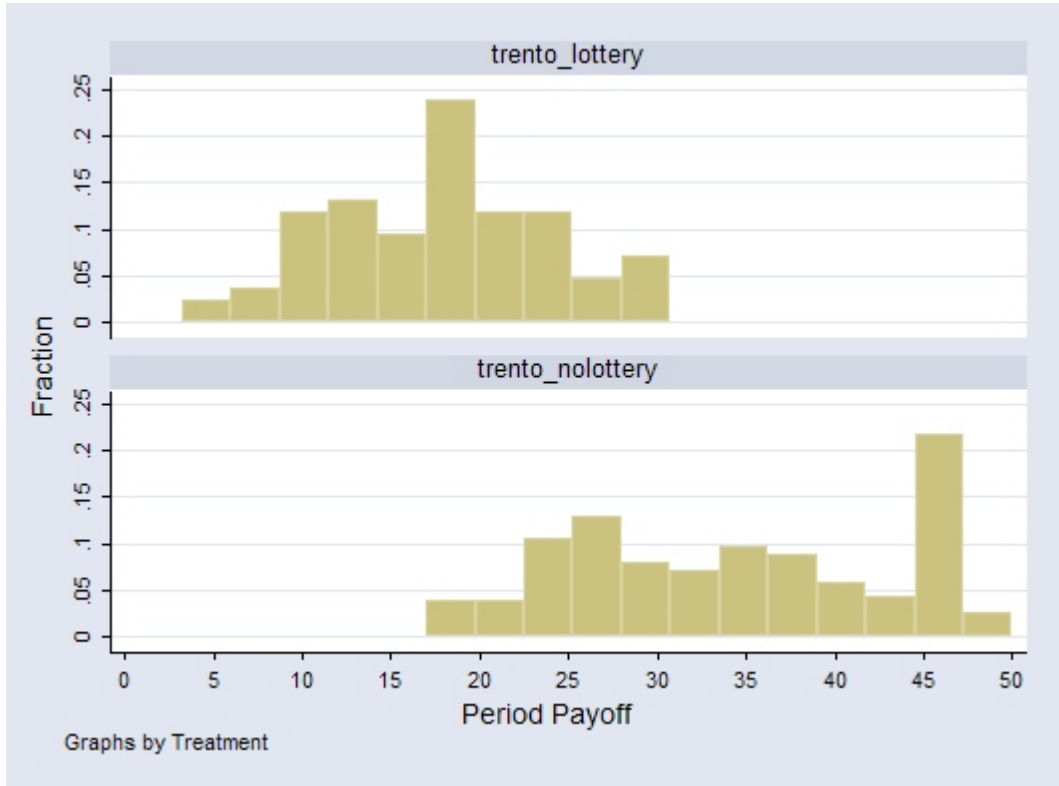


FIGURE 12: Pay to Lottery Losers vs Pay with No Lottery