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Essays in Pro-social Behavior

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ABSTRACT

This dissertation examines individuals' actions to improve social outcomes when unrecoverable investments are necessary. Situations involving non-pecuniary and pecuniary investments are considered. In the former, the prerequisite of real effort - a non-pecuniary, unrecoverable investment - is examined when said effort determines an individual's ability to procure their preferred social outcome. Theoretical predictions over an individual's effort provision are based on their revealed preferences for the social distribution of wealth according to the general axiom of revealed preference (GARP). Laboratory experiments reveal that individuals' effort provisions do not support the assumption of stable preferences (transitivity) of wealth distribution. Specifically, individuals who reveal a preference for egalitarian outcomes do not exert enough real effort toward said outcomes when all of the wealth can be distributed directly to them. In the latter, pecuniary situation, auction formats that require all bidders to pay their bid (i.e., all-pay auctions) are studied as a way of funding public goods, specifically in the context of charity auctions. An innovative theoretical variation of the war of attrition is designed. This variation requires bidders to make unrecoverable upfront investments in the auction in order to participate, and the amount of one's investment dictates how much one can potentially bid in the auction. In addition, an empirical analysis of this theoretical variation is provided via laboratory experiments. These experiments seek to highlight the bidder-specific and mechanism-specific characteristics that may lead to greater success in charitable fund-raising. The results suggest that auction mechanisms with an incremental bidding design outperform mechanisms with a lump-sum bidding design.

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DEDICATION

To my parents, the greatest teachers I have ever had.

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Statistics on volunteering reported by the Bureau of Labor Statistics (2013) show that approximately 26.5% of Americans volunteer a median of 50 hours annually for non-profit organizations. According to the Red Cross, approximately 9.5 million Americans donated blood in 2012. Pro-social activities such as these are evidence that some individuals experience personal benefit from social outcomes that transcend their immediate self-interest. This behavior is economically relevant and should be incorporated into our models. The foremost method of describing this behavior is by way of defining an individual's preferences for social outcomes. In particular, Andreoni (1990) outlines a social preference theory that allows individuals to have increasing utility in the improved outcomes of others, and Andreoni and Miller (2002) provide empirical evidence in support of this theory.

Using this framework, this chapter addresses a largely unconsidered dimension of social behavior: the directed effort that is necessary to generate one's preferred social outcome. In many situations it is not enough to simply express one's preference for social outcomes for those outcomes to then occur, although in many experimental studies this is all that is required. Eliciting a preference in this manner is likely an over-simplified method of understanding pro-social behavior in many naturally-occurring situations, such as the ones exemplified above. One way we can begin to close this gap is to incorporate a costly task that is associated with the successful implementation of one's social preference, whatever that preference may be. The core question this chapter attempts to answer is: Do individuals manifest effort in a way that is consistent with rational social preference theory? A model of effort provision is established in conjunction with social preference theory to predict individual action toward a social outcome, and laboratory experiments provide an empirical evaluation of this theory.

The experimental results reported in this chapter suggest that while effort provision is generally

consistent with the theory, social outcomes are not. In particular, those who reveal relatively

pro-social preferences (maximize welfare over personal gain) fail to procure their "preferred"

outcomes too frequently, by very small margins, when the state of the world is highly inequitable

in their favor. In situations where pro-social individuals have the opportunity to eschew effort

for a large personal gain, they do so – despite this outcome having already been revealed worse

by the individual. However, similar analysis of relatively selfish individuals (maximizing

personal gain over welfare) reveals no inconsistency between their stated social preferences and

their procurement of said preferences.

Several studies in both the economic and psychology literatures have illustrated that pro-social

behavior can be a mercurial social phenomenon difficult to express in the form of an internally

consistent preference. Within a modified dictator game, Dana et al. (2007) compares dictator

choice in treatments where the receiver's payout is known to treatments where the receiver's

payout is not known (but may become known at no cost). When the receiver's payout is

unknown, dictators became much more self-serving compared to when it is known.[1] These

authors argue that subjects often display an illusory preference for fairness in many dictator

games, but require only the slightest opportunity to act in their self-interest for their behavior to

change.

There are several studies, including Dana et al. (2007), that suggest individuals endure

dissonance when faced with making a pro-social decision at a personal expense. In a laboratory

experiment, Lazear (2009) finds that individuals will often choose to remove themselves from the

situations that typically lead to them sharing. DellaVigna (2009) reports similar results in a field

experiment for fundraising. Specifically, when individuals are told the time the fundraisers will

visit there is a ten to twenty-five percent decrease in the number of doors opened. The behaviors

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[1]Dana et al. (2007) has been shown to be robust by Larson and Capra (2009) and Grossman (2010).

in each of these studies provide support for cognitive dissonance influencing social outcomes by motivating individuals to avoid certain information or situations, if possible, as a way of abating the dissonance (Festinger 1957).

It may be more natural, then, to say individuals do not have "preferences" regarding social outcomes, rather they have a "constraint" that limits their ability to act in their own self-interest.[2] Rabin (1995) discusses theoretically how, in the presence of a moral constraint, individuals may seek to relax that constraint by avoiding information or situations in a manner that is consistent with the experiments described here.

Contrary to the notion that social preferences are illusory, the theory of ego depletion would suggest that while individuals *may have* well-defined pro-social preferences they also have a limited "mental resource" that can promote the pro-social outcome. Baumeister et al. (1998) experimentally reveals that actively weighing the costs and benefits of one's actions, whether they be pro-attitudinal or counter-attitudinal, weakens one's self-control for decisions in similar situations in the future. However, if one's actions do not have meaningful consequences (i.e. no real cost/benefit analysis is required) then the ego will not deplete. Their paper draws originally upon the structural theory of the psyche (Freud 1961), wherein the ego manages the desires of instinctual (id) and rule-based (superego) constructs. As the ego weakens, it will naturally acquiesce to more instinctual desires.

In the context of this chapter, it would be predicted that more selfish behavior will be observed as one's ego is depleted, which can be accomplished simply by (for example) asking individuals to make several meaningful choices (i.e. that require cost/benefit analysis). Ego depletion has been documented to reduce the likelihood of pro-social outcomes in laboratory experiments. In

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[2]See Wilson (2010) for a broader criticism of social preference theory. This essay argues that defining preferences over social outcomes is forcing an economic model onto situations for which there is not enough information. In addition, experimental results in Bardsley (2008) lead us to believe the inference of social preferences are an artifact of the experiment design.

Achtziger et al. (2011), proposers in an ultimatum game make smaller offers under ego depletion, and responders are more like to reject those offers under ego depletion.

The model and results reported in this chapter are important because they illuminate the effects of a previously unconsidered component of social behavior: directed effort toward a preferred outcome. Empirical evidence from controlled laboratory experiments suggests the effect of effort leads to an unrectifiable inconsistency between social outcomes and social preferences in relatively pro-social individuals. These results contradict those reported in Gneezy et al. (2012) where costly pro-social behavior leads to consistent behavior in the future. Moreover, the repeated nature of the experiment reveals that individuals determining social outcomes (dictators) experience ego depletion, as they are less likely to choose pro-social outcomes through time, while those who do not determine social outcomes (receivers) are not.

1.1   A Model of Effort Provision

A model of effort provision is established in conjunction with social preference theory to predict individual action toward a social outcome. The model, simply stated, considers an individual who prefers a particular social outcome over an exogenously determined outcome, which can be thought of as the "state of the world". Effort is costly to the individual, and the effort level necessary to execute their preferred social outcome is known. In this setup, the individual should only exert effort to execute their preferred outcome if the net surplus from doing so is greater than the current benefit received from the exogenously determined state of the world while exerting no effort. This model is then tested using binary dictator games and real effort tasks. Consider an agent d (a dictator) who has preferences over outcomes that involve herself and another agent r (a recipient). Assume that, first, d chooses a social outcome o^* from a set of potential outcomes O, from which d and r receive a private benefit of π_d^* and π_r^*, respectively.

Then, d exerts effort to replace the state of the world, s, with o^*. Let d and r receive a private

benefit of π_d^s and π_r^s, respectively, from the current state of the world.

Let the effort exerted by d in an attempt to procure o^* instead of s be defined by $e_d \in \mathbb{R}^+$. Assume

that exerting effort is costly to d, and this cost can be described by $C_d(e_d)$, with $C_d(e_d)$ being

strictly increasing. Let $\tilde{e}_d$ be the level of effort necessary to procure o^*, which is assumed to be

known by d and independent of her preferred outcome.

Let $u_d(\pi_d^*, \pi_r^*)$ and $u_d(\pi_d^s, \pi_r^s)$ be the utility d receives from procuring o^* and the state of the world,

respectively.[3] In this case, d will exert effort equal to $\tilde{e}_d$ if $u_d(\pi_d^*, \pi_r^*) - C_d(\tilde{e}_d) \geq u_d(\pi_d^s, \pi_r^s)$,

otherwise she will not exert any effort and receive $u_d(\pi_d^s, \pi_r^s)$. Then the optimal effort provision

by d is

$$
e_d^* = \begin{cases} \tilde{e}_d & \text{if } u_d(\pi_d^*, \pi_r^*) - C_d(\tilde{e}_d) \geq u_d(\pi_d^s, \pi_r^s) \\ \\ 0 & \text{else.} \end{cases} \tag{1.1}
$$

This model of effort provision predicts that d is more likely to exert effort for outcome o^* as it

becomes increasingly more valuable than outcome s. In this chapter, this model will be applied

to a two person binary dictator game setting to test if effort is being exerted by d in a manner that

is consistent with her revealed social preferences. Revealed preference theory is used as the

measure of consistency, which gives specific predictions regarding an individual's preference for

one outcome over another. As described in this model, these predictions over preferences can be

extended to the predictions of effort provision to procure one outcome over another.

As a methodological example, suppose d plays a binary dictator game and may choose a social

outcome from the set $\{\text{Altruistic, Selfish}\} = \{(5,5),(7,3)\}$, where $(5,5)$ means d and r each

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[3]I will model an individual's utility as $u_d(\pi_d, \pi_r)$, even though for agents with no social prefer-
ence it may be parsimoniously modeled by only their own payout $u_d(\pi_d)$.

Figure 1-1: Revealed Preference Based on Binary Dictator Game

(a) Outcomes revealed worse if $(5,5) \succeq (7,3)$

(b) Outcomes revealed worse if $(7,3) \succeq (5,5)$
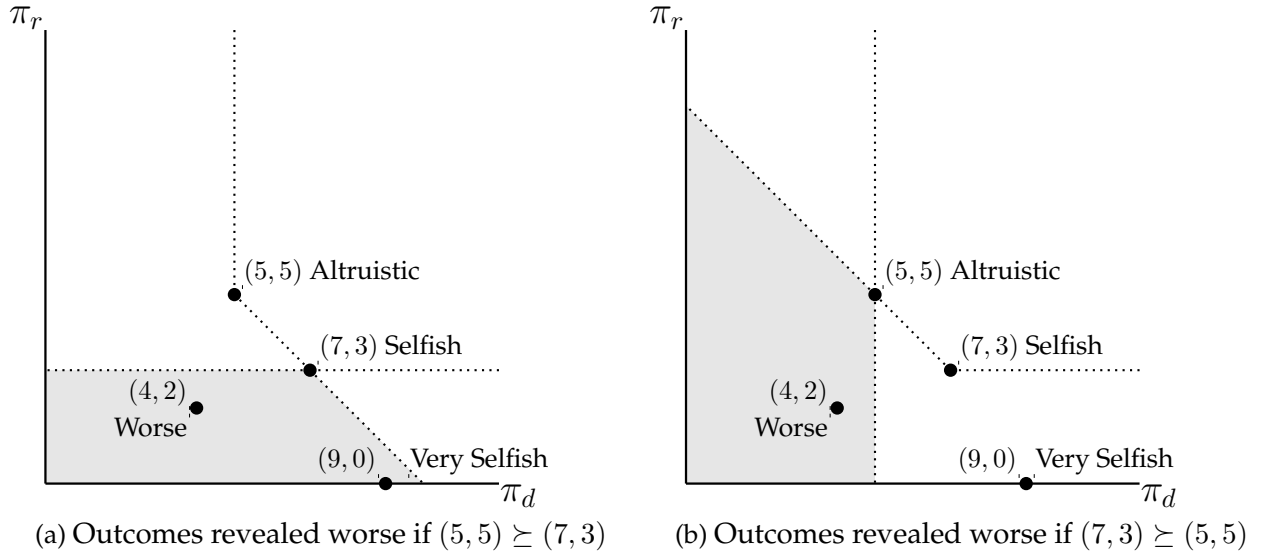
Shaded areas represent outcomes that are revealed worse based on the dictator's revealed preference in the dictator game. In panel (a) the shaded outcomes are revealed worse than $(7,3)$, while in panel (b) the shaded outcomes are revealed worse than $(5,5)$.

receive a payout of 5, and $(7,3)$ means d receives a payout of 7 and r receives a payout of 3. If d chooses $(5,5)$, then $(5,5)$ is weakly directly revealed preferred to $(7,3)$, i.e. $u_d(5,5) \geq u_d(7,3)$. Given standard assumptions associated with well-behaved utility functions this also tells us more about where her indifference curve may fall for $(7,3)$. The shaded areas in Figure 1-1 describe the outcomes that are revealed worse than the social outcome *not chosen* by d. Using the model on effort provision and a binary dictator game, predictions can be made on the outcomes for which individuals would be willing to exert more (or less) effort. For instance, suppose for a particular individual that the outcome $(5,5)$ is weakly directly revealed preferred to $(7,3)$. In this case, Figure 1-1(a) illustrates two outcomes that are revealed worse than the outcome $(7,3)$. These outcomes are $(4,2)$ (Worse) and $(9,0)$ (Very Selfish). In this case, then it is predicted that this individual is more likely to exert effort to manifest $(5,5)$ when the state of the world is $(4,2)$ or $(9,0)$ than when the state of the world is $(7,3)$. This is the basis of Hypothesis 1a and Hypothesis 1b.

Hypothesis 1a: *Dictators who reveal a preference for the outcome Altruistic in a binary dictator game will exert the effort needed to procure this outcome more often when the state of the world is Very Selfish than when the state of the world is Selfish.*

Hypothesis 1b: *Dictators who reveal a preference for the outcome Altruistic in a binary dictator game will exert the effort needed to procure this outcome more often when the state of the world is Worse than when the state of the world is Selfish.*

If, instead, the outcome $(7, 3)$ is weakly directly revealed preferred to $(5, 5)$, then Figure 1-1(b) illustrates that only one of these outcomes is revealed worse to $(5, 5)$, which is $(4, 2)$ (Worse). This means for individuals with well-behaved utility functions who demonstrate Selfish $\succ$ Altruistic that we can also infer Altruistic $\succ$ Worse. However, we cannot infer this about the outcome Very Selfish; Figure 1-1(b) illustrates that this outcome could conceivably be above or below this individual's indifference curve running through Altruistic. As a result, the effort provision model can only make one prediction: when Selfish is weakly directly revealed preferred to Altruistic, then this individual is more likely to exert effort to manifest the outcome Selfish when the state of the world is Worse than when it is Altruistic. This is the basis of Hypothesis 2.

Hypothesis 2: *Dictators who reveal a preference for the outcome Selfish in a binary dictator game will exert the effort needed to procure this outcome more often when the state of the world is Worse than when the state of the world is Altruistic.*

Note, it is important that effort provision from d is not compared across different revealed preferences in the binary dictator game (Altruistic vs. Selfish). Because the predictions of this model are restricted by d's revealed preferences in the binary dictator game, this means that the effort provision of dictators who reveal a preference for the outcome Selfish cannot be compared to the effort provision of dictators who reveal a preference for the outcome Altruistic.

1.2 Experiment Design

62 undergraduates from a large university volunteered to participate in an experiment that lasted approximately 50 minutes. They were brought into the laboratory on campus in groups that ranged from 10 to 14 in size where they sat at partitioned computer workstations to ensure private decision-making. Subjects were given computerized instructions and a series of binary dictator games including real effort provision tasks with the use of z-Tree (Fischbacher 2007).[4] The instructions included a practice period and multiple opportunities to ask questions. During the instructions, subjects were randomly assigned a role for the entire experiment. Half of the subjects were assigned Role A (the dictator) while the other half were assigned to Role B (the receiver). To best test the hypotheses stated in Section 2, all subjects were told those in Role A would be making real payout decisions for themselves and a random individual in Role B while those in Role B would be making hypothetical decisions. This setup explicitly eliminates the possibility of reciprocity or tacit collusion that may otherwise exist.[5]

The instructions explained that the experiment consisted of several periods, each of which had three parts. For every period the experiment proceeded as follows:

Part I: Both Role A and Role B were asked privately to choose the option they preferred from a randomly selected binary dictator game.

Part II: Role A was presented with a randomly assigned alternative (state of the world) to the option she chose in Part I.

Part III: Role A completed a counting task where successfully completing the

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[4]The instructions administered during the experiment can be found in the appendix.

[5]An alternative setup would have been to have all subjects play as the dictator while knowing that there was a 50% chance that their role would be reversed to the receiver at the end of the experiment. Although this setup would have allowed for more observations, it would likely distort behavior if subjects received utility from selecting an altruistic choice even if by chance that choice did not affect the outcome.

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counting task would allow Role A to keep her choice from Part I, and not successfully

completing the counting task would cause her choice in Part I to be replaced with the

random assigned alternative from Part II.

Both roles were informed that Role B would not be told the choices Role A made in the dictator

game nor the outcome of the effort task at any point. They were also told the computer would

randomly choose one period for each subject in Role A to determine the payouts for the

experiment. This procedure is designed to minimize the possibility of any wealth effects or

concern about meta-game analysis. Once the twenty periods were completed subjects were paid

privately, including an additional five dollars for participating, and left the lab. On average,

subjects were paid $14.40, including the participation payment.

1.2.1 The Dictator Games and the Effort Task

Each binary dictator game consisted of two potential payout bundles $\{(\pi_d, \pi_r), (\pi'_d, \pi'_r)\}$. The

bundles in each game were designed such that $\pi_d > \pi'_d \geq \pi'_r > \pi_r$ and $\pi'_d + \pi'_r > \pi_d + \pi_r$. This

means that the bundle (π_d, π_r) allocates relatively more money to the dictator and relatively less

money to the receiver than bundle (π'_d, π'_r) does. It also means that (π_d, π_r) is a welfare inefficient

option. There were 20 different binary different dictator games in total, each of which are listed in

Table 1.1(a). They are labeled "Altruistic" and "Selfish" in a manner that is consistent with the

configuration of Figure 1-1.[6] In choosing these binary dictator games, much consideration was

given to ensure there was a salient monetary difference between the two options to avoid

dictators from being indifferent. Moreover, it was equally important that the set of random states

of the world did not "bunch" together with respect to allocations either, leading the dictator to be

relatively indifferent between the possible outcomes.

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[6]The labels "Altruistic" and "Selfish" were not used in the experiment.

In the case that a dictator chooses the Altruistic option she would typically lose only a few dollars to give the receiver three or four in return. For each game, subjects were shown the two payout bundles Altruistic and Selfish on the computer as Option A and Option B, and they were asked to click the option they preferred. Those in Role A were reminded that their decision would determine the payouts to themselves and an individual in Role B. Those in Role B were reminded that their decisions were hypothetical. Each subject played the dictator games in random order to avoid ordering effects.

Table 1.1: Dictator Games (a) and Potential States of the World (b)

Binary Dictator Game Options			Potential States of the World			
(π'_d, π'_r)		(π_d, π_r)				
Altruistic		Selfish	Altruistic	Selfish	Very Selfish	Worse
(9,7)	or	(10,4)	(9,7)	(10,4)	(11,0)	(8,3)
(11,11)	or	(12,6)	(11,11)	(12,6)	(13,0)	(10,5)
(11,9)	or	(12,5)	(11,9)	(12,5)	(13,0)	(10,4)
(12,11)	or	(13,6)	(12,11)	(13,6)	(14,0)	(11,5)
(10,10)	or	(13,3)	(10,10)	(13,3)	(14,0)	(9,2)
(13,10)	or	(14,6)	(13,10)	(14,6)	(15,0)	(12,5)
(11,11)	or	(14,4)	(11,11)	(14,4)	(15.5,0)	(10,3)
(12,8)	or	(14,3)	(12,8)	(14,3)	(15,0)	(11,2)
(11,9)	or	(14,3)	(11,9)	(14,3)	(15,0)	(10,2)
(14,7)	or	(15,4)	(14,7)	(15,4)	(16,0)	(13,3)
(12,9)	or	(15,3)	(12,9)	(15,3)	(16,0)	(11,2)
(13,8)	or	(15,3)	(13,8)	(15,3)	(16,0)	(12,2)
(15,9)	or	(16,5)	(15,9)	(16,5)	(17,0)	(14,4)
(16,9)	or	(17,5)	(16,9)	(17,5)	(18,0)	(15,4)
(15,8)	or	(17,4)	(15,8)	(17,4)	(18.5,0)	(14,3)
(15,8)	or	(17,3)	(15,8)	(17,3)	(18,0)	(14,2)
(17,8)	or	(18,5)	(17,8)	(18,5)	(19.5,0)	(16,4)
(16,8)	or	(18,3)	(16,8)	(18,3)	(19,0)	(15,2)
(17,10)	or	(19,4)	(17,10)	(19,4)	(20,0)	(16,3)
(18,9)	or	(20,5)	(18,9)	(20,5)	(22,0)	(17,4)
(a)			(b)			

Dictators first choose a preferred outcome for a dictator a given dictator game from (a). Then, one of the four states of the world (b) is independently and randomly revealed. Dictator games and potential states of the world are paired by row.

After having made their decision in the dictator game, subjects in Role A were shown the option

they chose and a "Random Alternative" (state of the world). The potential states of the world are listed in Table 1.1(b), which were paired to the binary dictator game options in the same row. Refer to Figure 1-1 for a visual representation of the placements of these potential states of the world.

For convenience, the dictator who, for a given period, prefers the relatively pro-social outcome, Altruistic, will often be referred to as an "altruistic dictator," and the dictator who, for a given period, prefers the outcome Selfish will often be referred to as a "selfish dictator". The states of the world for each game were chosen such that two of the four were the options in the dictator game (Altruistic and Selfish); one state of the world was selected to fall only within the revealed worse convex hull of the altruistic dictator (Very Selfish); and one state of the world was selected to fall within the intersection of both altruistic and selfish dictators' revealed worse convex hulls (Worse). The state of the world was chosen randomly among these four, independent of the dictator's preference. This aspects of the design is critical to the incentive compatibility of dictators to truthfully reveal their preference in the binary dictator game. Because the potential state of the world is independent of the dictator's choice in the dictator game, the dictator has no incentive to misrepresent her preferences. If the potential states of the world were somehow conditional on the dictators' choices then they may no longer have an incentive to choose their true preferences in the dictator game.

It is also important to note that the necessary cost of effort is independent of the dictator's choice (i.e. effort tasks are not systematically easier or harder to complete given their preference in the dictator game). If, randomly, the dictator's choice and the state of the world were identical (e.g. the dictator chose the outcome Altruistic and the random state of the world was also the outcome Altruistic), then effort provision cannot change the outcome. In this case, the dictator's optimal effort provision is zero.

After being shown their choice from the dictator game and the state of the world, those in Role A

completed an effort provision task that would allow them to keep their choice from the dictator

game. This task consisted of counting how many numbers (0-9) there were in a series of 120

random characters that included both digits (0-9) and letters (A-Z). Each of the 120 characters

was equally likely to be one of the 36 alphanumeric characters. Role A was given ninety seconds

to complete this task and report their answer to the computer. If Role A was correct or had a

margin of error of one she kept the option she chose from the dictator game, otherwise she and

her receiver were assigned the state of the world that was shown to them. Table 1.2 shows an

example of the effort task completed in this experiment.[7]

Table 1.2: Effort Task Example

8	3	P	2	M	9	L	K	V	5	W	9	G	5	2	X	M	E	G	P
6	E	Y	R	4	D	S	S	9	L	V	X	3	Q	S	M	O	H	B	A
R	9	Y	Y	P	2	4	A	V	0	D	R	L	Z	X	8	3	A	L	J
7	Q	7	M	I	2	D	Z	V	6	W	Z	U	P	L	2	G	P	Q	J
F	N	N	L	Y	J	N	N	G	D	X	J	L	Q	7	5	4	T	F	Q
V	R	H	R	D	8	R	0	7	C	G	P	P	X	3	L	C	X	9	0

This task was selected for measuring effort for several reasons. First, it is important that subjects

do not vary significantly in ability. Second, because letters and numbers appear randomly it is

truly cognitively taxing for subjects to track how many numbers have appeared while paying

close enough attention to distinguish between 0s and Os, ls and 1s, et cetera. Finally, to be in

accordance with the theory, it is important that subjects have a good idea of how much effort it

will take for them to complete the task successfully. While the absolute number of numbers may

vary from task to task this does not change the fact that the subject must still verify whether a

given alphanumeric character is either a letter or a number. In this sense, the necessary effort

provision is essentially constant.

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[7]This example has 32 numbers in it. If Role A reported 31, 32, or 33 then she would keep the
option she chose in the dictator game.

1.3 Results

1.3.1 Dictator Game

In this study 31 dictators (Role A) and 31 receivers (Role B) each participated in 20 dictator games, and dictators also completed an effort provision task after each dictator game. Since dictators made decisions for real outcomes and receivers made decisions for hypothetical outcomes, for the analysis of monetary payoffs there were 620 observations. Dictators chose the option Selfish in the dictator game 71% of the time while receivers chose the option Selfish in the (hypothetical) dictator game 33% of the time. While the amount of selfish behavior by subjects making salient decisions sounds high, this option still allocated almost 22% of the payment to the receiver on average. 71% of dictators chose the option Altruistic in at least one of the twenty dictator games. Dictators typically chose the option Altruistic more often when the gain to the receiver was relatively large compared to the decrease in their own payout, which is consistent with Andreoni and Miller (2002). This is the trade off measured by the ratio of exchange in payout from the dictator to the receiver, or the (negative) slope of a "budget constraint" through the two bundles. When the difference between the two bundles in the dictator game was such that dictators could give up one dollar for themselves to give their receivers an additional two dollars (or something proportionate to that), dictators chose the altruistic bundle approximately 22% of the time. When the difference between the two bundles was such that dictators could give up one dollar for themselves to give their receivers an additional five dollars (or something proportionate to that), dictators chose the altruistic option 48% of the time.

Table 1.3 reports the marginal effects of a random effects probit on the chosen option made in the dictator game by dictators and (hypothetically by) receivers. Choice is a binary variable, where a 1 is having chosen the option Selfish and 0 is having chosen the option Altruistic. Rate of

Exchange is the (negative) slope of the budget constraint on which the two options in the dictator game sat. This variable was always a negative number, calculated by $\frac{\pi'_r - \pi_r}{\pi'_d - \pi_d}$. Period is the period (1-20) that the dictator game appeared to that particular dictator. Δ in Own Payout is the exact personal monetary gain to the dictator from choosing the option Selfish $(\pi_d - \pi'_d)$. Δ in Total Payout is the welfare gain from the dictator choosing the option Altruistic $[(\pi'_d + \pi'_r) - (\pi_d + \pi_r)]$. There is no multicollinearity present in the variables in Table 1.3.

Dictators and receivers both chose the option Altruistic more frequently as the benefit to the receiver increased. In this sense, receivers may be biased in how often they would choose the option Altruistic for real stakes, but respond to the "cost of sharing" in a very similar way to dictators. Dictators chose the option Selfish more often through time, while receivers did not. This result is very relevant to the consideration of ego depletion in the next sub-section. Since receivers did not complete the effort task and their choices did not vary significantly over time, this suggests that an individual's willingness to pursue a pro-social outcome may decrease over time when it requires effort.

1.3.2 Effort Task

Recall that the effort task in this experiment is to review 120 random alphanumeric characters and report to the computer how many numbers (0-9) there are. This was a task performed only by dictators. After choosing an option in the dictator game (Altruistic or Selfish), dictators were randomly assigned a state of the world (Altruistic, Selfish, Very Selfish, or Worse). At this point, dictators completed the effort task to replace the state of the world with their preference from the dictator game.

Overall, approximately 70% of the time (i.e. in 431 out of 620 effort tasks) dictators reported the correct number of digits exactly. Figure 1-2 describes the distribution of *actual* and *reported*

Table 1.3: Random Effects Probit of Subject Choice in Dictator Game

	Dependent Variable: Choice in Dictator Game (1=Selfish)					
	Dictators (Real Stakes)			Receivers (Hypothetical Stakes)		
Period	0.05***	0.05***	0.05***	0.00	0.00	0.00
	(0.014)	(0.015)	(0.015)	(0.01)	(0.01)	(0.01)
Rate of Exchange	0.55***	0.46***	0.47***	0.45***	0.33***	0.00
	(0.088)	(0.125)	(0.13)	(0.08)	(0.13)	(0.30)
Δ in Own Payout		0.16	0.15		0.18	0.56
		(0.16)	(0.16)		(0.14)	(0.35)
Δ in Total Payout			0.01			-0.31
			(0.028)			(0.25)
Observations	620	620	620	620	620	620

Notes: marginal effects are reported. Standard errors are in parentheses.
*,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

numbers in the effort task. The distribution of *actual* numbers are represented by gray bars and the distribution of *reported* numbers are represented by white bars. This comparison demonstrates that there was little evidence of pure shirking in the task; many subjects exerted some effort on the task, and if they did not report correctly they often under-reported.

In analyzing the performance of dictators in the effort task, this chapter proceeds in two ways. The first analysis asks what the *average error* is for a given revealed preference from the dictator game (selfish or altruistic) in the presence of a randomly selected "state of the world". For a true number of digits $\tilde{n}$ and a reported number of digits n_d, error is defined as $|\tilde{n} - n_d|$. The second asks what the *failure rate* is for procuring a given revealed preference in the presence of a randomly selected state of the world. As per the experimental instructions, a failure is defined as $|\tilde{n} - n_d| \geq 2$. Both of these measures are reported in this sub-section for altruistic and selfish dictators, respectively. Without separating dictators by revealed preference, according to *average error* 42% of subjects were inconsistent in at least one of the three tested hypotheses.

Figure 1-2: Histograms of Actual Vs Reported Numbers in Effort Task

Actual numbers are gray and reported numbers are white.
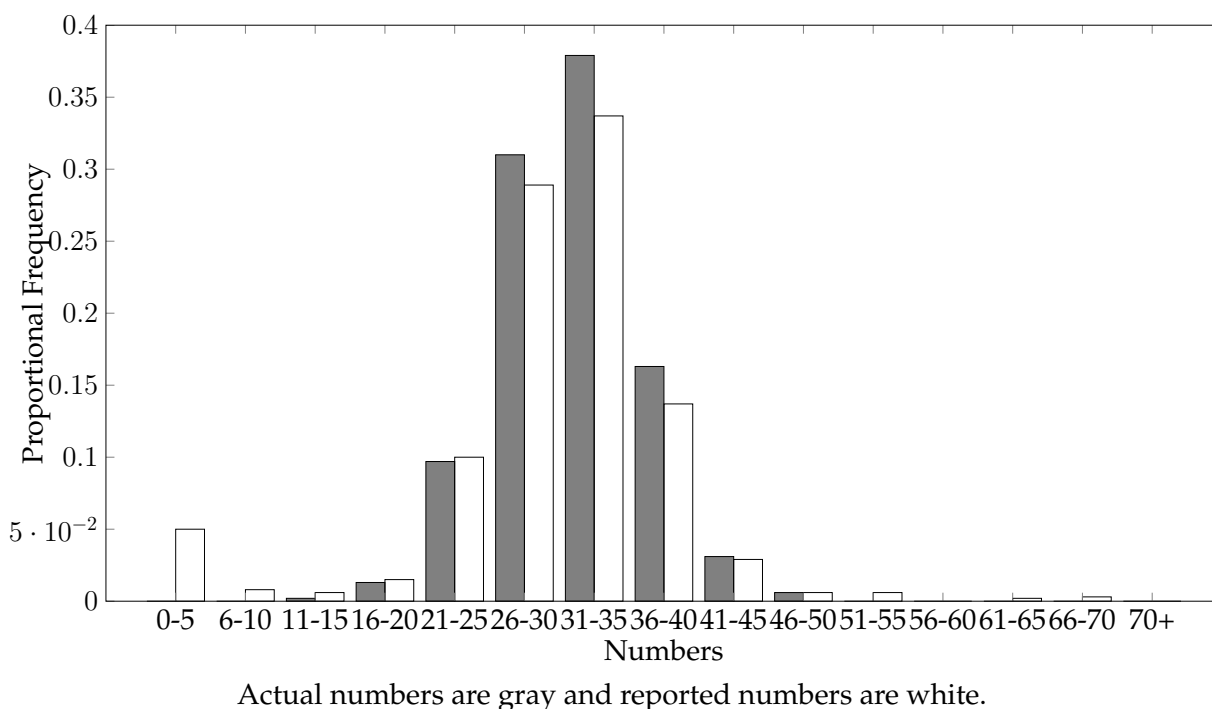
Alternatively, according to *failure rates* 57% of subjects were inconsistent in at least one of the three tested hypotheses.

Altruistic Dictators

Table 1.4 reports the results of four random effects estimates on altruistic dictators - those dictators who, for a particular period, revealed a preference for the option Altruistic over the option Selfish in the dictator game. The two leftmost specifications are random effects probit models on the variable Fail, which is a binary variable that is equal to 1 if the altruistic dictator failed the effort task and is equal to 0 if the she was successful. Marginal effects are reported for two estimates of this model. The two rightmost specifications are random effects generalized least squares estimates of the size of the error in the effort task in absolute value. Errors in this task are reported in absolute value, since the dictator could either over- or under-report relative to the correct answer. The independent variables used to estimate these models are dummy

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variables that represent which state of the world was randomly assigned to the dictator. The period in which the dictator played this dictator game is represented by the variable Period, and the random realization of how many numbers that they needed to report to the computer is represented by the variable Numbers.

For altruistic dictators, Very Selfish represents the state of the world that is revealed worse than the option Selfish from the dictator game (See Figure 1-1). The predictions from the model are that dictators will execute their preferred social outcome more often if the state of the world is Very Selfish than if the state of the world is Selfish (Hypothesis 1a). The results reported in Table 1.4 do not support Hypothesis 1a, which show that altruistic dictators fail the effort task more often if the state of the world is Very Selfish than when the state of the world is Selfish.

Result 1a: *Contradictory to theoretical predictions, dictators who revealed a preference for the outcome Altruistic in the dictator game and received the random state of the world Very Selfish failed the effort task more often on average than dictators who revealed a preference for the outcome Altruistic in the dictator game and received the random state of the world Selfish.*

The GLS estimates on absolute error show that average error by an altruistic dictator in the effort task is less on average when the state of the world is Very Selfish than when the state of the world is Selfish. This result, when compared to the failure rate of dictators, is difficult to explain. Why would dictators come closer to reporting the correct number while also failing the task more often? The outcome Very Selfish always offers a larger personal payout than the option Selfish does. One possible explanation for Result 1a is that dictators are deliberately misrepresenting the solution to the effort task by small amounts; this allows them to maintain a well intentioned self-image while receiving a larger personal payout. Figure 1-3(a) provides graphical support for this interpretation. This figure reports the kernel-weighted local polynomial smoothing CDFs of effort task errors by various states of the world, separated by the dictator's revealed preference

(panel (a) for altruistic dictators). A strong result for rational preferences would be to see the CDF of errors for the state of the world Selfish first-order stochastically dominate the CDF of errors for the state of the world Very Selfish. While for the bulk of the density this is true, we find that many of the errors associated with the state of the world Very Selfish are very small, which eliminates the first-order stochastic dominance. A two-sample Kolmogorov-Smirnov (KS) test of the CDFs in panel (a) reveal that the distributions are not drawn from different distributions, ($p<0.977$) for Selfish=Very Selfish and ($p<0.952$) for Selfish=Worse.

Table 1.4: Random Effects Estimates of Altruistic Dictator Decisions in the Effort Task

Model:	Probit		GLS	
Dependent Variable:	Failed the Effort Task (1=Fail)		Error in Absolute Value	
	Marginal Effects			
Period	-0.003		0.02	
	(0.005)		(0.11)	
Numbers	0.001		0.06	
	(0.005)		(0.12)	
Altruistic	0.33***	0.34***	6.43***	6.56***
	(0.10)	(0.10)	(1.61)	(1.57)
Selfish	0.16	0.16	2.58	2.61*
	(0.10)	(0.10)	(1.61)	(1.58)
Very Selfish	0.20**	0.20**	0.95	1.02
	(0.10)	(0.10)	(1.70)	(1.67)
Constant (Worse)			-0.59	1.63
			(4.08)	(1.78)
Observations	182	182	182	182

Notes: standard errors are in parentheses. *,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Although the data do not support Hypothesis 1a, the results in Table 1.4 support Hypothesis 1b. When altruistic dictators were randomly assigned the state of the world Worse they failed the effort task less often on average than when the state of the world was Selfish.

Result 1b: *Dictators who revealed a preference for the outcome Altruistic in the dictator game and received the random state of the world Worse failed the effort task less often on average than dictators who revealed a preference for the outcome Altruistic in the dictator game and received the random state of the world Selfish.*

The state of the world Worse is inferior compared to the outcome Selfish for all dictators by the model in Section 2; the outcome Worse always offers a smaller payout for both the dictator and the receiver. As the results in Table 1.4 show, both the failure rate and the average error in the effort task for this state of the world are less than for the other states of the world (as noted by all positive coefficients), suggesting this outcome indeed is generally regarded as the most inferior. Altruistic dictators occasionally received the random state of the world Altruistic, which was identical to their choice in the dictator game. In these cases, Table 1.4 demonstrates that altruistic dictators failed the effort task most often. This result suggests that dictators did not enjoy doing the effort task (i.e. they found the task costly), and that they understood what was at stake for their effort provision.

Selfish Dictators

For selfish dictators - those who, for a given period, revealed a preference for the option Selfish over the option Altruistic - the state of the world Worse is theoretically predicted to be an inferior outcome relative to the outcome Altruistic. According to the model in this chapter, this should lead to fewer failures in the effort task on average when the state of the world is Worse than when it is Altruistic. This is the result that is reported in Table 1.5, which provides the same analysis as Table 1.4, except for selfish dictators. The marginal effects of the variable Altruistic are positive in both estimates, showing that subjects on average failed the effort task more often when the random state of the world was Altruistic than when it was Worse. These analyses

provide support for Hypothesis 2. The average error by selfish dictators is larger when the state

of the world is Altruistic. The state of the world that was most often failed, and by the largest

margin, was the state of the world Very Selfish, which allocated nothing to the receiver. This

suggests many selfish dictators had no social preference whatsoever.

Result 2: *Dictators who revealed a preference for the outcome Selfish in the dictator game and received the*

random state of the world Worse failed the effort task less often on average than dictators who revealed a

preference for the outcome Selfish in the dictator game and received the random state of the world

Altruistic.

For graphical verification of this result, Figure 1-3(b) provides a non-parametric description of

the distributions of errors in the relevant effort tasks. This figure (in panel a) demonstrates that

the CDF of errors for selfish dictators that is associated with the state of the world Altruistic

first-order stochastically dominates the CDF of errors associated with the state of the world

Worse. This is strong evidence that selfish dictators manifest effort in a rational manner. The

two-sample KS test of these distributions are not statistically different ($p < 0.45$). For comparative

purposes, the CDF of errors associated with the state of the world Very Selfish is included in

panel (b) of this figure. While some selfish dictators chose to exert effort to avoid the outcome

Very Selfish (less than 50%), many had rather large errors relative to the other states of the world.

This distribution is statistically different from the others in panel (b) according to the two-sample

KS test ($p < 0.00$).

An Alternate Measure of Effort

Another way to approximate the effort exerted by dictators is to consider how long they spent

completing the effort task for each state of the world. Table 1.6 reports these results. Both selfish

and altruistic dictators spent the most time on average completing the effort task when the state

Table 1.5: Random Effects Estimates of Selfish Dictator Decisions in the Effort Task

Model:	Probit		GLS	
Dependent Variable:	Failed the Effort Task (1=Fail)		Error in Absolute Value	
Marginal Effects				
Period	-0.001		0.06	
	(0.003)		(0.05)	
Numbers	-0.003		-0.02	
	(0.003)		(0.06)	
Altruistic	0.03	0.03	0.60	0.58
	(0.06)	(0.06)	(0.93)	(0.93)
Selfish	0.13**	0.13**	1.45	1.41
	(0.05)	(0.05)	(0.89)	(0.89)
Very Selfish	0.32***	0.33***	8.09***	8.11***
	(0.06)	(0.06)	(0.87)	(0.87)
Constant (Worse)			0.15	0.09
			(2.25)	(0.71)
Observations	438	438	438	438

Notes: standard errors are in parentheses. *,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

of the world was Worse. Both also spent less time on the effort task as the experiment proceeded.

Altruistic dictators spent less time completing the effort task when the random state of the world was Very Selfish, averaging 42.52 seconds, than when the state of the world was Selfish, averaging 39.34 seconds. This result suggests that altruistic dictators did exert more effort when the state of the world was Very Selfish than when the state of the world was Selfish. Moreover, altruistic dictators spent significantly more time on the effort task when the state of the world was Worse than when it was Selfish, which also suggests that these dictators exerted more effort to avoid Worse than to avoid Selfish.

Selfish dictators spent 50.53 seconds on average on the effort task when the random state of the world was Worse. They spent significantly less time on the effort task when the state of the world

Figure 1-3: Kernel-weighted Local Polynomial Smoothing CDFs of Effort Task Errors by State of the World

(a) Altruistic Dictators

(b) Selfish Dictators
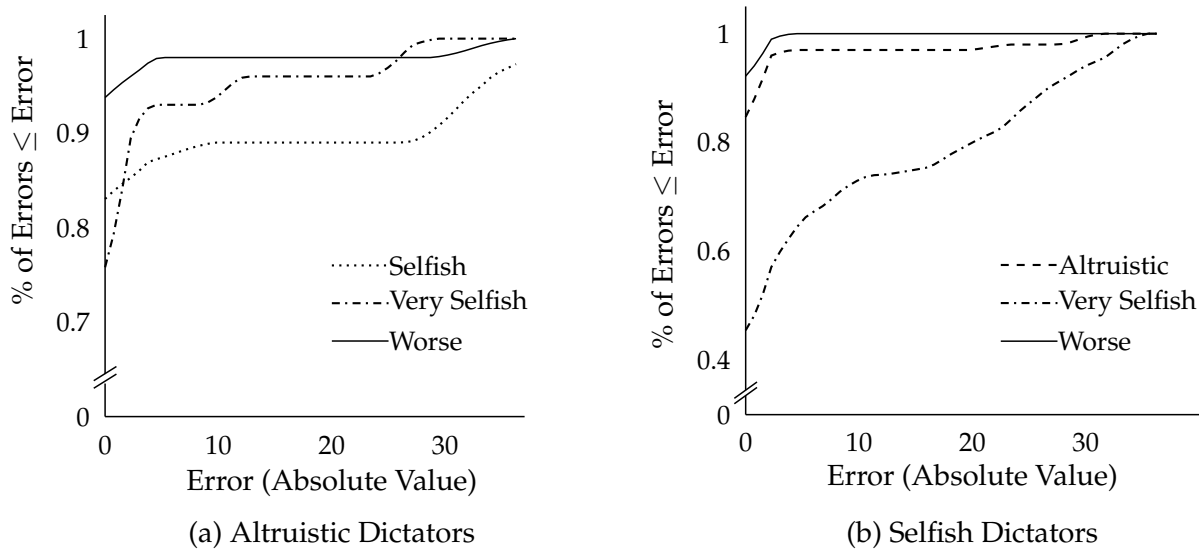
was Very Selfish (32.81 seconds on average). Unlike altruistic dictators, selfish dictators spent statistically significantly more time on the effort task as the amount of numbers they needed to count increased.

Alternative Theories: Ego Depletion and Cognitive Dissonance

The incompatibility of experimental results with Hypothesis 1a motivates the exploration of alternative theories to the rational social preference model. In particular, the results of similar experiments, which were discussed in the introduction of this chapter, leads to the natural consideration of ego depletion and cognitive dissonance as possible explanations for observed behavior. This section seeks to provide predictions to the question: How will dictators choose preferred social outcomes (in the dictator game) in the presence of ego depletion or cognitive dissonance when effort provision is needed to procure that outcome? The effects of ego depletion and cognitive dissonance lead to diverging predictions with respect the question posed. Suppose that a dictator has preferences over social outcomes, but she sometimes also feels

Table 1.6: Random Effects GLS of Time Completing Effort Task

	Dependent Variable: Time Completing Effort Task (in seconds)			
	Selfish Dictator Decisions		*Altruistic Dictator Decisions*	
Period	-0.85***		-0.84***	
	(0.13)		(0.22)	
Numbers	0.35**		0.07	
	(0.15)		(0.24)	
Altruistic	-2.27	-1.80	-12.59***	-12.41***
	(2.28)	(2.41)	(3.29)	(3.39)
Selfish	-8.47***	-7.80***	-7.31**	-7.17**
	(2.17)	(2.29)	(3.29)	(3.40)
Very Selfish	-17.56***	-17.72***	-4.21	-3.99
	(2.13)	(2.25)	(3.48)	(3.59)
Constant (Worse)	50.00***	50.53***	53.63***	46.51***
	(6.14)	(3.22)	(8.63)	(4.09)
Observations	438	438	182	182

Notes: standard errors are in parentheses. *,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

constrained (e.g. morally or socially) to be more altruistic than these preferences prescribe. Assume further that this binding constraint creates dissonance in the dictator. The theory of cognitive dissonance (Festinger 1957) states she will seek to reduce said dissonance, which may include avoiding situations and information that lead to its presence. It is arguable, then, that this dictator may misrepresent her preferences in the dictator game by being too altruistic, and use the effort task as a way of alleviating the dissonance. For this dictator, the effort task may allow her to display the semblance of altruism while also procuring the outcome she truly preferred by failing the task, thereby following a "path of least dissonance". As a result, it would be predicted that this dictator will choose relatively altruistic options in the dictator game but fail the effort task - perhaps by a small margin - when the state of the world yields payouts more in line with

their preferences (i.e. relatively selfish outcomes). Moreover, there is no *a priori* reason to believe this dissonance would abate over time, so the dictator would always be motivated to employ this strategy.

Instead, suppose that a dictator has pro-social preferences over social outcomes, but her capacity to promote those preferences is finite, as defined by the theory of ego depletion (cf. Baumeister et al. 1998). According to this theory, one method of depleting the ego is by engaging individuals in meaningful decision-making (i.e. where costs and benefits must be weighed). Regardless of whether the individual's decision is pro-attitudinal or counter-attitudinal, this act should make it more difficult to make controlled decisions in the future. When deciding social outcomes, a dictator whose ego is depleted will find it difficult to inhibit themselves from choosing relatively selfish outcomes. As a result, it is arguable that ego depletion will lead to dictators choosing relatively more selfish options in the dictator game as the experiment progresses. Alternatively, if the dictator were asked to make similar decisions over social outcomes but those decisions would not be implemented, and therefore had no real meaning, then there would be no depletion of the ego. As a result, there should be no trend associated to the dictator's revealed preferences through time.

While cognitive dissonance does not predict that dictators "drift" in their revealed preferences through time, the theory of ego depletion does. Table 1.3 reveals that dictators, indeed, tend to choose the more selfish option through time, as denoted by the statistically significant coefficient on the variable Period. Moreover, ego depletion states this trend is the result of repeatedly making meaningful decisions. Those in the role of receiver were also asked to make the same allocation decisions in the dictator game, but for hypothetical stakes. Table 1.3 provides support for ego depletion once again with the absence of any time trend in their revealed preferences. The data available from this experiment make inferences over cognitive dissonance difficult, however

certain modifications could be made for future studies, such as developing a treatment wherein dictators may easily verify they have successfully completed the effort task before it is over.

1.4 Conclusion

The predominant method among economists of analyzing pro-social behavior is to assume that individuals have preferences over social outcomes. This preference mapping leads to predictions of stability and internal consistency that correspond to rational pro-social behavior. Studies such as Andreoni and Miller (2002) demonstrate that a preponderance of individuals reveal rational pro-social preferences according to the general axiom of revealed preference (GARP). Other studies such as Dana et al. (2007) suggest that the rationality of pro-social behavior sits on a knife's edge, which can be drastically altered by small, contextual changes in an experiment. In the naturally-occurring world, there are many situations in which an individual cannot simply impose their preferences onto a situation for them to then exist; often they must exert unobservable effort to execute their preferences. This chapter addresses this aspect of pro-social behavior by appending a real effort task to a binary dictator game. A model of effort provision is used to predict effort provision that is consistent with social preference theory. The results of the experiment suggest that individuals with relatively pro-social preferences do not manifest social outcomes in manner that is consistent with their stated preferences. This inconsistency arises when a large personal gain is the status-quo and can be maintained with no effort provision. Similar measures of consistency are measured for individuals with relatively selfish preferences, which find no inconsistency according to the same model.

The results of this chapter add to a growing literature that suggests pro-social behavior requires the consideration of many non-economic factors, and that several psychological factors may be routinely at play. A discussion of the effects that ego depletion and cognitive dissonance may

have on individual behavior is provided for this experiment. Individuals tend to reveal relatively

selfish preferences through time when the stakes are real but exhibit no change in revealed

preferences through time when the stakes are hypothetical. This result is consistent with the

theory of ego depletion.

2   Chapter 2: Wars of Attrition with Unrecoverable Upfront Investments

Originally introduced by biologists to describe animal conflicts (Smith 1974), the war of attrition

has grabbed the attention of economists as a way to describe many manifestations of competitive

behavior. In general, the war of attrition models n contestants vying for $k < n$ indivisible prizes.

It is assumed that contestants must make unrecoverable investments through time until they

choose to exit the contest, and the prizes are awarded to the k contestants who are willing to stay

in the contest the longest.

The variety of applications for the war of attrition is impressive. While suitable for modeling

fighting among fiddler crabs (Morrell et al. 2005), it is equally suited for modeling

macroeconomic stabilization (Alesina and Drazen 1991). Economists have gleamed theoretical

insights from this model in markets facing decreasing net present value (Ghemawat and

Nalebuff 1985, 1990; Fudenberg and Tirole 1986), labor strikes (Kennan and Wilson 1989), patent

races (Leininger 1991), political lobbying (Dekel et al. 2008, 2009) and terrorist activities

(Sánchez-Cuenca 2004).

This chapter presents a theoretical variation of the war of attrition where contestants must make

fully, partially or non-recoverable upfront investments to participate in the contest, and these

investments also dictate for how long a contestant may potentially compete. In particular, this

chapter considers pre-calculated wars of attrition where contestants understand that there will be

a contest and have planned strategically for the conflict. The planning stage allows contestants to

decide the amount of resources (i.e. endowment) they are willing to commit to the conflict.

Contestants then decide for how long they are willing to compete given their resources. The

duration of the contest is determined by how easily unused resources from the contest can be

re-purposed (e.g., for future contests). This design can be applied in many economic areas,

including firms' production strategies in declining markets when their product is, to varying

degrees, an imperfect substitute in other markets.

2.1 Literature Review

Due to its broad appeal, a vast literature has developed with respect to wars of attrition since its

original formulation in Smith (1974). This initial application was with respect to animal conflicts,

and how these conflicts may or may not be avoided. Here, the war of attrition assumed there

were two animals fighting for a single prize, which could be for territory, food or mating rights.

Typically, an apparent asymmetry between the two animals' ability to compete allowed for

costless determination of the victor (the relatively strong contestant). This was first defined as the

handicap principle in Zahavi (1975, 1977), which states that costly signals can help minimize

animal conflicts. On the other hand, when there is no salient asymmetry between the contestants

the conflict can result in costly investments to determine the winner. In an important early

contribution, Riley (1980) provided a "strong evolutionary equilibrium" in the war of attrition,

essentially demonstrating there is a continuum of equilibria upon which contestants can

coordinate. This result relies upon the assumption that the cost of fighting is common knowledge.

Several papers consider situations where there is asymmetry in the value of the prize to the

contestants, which is public knowledge, such as Smith and Parker (1976) and Hammerstein and

Parker (1982). These papers demonstrate that the stronger contestant (defined as the one with a

higher value if costs are equal) tends to win uncontested, as well as validate that if there is no

heterogeneity among the contestants then there are no asymmetric equilibria. If, instead, the

identities of valuations are unknown then the continuum of asymmetric equilibria is maintained

and a "pecking order" emerges among the contestants (Nalebuff and Riley 1983). Here, contests

often resolve with one very aggressive contestant and one very passive contestant. However, it is

possible (though still improbable) for those lower in the pecking order to make serious

challenges. More recently, Myatt (2005) looks at asymmetric wars of attrition where contestants have different distributions from which they draw their private values. Contestants' "stochastic strengths" are compared based on these distributions, where a contestant is stochastically strong if she has a larger *ex ante* valuation - even if her realization *ex post* is smaller. The standard design is modified by, for example, setting a time limit (then a winner is picked randomly). Myatt (2005) shows that the stochastically weaker contestant exits instantaneously.

Economists began employing the war of attrition by applying it to firms exiting markets with declining future values. This addition to the literature began to balance out the more dominant consideration of strategic market entry. Beginning with Ghermawat and Nalebuff (1985), it was assumed that a potentially heterogeneous duopoly resulted in negative firm profits, but a monopoly was sustainable. In their paper, it was further assumed that production was rigid, leading firms to exit in an "all-or-nothing" manner. This led to the prediction that the biggest firms in the market will, in expectation, exit first. The somewhat unrealistic assumption placed on firms' all-or-nothing strategy for production was relaxed in Whinston (1988), where firms instead had multiple plants allowing for down shifts in production. That paper corroborated the original prediction that larger multi-plant operations exit the declining market first. In a third paper, Ghemawat and Nalebuff (1990), the production assumption was relaxed further, allowing for firms to continually adjust the production levels. The results of their theoretical model predict that relatively large firms will shrink to the sizes of their (formerly) smaller rivals.

In a slightly different context, Fudenberg and Tirole (1986) offers a theory of exiting in an unsustainable duopoly. The model is largely based on differing fixed or opportunity costs, which are private knowledge to the firms. In their model, the only strategic variable for firms is the time of exit, the last of which receives monopoly profits. Finally, to generate a unique equilibrium it is also assumed that firms could potentially compete forever - which is justified by suggesting that

the market may at some point be able to sustain the current duopoly. This model of firm exit was directly tested by Oprea et al. (2013), where it is reported that firm exits are efficient (76% of the time higher cost firms exit first) and very closely resemble the point predictions of the model. It is further reported that there is little difference in strategies when payoffs are framed as losses or gains.

Almost simultaneously, applications for the war of attrition were being fashioned within firms' research and development (R&D) strategies. In a very interesting first take, Harris and Vickers (1985) model two contestants seeking to claim an indivisible prize. The prize is awarded to the contestant to reach the "finish line" first (i.e. to complete some task first), which involves several stages of making unrecoverable investments. In their model, it is shown that the winner behaves exactly as if she was the only contestant. Moreover, it is shown that another contestant has the potential to impact the winner's behavior in the first stage of the game only, and not thereafter. Building from this base, Leininger (1991) models a patent race using a dynamic, turn-based all-pay auction. Here, only by outbidding one's opponent can one remain in the race. Because that paper abstracts from discounting payouts through time, the characterization of equilibrium becomes quite complicated.

It is easy to envision that the repeated play of these games requires some consideration for the potential of reputational effects. One of the first papers to consider the role of reputations in finitely repeated games was Kreps and Wilson (1982) in the context of "the chain-store paradox" (Selten 1978). Their paper considers how imperfect information acts as a mechanism for how strategies in one period can influence payoffs in the next. Allowing for one-sided and two-sided uncertainty, they demonstrate that the development of a reputation can, in fact, be advantageous in the way one intuitively expects. Technically, they also demonstrate that a discrete, turn-based model converges to a continuous, simultaneous-move model.

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Not long after Kreps and Wilson (1982), an impressive literature on bargaining followed, predominantly assuming situations with one-sided incomplete information. This began a literature on signaling in dynamic games, foremost were Grossman and Perry (1986), Chatterjee and Samuelson (1987) and Admati and Perry (1987). In these papers, the seller's valuation is common knowledge but buyers have multiple types. The common theoretical result is that buyers with low valuations delay in their response to a seller's proposal as a way to signal their true valuation. This leads to better payoffs for these buyers. More recent developments in this area have included the consideration of mediators (Jarque et al. 2003). Here, bargaining takes place without each of the contestants knowing the concessions made by others - they are only aware that the contest is still ongoing. Multiple "levels" of concessions are allowed, and the mediator ends the contest when an agreement takes place. In an interesting, and more recent paper, Hörner and Sahuguet (2007) explores strategies in a two-stage all-pay auction that involve signaling from weak players (bluffing) as well as the possibility for strong players send misrepresent their strength (sandbagging). These strategies are advantageous in the model design because there are multiple auctions.

Another important application of the war of attrition, which is particularly important to this chapter, is with respect to funding public goods. Bliss and Nalebuff (1984) suggests that finding a contributor for a public good is very similar to a war of attrition because until the public good is funded the participants are not benefiting from the good, which is costly. In their paper, the example they offer is that of a library being built, or waiting for someone to open a window when it's hot. The notion here is that each contestant has an individual cost they must incur until the public good is provided. That paper also presents a series of theorems that reflect standard predictions in this public goods setting. Some of the more insightful predictions include "Theorem 1: Each agent's optimal waiting time increases monotonically with respect to his cost

of providing the good and is directly proportional to n-1 when there are n agents," "Theorem 2: Increasing the number of participants, although increasing everyone's waiting time, also raises their expected utility," and "Theorem 4: The good will always be supplied by the agent with the minimum cost. When the distribution of the minimum cost agent becomes 'riskier', this change is expected to prolong the waiting time before the good is supplied," Bliss and Nalebuff (1984, p. 3).[1] A similar paper, Osborne (1985), also addresses this waiting game in public good contributions, but instead defines a finite horizon game where an indivisible prize shrinks in value through time. In that paper, one contestant must make a concession for the prize to stop shrinking. This chapter relies on an assumption that each party will, with some probability, concede immediately at the beginning. A more recent paper in this area, LaCasse et al. (2002), extends the analysis of Bliss and Nalebuff (1984) with a model that assumes there are c public goods and n contestants. Here, c wars of attrition are waged simultaneously to determine who will provide these public goods. That paper presents the subgame perfect equilibrium when $c = n = 2$, but finds that the multiplicity beyond this special case makes characterizing equilibrium difficult.

The lobbying of legislatures is a more recent application of the war of attrition in political science. In a pair of papers, Dekel et al. (2008, 2009) consider, first, how candidates for public office would solicit votes in an election when the notion of buying votes is publicly acceptable and legal. While the model relies on an all-pay auction to describe investments from candidates, this notion of "buying" can be framed as designing one's platform for the campaign. Here, the authors focus primarily on a sequential and complete information design. Second, the authors consider the payments lobbyists would make to legislatures in a similar design, again, if doing so were publicly acceptable and legal.

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[1]Bliss and Nalebuff (1984) use the definition provided by Rothschild and Stiglitz (1970) for what is "riskier".

Other theoretical considerations that are apropos to the war of attrition include the dollar auction, the tug of war and the ability to jump bid in a sequential all-pay auction. The dollar auction is an all-pay auction where the two highest bidders must pay their bids, but only the higher of the two gets the dollar. This auction was designed to show that individuals who have complete information in a sequential move game will indeed make economically irrational decisions. In O'Neill (1986) and Leininger (1989), the authors modify the original dollar auction presented in Shubik (1971). These modifications both assume that there are known budget constraints that allow for backward induction to take place, which does not allow for escalation to take place. Here, only one bid is offered and the level of this bid is sensitive to the budget constraints.

The "tug of war" is a modification of the war of attrition. Here, a player must win a series of contests to claim a prize, whereas in the war of attrition a contestant may quit at any time. It is called a tug of war because, reminiscent of the gym class activity, each contest won brings the participant closer to a victory. Konrad and Kovenock (2005) reports a unique Markov perfect equilibrium where contestants focus their effort on "tipping states" which are determined, in part, by their relative strength. They also show that each contest outcome in the tug of war is stochastic, but the eminence of one's victory increases the probability that they win. Moreover, Agastya and McAfee (2006) corroborate the prediction that one's likelihood of losing the tug of war decreases the likelihood they win succeeding battles.

With respect to jump bidding, Hörner and Sahuguet (2011) suggest that a single and continuous cost paid per time unit is an unreasonable assumption to make for many situations currently modeled as a war of attrition. In an alternative proposition, the authors evaluate how strategies would change when contestants are allowed to vary the amount they choose to spend in a given time period. In their setup, these bids reveal information about valuations, and contestants must match their opponents' total expenditures or else exit. Games of complete information are given

the primary focus, along with the mixed strategies thereof - though there are asymmetric equilibria where a bidder will give up with a high probability at the beginning. The authors find that expected delay is shorter and rent dissipation is smaller with these assumptions. This is partly due to the ability for contestants to jump bid.

Finally, among the most advanced and generalized models of the war of attrition includes Bulow and Klemperer (1999), which provides defines the unique perfect Bayesian Nash equilibrium for any n contestant and k prize contest with private information. Their paper built from the contributions of Hendricks et al. (1988). In Bulow and Klemperer (1999), the authors show that for any war of attrition with no continuation cost (i.e. when contestants who exit don't incur any costs while the contest is ongoing) all but $k + 1$ contestants will drop out instantaneously. It is further shown that this result is efficient.

2.2   Theoretical Overview of the War of Attrition

The war of attrition is a form of competition that requires each of the n participants to pay a continuation cost for the right to one of $k < n$ prizes. This process continues until only k participants are willing to continue paying said cost, and these participants receive the prizes. A participant's unwillingness to continue will be referred to as exiting. The war of attrition is very similar to the all-pay auction, in which all bidders must pay their bids, regardless of whether they claim the auctioned item(s). In fact, a war of attrition is equivalent to the $(k + 1)^{\text{th}}$ price all-pay auction since the contest ends when $(k + 1)^{\text{th}}$ participant exits and the $n - k$ participants who exited must pay their bids. In this section, I will delineate a participant's optimal strategy in the war of attrition under various assumptions, each of which will help us understand the solution provided for a setting that requires upfront investments.

2.2.1 N Participants, K Prizes, and Complete Information

To begin, let's consider a very simple situation where there are $n = 2$ participants and $k = 1$ prizes. This discussion is largely derived by Levin (2004). Assume both participants' values for the prize are common knowledge. The continuation cost is c per unit time, t. A pure strategy for participant i is to choose a time t_i that she will exit. Alternatively, a mixed strategy requires that participant i choose a distribution $F_i(t)$ over exit times where $f_i(t)$ defines the probability of exiting at time t.

In the mixed strategy equilibrium, participant i's strategy must make participant $j \neq i$ indifferent between dropping out at time t_j and waiting to drop out at time $t_j + dt_j$. The payout function for participant j can be defined as

$$u_j(t_j) = \int_0^{t_j} [v_j - cx] f_i(x) dx - ct[1 - F_i(t_j)]. \tag{2.1}$$

The first terms of this payout function, $\int_0^{t_j} [v - cx] f_i(x) dx$ defines the payout to j from choosing to stay in until t_j, based on i choosing to exit at time $x \leq t$ with the probability $f_i(x)$. The second term, $ct[1 - F_i(t_j)]$ defines the payout to j when i chooses to exit at a time greater than t_j. Differentiating (2.1) with respect to t_j and setting the result equal to 0 gives the first order condition,

$$[v_j - ct_j] f_i(t_j) - c[1 - t f_i(t_j) + F_i(t_j)] = 0.$$

Rearranging this expression, and suppressing the subscript on t for simplicity, yields

$$v \frac{f_i(t)}{1 - F_i(t)} = c \tag{2.2}$$

where $\frac{f_i(t)}{1-F_i(t)}$ is more commonly referred to participant i's hazard rate, $h(t)$. Equation (2.2)

reflects that the benefit of staying in must equal the cost. Alternatively, setting $vh(t)dt = cdt$ states that the marginal benefit of staying in dt longer must equal the marginal cost. Solving the differential equation and imposing that $F(0) = 0$ leads to Proposition 1.

Proposition 1. For $n = 2$ there is a unique symmetric mixed strategy Nash equilibrium where

$$F_i(t) = 1 - \exp\left(-\frac{c}{v_j}t\right). \tag{2.3}$$

This mixed strategy solution leads to rather unintuitive predictions of competition when $v_i \neq v_j$. For example, if $v_i = av_j$, then participant i must exit at a rate $\frac{1}{a}$ of j. This implies that the participant with the relatively large value exits faster in expectation.

Now consider the possibility of pure strategy equilibria in this setting. There is no pure strategy where participant i will compete until some predetermined time $0 < t_i^* < v_j$, as this motivates the participant j to exit at time $t_i^* + \epsilon$ where j wins for certain. Participant i would have been better exiting at time $t = 0$. The incentive to one-up the other participant means there is no symmetric pure strategy equilibrium. This leads to Proposition 2, which presents the only stable pure strategies in this setting.

Proposition 2. There exist asymmetric pure strategy Nash equilibria such that participant i exits at $t_i \geq v_j$ and participant j exits at $t = 0$. These equilibria are efficient when bidder i wins if $v_i \geq v_j$.

Relative to the mixed strategy equilibrium from Proposition 1, the notion of an asymmetric pure strategy is more appealing for $v_i \neq v_j$. Moreover, the equilibria in Proposition 2 are efficient while the equilibrium in Proposition 1 is not.[2] This is due to one of the participants exiting immediately for certain in the former, which eliminates the contest entirely. This, however, will

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[2]This notion of efficiency is relevant in the context of most contests, except when there are welfare gains to some third party from the amount of effort/resources spent, such as in an auction setting.

not normally be the case in the latter.

The logic of the mixed and pure strategies in this simple setting extends to the more general model with n participants and k prizes. The consequence of generalizing the model is that there is no longer a unique equilibrium in mixed strategies. While all equilibria will not be addressed, nor proofs provided, a few examples will be. As in the $n = 2$ case, pure strategies involving a participant exiting for certain after a predetermined time $T > 0$ cannot be optimal; these participants will always be better off exiting at $t = 0$. However, pure strategy equilibria where $n - k$ participants drop out immediately are possible, though they require the coordination to do so.

Among mixed strategy equilibria in the generalized model, exits must occur at either the beginning or the end of the contest, and they often require a great deal of coordination among the participants. For instance, all n participants may delay exit so long as they coordinate upon who among them will exit simultaneously and instantaneously as a response to another's exit. As will be discussed in the next subsection, another equilibrium allows for $n - k - 1$ participants to exit immediately while the remaining $k + 1$ participants to exit probabilistically. This equilibrium is thoroughly examined in Bulow and Klemperer (1999). Moreover their paper shows that, in the presence of unknown values, this is a unique symmetric perfect-Bayesian equilibrium.

2.2.2 N Participants, K Prizes, and Incomplete Information

In this subsection I will work through optimal bidding behavior for situations where there is incomplete information. In particular, I will address what an exit strategy looks like when the other participants' valuations of the prize are independently and identically distributed according to some distribution F. As a result of the added uncertainty over others' valuations, one's bidding strategy is now a function of their own valuation, $b(v)$. Again, I begin by

considering a simple setting where $n = 2$ and $k = 1$. After normalizing the continuation cost to one, the payout to a participant with valuation v who bids as though they have a valuation of r is

$$u(v, r) = \int_0^r [v - b(x)] f(x) dx - b(r)[1 - F(r)]. \tag{2.4}$$

A relevant question from this setup is whether a participant has an incentive to misrepresent their value so that $r \neq v$. This concern is thoroughly addressed in Myerson (1981), where, in Lemma 1 of that paper, the *revelation principle* allows for a payout-equivalent equilibrium where participants will truthfully reveal their types (i.e. to allow for $r = v$). Quoting the Lemma directly from Myerson (1981, p. 62), it will also be Lemma 1 of this chapter:

Lemma 1. (The Revelation Principle, Myerson 1981) Given any feasible auction mechanism, there exists an equivalent feasible direct revelation mechanism which gives to the seller and all bidders the same expected utilities as in the given mechanism.

Proof: See Myerson (1981)

Lemma 1 can be imposed without loss of generality. Setting the first derivative of (2.4) with respect to r equal to zero and imposing the revelation principle gives us

$$[v - b(v)] f(v) - b'(v)[1 - F(v)] + b(v) f(v) = 0.$$

This can be rewritten as

$$b'(v) = \frac{v f(v)}{1 - F(v)}.$$

Integrating this expression gives

$$b(v) = b(0) + \int_0^v \frac{x f(x)}{1 - F(x)} dx.$$

Since a participant with a zero valuation will bid zero ($b(0) = 0$), the optimal bidding strategy is defined in Proposition 3.

Proposition 3. For $n = 2$ there is a unique symmetric Nash equilibrium where

$$b(v) = \int_0^v \frac{xf(x)}{1 - F(x)}dx. \tag{2.5}$$

In the case where $n = 2$ is a subgame (i.e. there were originally $n > 2$ participants and all but 2 of them have exited at this point), this is also the unique symmetric perfect-Bayesian equilibrium (Bulow and Klemperer 1999). In addition, this equilibrium is efficient as the individual with the largest valuation will exit last. In the limiting case where all participants' values are known (as in the previous section), the pure strategy in Proposition 3 is replaced by the mixed strategy in Proposition 1.

In the general model with n participants and k prizes, Bulow and Klemperer (1999) show that all but $k + 1$ participants should drop out immediately, which they refer to as "instant sorting". The model presented in their paper relies on participants paying a cost $c > 0$ *after they exited the contest*, and this cost is paid per unit time until the contest is resolved by the remaining participants. Strictly speaking there is no equilibrium when $c = 0$, which would provide the generalized solution to Proposition 3. However the unique symmetric perfect-Bayesian equilibrium in their main proposition can be interpreted as c approaches zero.

2.3   The All-pay Auction

Addressing bidding behavior in the all-pay auction will also be important to understanding the predictions made in a war of attrition with partially unrecoverable upfront investments. While all-pay auctions are rarely used in auction settings, *per se*, they are very helpful in modeling many economic phenomena including lobbying efforts and conflict. One application that will be

explored further is the use of all-pay auctions to raise money for charity, which, it will be shown, outperform other auction mechanisms. I will limit the discussion of all-pay auctions to a specific case where there are n participants, $k = 1$ prizes, and complete information.

N Participants, 1 Prize, and Complete Information

In the all-pay auction, bidders who submit a positive bid must pay some positive amount less than or equal to their bid. In the case of the first price all-pay auction, which is what I will address here, each bidder is responsible for paying their bid exactly. Because one's bid must be forfeited regardless of winning or losing, this incentivizes bidders to bid aggressively, if at all. Moreover, all equilibria are in mixed strategies when there is complete information (Baye et al. 1996).[3] A symmetric equilibrium for an item with a pure common value, v, is straight forward to show - and this will be sufficient for the purposes of this chapter. Following Baye et al. (1996), let F define the cumulative density function where $F(x)$ gives the probability that a bidder bids less than x. A bidder's expected payout from bidding x in this setting is

$$U(x) = (v - x)F(x)^{n-1} - x\left[1 - F(x)^{n-1}\right]$$
$$= vF(x)^{n-1} - x.$$

(2.6)

To ensure a bidder is indifferent among all bids in the support of F, it must be that each x yields the same payout in expectation such that $U(x) = c$. Because a bid of zero must also have a payout of zero, $U(0) = 0 = c$, this yields $F(0) = 0$ from (2.6). Setting $U(x)$ in (2.6) equal to zero provides a unique symmetric mixed strategy Nash equilibrium,

$$F(x) = \left(\frac{x}{v}\right)^{\frac{1}{n-1}}.$$

(2.7)

_____

[3]Baye et al. (1996) also shows that there are asymmetric equilibria, even when the game itself is symmetric.

2.4 The War of Attrition with Unrecoverable Upfront Investments

This chapter models a war of attrition that requires participants to draw from a fixed endowment that is endogenously determined before the auction begins. This design may be helpful for understanding many competitive situations with limited but unknown resources. In addition to auctions, this includes situations where multiple participants must pre-commit to providing a certain good or service in exchange for an indivisible prize, but both may renege a fraction of said good or service when one forfeits pursuit of the prize (e.g. firms competing over market share or product quality, bribes, and contracts).

This theoretical design bridges the gap between the first price all-pay and the war of attrition by allowing the re-purpose value of endowments to vary. By setting the re-purpose value of unused endowments equal to zero (i.e., endowments only have value in the contest for which they were purchased) one can make direct comparisons to the more familiar first price all-pay auction. Setting the redemption value of unused endowments equal to their original cost (i.e., endowments do not lose value after the contest is over) recreates the war of attrition (the second price all-pay auction) as it is typically modeled.

2.4.1 Preliminaries

In this contest there are $n = 2$ risk-neutral participants looking to claim a single prize with a *pure common value* v. Figure 2-1 outlines the timing of the decision stages of this auction. Participants incur a cost to compete for the prize at a normalized rate of 1 per unit time, t. Let $t = 0$ be the pre-contest stage where participants privately choose an endowment $e \in [0, \bar{e}]$ they will draw from during the contest. Let e be drawn independently and identically from the distribution F where $F(0) = 0$ and $F(\bar{e}) = 1$. It is assumed $t = 0$ is the only time participants can contribute to their endowment for the contest. It is also assumed that $F(\cdot)$ is differentiable everywhere, and

this probability density function will be denoted by f. This distribution describes the probability with which a participant chooses a particular endowment z such that $f(z) = \Pr(e = z)$.

Figure 2-1: Timing of Decision Stages

<u>Endowment Stage:</u>   <u>Contest Stage:</u>

Participants privately choose
their endowments, e Participants choose to bid/exit

Time $t = 0$ Time $t > 0$
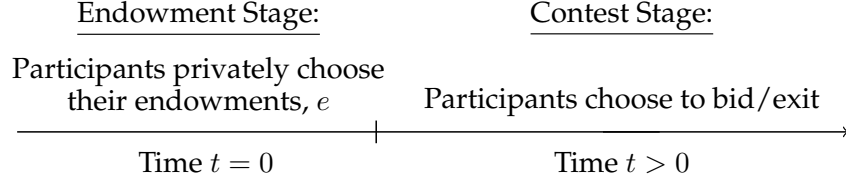
If, after the contest has been resolved, a participant has any endowment remaining (i.e. not spent in the contest) it may be re-purposed for another use at a rate $\theta \in [0, 1]$ per unit of e. This can occur in the contest for two reasons: 1) participants may choose to exit without using their entire endowment or 2) a participant may win the auction before her endowment is fully exhausted.

2.4.2 Equilibrium Analysis: Contest Stage

Wars of attrition have a well understood solution concept as described in Section 2.2: at time t, the cost of delaying an exit until $t + dt$ must equal the expected benefit of winning a prize at time $t + dt$. In the setup proposed by this chapter, participants have privately chosen their endowments before the contest begins. Each resource (endowment) unit has a re-purpose value of θ, thus the cost of staying in the auction dt longer is reduced to θdt, as described in the previous section. This also means for an endowment of e a participant brings to the contest she automatically forfeits $(1 - \theta)e$ of it.

Extending the analysis provided in subsection 2.2, the payout to a participant with an endowment of e who bids as though they have an endowment of r is

$$u(e, r) = \int_0^r [v - \theta b(x) - (1 - \theta)e] f(x) dx - (\theta b(r) + (1 - \theta)e) [1 - F(r)]$$

(2.8)

$$s.t. \ b(r) \le e.$$

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A unique constraint is placed on participants in this setting: bidding strategies must reflect that no one may bid more than their endowment, so $b(r) \leq e$. Taking the first derivative of (2.8) with respect to r, setting it equal to zero and then imposing the revelation principle gives us

$$vf(e) - \theta b(e)f(e) - (1-\theta)ef(e) - \theta b'(e)[1 - F(e)] + \theta b(e)f(e) + (1-\theta)ef(e) = 0,$$

which simplifies to

$$vf(e) = \theta b'(e)[1 - F(e)].$$

Rearranging and integrating this expression gives

$$b(e) = b(0) + \frac{v}{\theta} \int_0^e \frac{f(x)}{1 - F(x)} dx = \frac{v}{\theta} \int_0^e \frac{f(x)}{1 - F(x)} dx, \qquad (2.9)$$

with the second equality following from the fact that a participant with an endowment of zero must also have a bid of zero, i.e. $b(0) = 0$. One can show that if the constraint $b(e) \leq e$ is ignored then the optimal bidding strategy leads to a negative payout when $\theta < 1$. To see this, substitute (2.9) into (2.8), and the resulting expression reduces to $u = -(1-\theta)e$. Only when $\theta = 1$ is there a non-negative expected payout to participants ($u = 0$), which is the same result found in subsection 2.1. Another way to demonstrate that the "optimal bidding strategy" in (2.9) leads to negative payouts is to show that, after integrating (2.9), the solution for the bidding function can also be written as

$$b(e) = -\frac{v}{\theta} \ln[1 - F(e)].$$

This means the following inequality must hold:

$$-\frac{v}{\theta} \ln[1 - F(e)] \leq e.$$

After rearranging, this inequality can also be expressed as

$$F(e) \leq 1 - \exp\left(-\frac{\theta}{v}e\right). \tag{2.10}$$

Recall from Proposition 1 that the mixed strategy solution for exiting is $F(t) = 1 - \exp\left(-\frac{1}{v}t\right)$, where $\theta = c = 1$. Pairing Proposition 1 with (2.10) reveals that the F associated with the optimal bidding strategy for all θ first-order stochastically dominate the F in Proposition 1. Because of this, the optimal bidding strategy leads to the negative payouts expected for $\theta < 1$. This reveals that the constraint $b(e) \leq e$ must be binding so that $b(e) = e$. Another way to interpret this result is to say participants choose their endowments probabilistically and only exit when they have exhausted it.

2.4.3 Equilibrium Analysis: Endowment Stage

Using the bid function $b(e) = e$, which implicitly imposes the revelation principle, and substituting it into (2.8) yields

$$
\begin{aligned}
u(e) &= \int_0^e [v - \theta x - (1-\theta)e]f(x)dx - (\theta e + (1-\theta)e)\left[1 - F(e)\right] \\
&= \int_0^e [v - \theta x - (1-\theta)e]f(x)dx - e[1 - F(e)].
\end{aligned}
$$

Taking the first order condition and setting it equal to zero yields the differential equation

$$
\begin{aligned}
0 &= [v - \theta e - (1-\theta)e]f(e) + ef(e) - 1 + F(e) - (1-\theta)F(e) \\
&= vf(e) + \theta F(e) - 1.
\end{aligned}
$$

Solving the differential equation above and imposing $F(0) = 0$ leads to Proposition 4.

Proposition 4. For $n = 2$ and $\theta \in (0, 1)$ there is a unique symmetric perfect Bayesian Nash

equilibrium where

$$F(e) = \frac{1}{\theta} \left[1 - \exp\left(-\frac{\theta}{v} e \right) \right], \text{ and}$$

$$b(e) = e.$$

(2.11)

It is straight-forward to show that when $\theta = 0, 1$ we return to the solutions of the first price all-pay auction and war of attrition, respectively. In the former, this is due to $\lim_{\theta \to 0^{>}} F(e) = \frac{e}{v}$, which is equivalent to (2.7) for $n = 2$; in the latter, this is due to $F(e)$ being equivalent to (2.3) when $\theta = 1$.

Because this is an all-pay auction, and because revenue is determined by the bidder who exits first, we must rely on the first order statistic to determine expected revenue. For this war of attrition, when bidders draw their endowments let $f_{(1)}(e)$ define the probability that e is the smaller of two independent draws from F, thereby describing the first order statistic. There are two ways an endowment of e can be the smallest value drawn from f. The first is if $e_i < e_j$, and the second is if $e_j < e_i$. The probability a bidder chooses an endowment of e is $f(e)$, and the probability the other bidder has an endowment greater than e is $[1 - F(e)]$. Therefore, the first order statistic of this distribution is $f_{(1)}(e) = f(e_i)[1 - F(e_j)] + f(e_j)[1 - F(e_i)] = 2f(e)[1 - F(e)]$. Revenue is most easily identified by two separate sources. The first source is the *unredeemable* fraction of bidders' endowments, $(1 - \theta)e$. This source of revenue is independent of bidding strategies as it is determined when bidders choose their endowments at time $t = 0$. The second source is the amount of their endowment bidders choose to bid, which has a remaining per-unit value of θ. This, along with bidders only exiting when their entire endowment is exhausted,

leads to the revenue function

$$R = \underbrace{2(1-\theta) \int_0^{\bar{e}} e \, dF(e)}_{\text{Revenue from Endowments}} + \underbrace{2\theta \int_0^{\bar{e}} e \, dF_{(1)}(e)}_{\text{Revenue from Bidding}} \tag{2.12}$$

where $\bar{e} \Rightarrow F(\bar{e}) = 1$. The value of $\bar{e}$ varies with θ. To explicitly define the value of $\bar{e}$ for all θ we solve for $\bar{e}$ when $F(\bar{e}) = 1$ which gives us

$\frac{1}{\theta}\left[1 - \exp\left(-\frac{\theta}{v}\bar{e}\right)\right] = 1 \Rightarrow 1 - \exp\left(-\frac{\theta}{v}\bar{e}\right) = \theta \Rightarrow \bar{e} = -\frac{v}{\theta}\ln[1-\theta]$. We find that $\lim_{\theta \to 0 \atop >} \bar{e} = v$ and when $\lim_{\theta \to 1 \atop <} \bar{e} = \infty$. These distributions mirror those found in all-pay auctions and wars of attrition with complete information, respectively. It is straight forward to show that this auction adheres to the revenue equivalence theorem, as (2.12) reduces to $R = v$.

2.5   Wars of Attrition with Unrecoverable Upfront Investments for Charity

Auctions are an increasingly popular method for charitable organizations to meet their fund-raising goals. This trend is with merit, as much of the theoretical and empirical literature on bidder behavior in charity auctions demonstrate that they are superior revenue-raising mechanisms over similar methods (e.g., raffles or voluntary contributions). Moreover, auctions often play an important role in the fund-raising activities of many charitable and non-profit organizations. In many cases, the organization receives in-kind donations that do not have mission-oriented value but do have economic value. For instance, in a recent charity auction for a human rights organization, Apple CEO Tim Cook agreed to have a coffee date with the highest bidder, from which over \$600,000 was raised.

Engers and McManus (2007) reveals the very important result for auctions in charity settings that different mechanisms will raise different amounts of revenue in expectation. This stands in stark contrast to much of the for-profit auction literature (cf. Vickrey 1961; Riley and Samuelson 1981;

Klemperer 1999). The loss of revenue equivalence is due to the assumptions made regarding

bidders' preferences toward the auctioneer (i.e. charity). Typically, two marginal benefits are

assumed on behalf of bidders: 1) bidders receive indirect benefits from the amount of revenue

generated *by all bidders* for the charity, and 2) bidders feel good for personally contributing to the

charity (i.e., "warm glow"). In this context, Engers and McManus (2007) shows that winner-pay

auctions and all-pay auctions leverage bidders' preferences toward the auctioneer (i.e., charity) to

different degrees. Specifically, they show that the first price all-pay auction will raise more

revenue than the second price winner-pay auction, which in turn raises more than the first price

winner-pay auction. The intuition of this result rests in the source of revenues: in winner-pay

auctions the revenue is generated from a single bidder (the winner), while in all-pay auctions the

revenue is generated by all bidders. This difference incentivizes relatively larger contributions in

all-pay auctions. Goeree et al. (2005) shows, albeit in a relatively extreme example, that this

advantage over winner-pay auctions can be extended to lotteries as well.

Carpenter et al. (2013) extends the theoretical predictions of all-pay charity auctions in Enger and

McManus (2007) and Goeree et al. (2005) to the war of attrition through a mechanism called the

"bucket auction". The war of attrition is shown to raise more revenue in expectation than the first

price all-pay auction. The improvement is non-negligible, too: for $n = 10$ participants, the war of

attrition should raise nearly 10% more revenue than the first price all-pay auction (and nearly

25% more than the first price winner-pay auction).

As mentioned previously, these theoretical predictions are a result of assuming two types of

preferences toward the charity. This section adopts the literature's two primary assumptions

formally: 1) participants receive a constant marginal benefit $\alpha > 0$ for each unit of revenue

generated by all bidders, and 2) participants receive a constant marginal benefit $\gamma > 0$ for each

unit of revenue they personally generated. To avoid the theoretical possibility that bidders are

willing to give an unlimited amount of money to the charity, it is assumed that $2\alpha + \gamma < 1$, as the cost of bidding has been normalized to one.

2.5.1 Equilibrium Analysis: Contest Stage

The necessary modification of the theory from Section 2.4 is the introduction of the constant marginal benefits α and γ. As before, consider a contest with $n = 2$ bidders. Let $b(r)$ denote the bid function of a bidder with an endowment of e, who behaves as though they have an endowment of r. Table 2.1 defines the costs and benefits to bidder i from winning the auction.[4] The first column labeled "Auction-based" describes the payouts attributed to bidding in the bucket auction without considering the social preferences captured in α and γ. The second column labeled "Indirect Benefit" captures the benefits associated with α, the amount of revenue that is raised. Note that in the two bidder case, this benefit is generated from the amount contributed through bidding *and* through the unredeemable portion of each bidder's auction currency. Since the auction currency purchased by others is never revealed, the contribution from their unredeemable currency is based in expectation. In the last column, the payouts associated with warm glow are captured by γ. Rows break down payouts based on bidders' strategies. The first row is based on one's bidding strategy, while the second and third rows break down payouts by each bidder's endowment strategy.

Table 2.1: Payout from Winning

	Auction-based	Indirect Benefit	Warm Glow Benefit
Bidding Strategy:	$v - \theta b(r)$	$+2\alpha\theta b(r)$	$+\gamma\theta b(r)$
Endowment Strategy:	$-(1-\theta)e$	$+\alpha(1-\theta)e$	$+\gamma(1-\theta)e$
Other's Endowment Strategy:		$+\alpha(1-\theta)\int zf(z)dz$	

---

[4]The only modification to Table 2.1 needed to describe the payout to losing the auction is to remove the value of the item, v.

The terms in Table 2.1 are combined into the bidder's payout function,

$$u(r,e) =$$

$$\int_0^r \left[v - (1 - 2\alpha - \gamma)\theta b(x) - (1 - \alpha - \gamma)(1 - \theta)e + \alpha(1 - \theta)\int zf(z)dz \right] f(x)dx$$

$$- \left((1 - 2\alpha - \gamma)\theta b(r) + (1 - \alpha - \gamma)(1 - \theta)e - \alpha(1 - \theta)\int zf(z)dz \right) \left[1 - F(r) \right] \quad (2.13)$$

$$s.t.\ b(r) \le e,$$

which also reflects the constraint that one's bid may not exceed their endowment, $b(r) \le e$. By

taking the first derivative of (2.13) with respect to r and setting it equal to zero we find

$$0 = vf(r) - \theta(1 - 2\alpha - \gamma)[1 - F(r)]b'(r).$$

Imposing the revelation principle and rearranging for $b'(e)$ reveals

$$b'(e) = \frac{v}{(1 - 2\alpha - \gamma)\theta}\frac{f(e)}{1 - F(e)}.$$

Integrating over $b'(e)$ gives

$$b(e) = b(0) + \frac{v}{(1 - 2\alpha - \gamma)\theta}\int_0^e \frac{f(x)}{1 - F(x)}dx = \frac{v}{(1 - 2\alpha - \gamma)\theta}\int_0^e \frac{f(x)}{1 - F(x)}dx \quad (2.14)$$

where the constant of integration $b(0) = 0$, a result of the participant with an endowment of zero

being forced to submit a bid of zero. Also, when $\theta = 1$, we find the same theoretical result

reported in Carpenter et al. (2013) where $\theta = 1$ is an implicit assumption in their model.[5]

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[5]The only difference here is that this model assumes a pure common value while Carpenter et al. (2013) assumes a distribution of values.

Notice that the optimal bid function leads to larger bids in the charity setting, *ceteris paribus*:

$$\underbrace{\frac{v}{\theta} \int_0^e \frac{f(x)}{1 - F(x)} dx}_{\text{For-profit}} < \underbrace{\frac{v}{(1 - 2\alpha - \gamma)\theta} \int_0^e \frac{f(x)}{1 - F(x)} dx}_{\text{Charity}} .$$

As a result, the optimal bid function in the contest stage will also be bounded by the constraint

$b(e) \leq e.$

2.5.2 Equilibrium Analysis: Endowment Stage

Using the bid function $b(e) = e$, which implicitly imposes the revelation principle, and substituting it into (2.13) yields

$$u(e) =$$

$$\int_0^e \left[v - (1 - 2\alpha - \gamma)\theta x - (1 - \alpha - \gamma)(1 - \theta)e + \alpha(1 - \theta) \int z f(z) dz \right] f(x) dx$$

$$- \left((1 - 2\alpha - \gamma)\theta e + (1 - \alpha - \gamma)(1 - \theta)e - \alpha(1 - \theta) \int z f(z) dz \right) \left[1 - F(e) \right]$$

$$=$$

$$\int_0^e \left[v - (1 - 2\alpha - \gamma)\theta x - (1 - \alpha - \gamma)(1 - \theta)e + \alpha(1 - \theta) \int z f(z) dz \right] f(x) dx$$

$$- \left((1 - (1 + \theta)\alpha - \gamma)e - \alpha(1 - \theta) \int z f(z) dz \right) \left[1 - F(e) \right].$$

Taking the first order condition and setting it equal to zero yields the differential equation

$$0 = vf(e) + (1 - 2\alpha - \gamma)\theta F(e) - (1 - (1 + \theta)\alpha - \gamma). \tag{2.15}$$

Solving (2.15) and imposing $F(0) = 0$ leads to Proposition 5.

Proposition 5. For $n = 2$ and $\theta \in (0, 1)$ there is a unique symmetric perfect Bayesian Nash

equilibrium where

$$F(e) = \frac{1 - (1 + \theta)\alpha - \gamma}{(1 - 2\alpha - \gamma)\theta} \left[1 - \exp\left(-\frac{(1 - 2\alpha - \gamma)\theta}{v} e \right) \right], \text{ and}$$

$$b(e) = e.$$

(2.16)

As in the for-profit setting, one can consider the solutions of the first price all-pay auction and war of attrition when $\theta = 0, 1$, respectively. In the former, this is due again to $\lim_{\theta \to 0 \atop >} F(e) = \frac{1 - \alpha - \gamma}{v} e$, which is equivalent to (2.7) for $n = 2$ in a charity setting; in the latter, this is due to $F(e)$ being equivalent to (2.3) when $\theta = 1$ in a charity setting.

Corroborating the theoretical results of earlier papers, revenue in this charity setting does not adhere to revenue equivalence. In particular it can be shown using (2.12) that expected revenue is strictly increasing in θ according to the F in (2.16). The value of $\bar{e}$ increases due to the charity parameters, which means that bidders are willing to take a larger endowment. A restriction of non-negative values for α and γ leads to

$$\bar{e} = -\frac{v}{(1 - 2\alpha - \gamma)\theta} \ln \left[1 - \frac{(1 - 2\alpha - \gamma)\theta}{1 - (1 + \theta)\alpha - \gamma} \right].$$

While the expected revenue function does not reduce into a compact or interpretable solution, the loss of revenue equivalence is illustrated in Figure 2-2 for given values for v, α, and γ. This is a representative illustration of how revenue changes with θ as long as $\alpha > 0$. For cases where $\alpha = 0$ and $\gamma > 0$ revenue equivalence holds and expected revenue increases with γ.

2.6   Conclusion

In many wars of attrition, particularly ones that are pre-calculated, contestants may need to choose how much of their resources they are willing to devote to the conflict. This resource

Figure 2-2: Expected Revenue Increases with the Redemption Value (θ)
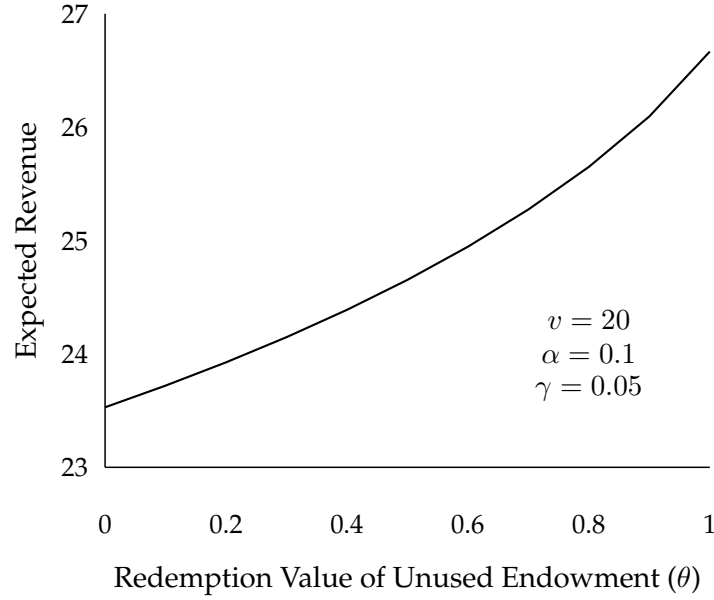
allocation to the contest simultaneously determines the maximum amount of time that a

contestant can compete. In a theoretical variation from the traditional war of attrition, this

chapter considers how bidder strategies change when it is necessary for resource endowments to

be determined. It does so through a two-stage design where, in the first stage, contestants choose

how much of their resources they are willing to contribute to the contest, which is private

information, and, in the second stage, choose for how long to compete given those resources. In

addition, it is assumed that resources dedicated to the conflict, but not ultimately utilized for that

purpose, have a re-purpose value. This re-purpose value is common to all contestants, but is

allowed to vary from zero re-purpose value to full re-purpose value. When the re-purpose value

is zero for contestants, then this variation of the war of attrition is effectively a first price all-pay

auction. When the re-purpose value is full, then this war of attrition reverts to the standard

model.

The model presented in this chapter demonstrates that there is a unique symmetric perfect

Bayesian equilibrium where bidders in the second (bidding) stage use a pure strategy of

competing until their resource is exhausted, and rely on a mixed strategy in the first stage when they choose their resource endowment. Furthermore, it is shown that the larger the re-purpose value of unused resources the longer the contest lasts in expectation. However, this change in contest duration is counteracted by changes in the equilibrium distribution of resource endowments, which maintains revenue equivalence - regardless of the re-purpose value of unused resource endowments, the war of attrition always generates an expected revenue of the item's value.

Finally, the theoretical results are extended to describe bidding behavior in charity auctions. Here, common assumptions of bidders' revenue-based benefits demonstrate how behavior changes with the re-purpose value of resources dedicated to the charity. Interestingly, revenue equivalence breaks down. Given standard rational assumptions of bidders in charity auctions, wars of attrition with larger re-purpose values will generate larger revenues. This corroborates similar theoretical findings in the charity auction literature.

3   Chapter 3: Bidder Behavior in All-pay Auctions for Charity

Auctions are an increasingly popular method for charitable organizations to meet their

fund-raising goals. This trend is with merit, as much of the theoretical and empirical literature on

bidder behavior in charity auctions demonstrate that they are superior revenue-raising

mechanisms over similar methods (e.g., raffles or voluntary contributions). Moreover, auctions

often play a fundamental role in the fund-raising activities of many charitable and non-profit

organizations; in many cases, the organization receives in-kind donations that do not have

mission-oriented value but do have economic value. For instance, in a recent charity auction for a

human rights organization, Apple CEO Tim Cook agreed to have a coffee date with the highest

bidder, from which over $600,000 was raised.

This chapter investigates the first price all-pay auction and several variations of the bucket

auction, a type of war of attrition, which involves incremental bidding, to identify

mechanism-specific characteristics (e.g., incremental vs. sump-lum bidding) and bidder-specific

characteristics (e.g., competitiveness, sunk cost sensitivity) that may be responsible for their

overwhelming success. The theoretical model presented in this chapter underpins the bidding

behavior of rational agents, while the experiments highlight the behavioral tendencies of human

subjects.

3.1   Literature Review

There are several reasons to be optimistic about the potential of all-pay auctions for fund-raising

purposes. Lotteries, which themselves are inefficient all-pay auctions, are extremely popular

across the world. The North American Association of State and Provincial Lotteries reports that

nearly 69 billion dollars was spent on lotteries in the United States in 2012 - 19.4 billion was

returned to players in the form of winnings (NASPL 2014). This is equivalent to every single

American spending, on average, $219 a year on lotteries. Moreover, according to the aforementioned association, in the last 50 years over 290 billion dollars have been generated for education and public projects through these state-run lotteries.

In lotteries, a participant's purchase of tickets creates a negative externality on other participants by making others' tickets less valuable in expectation. This is counteracted by the positive externality giving to the public good has. In laboratory settings, Morgan and Sefton (2000), Lange et al. (2007) and Orzen (2008) demonstrate that lotteries are more successful at funding public goods than the voluntary contribution mechanism (VCM). Similar results are reported in Landry et al. (2006), which provides evidence from a field experiment that lotteries are capable of eliciting larger (gross) contributions for a charity more successfully than VCM. These results are consistent with the theoretical advantages of lotteries over the VCM. In particular, Morgan (2000) demonstrates that lotteries, relative to VCM, will raise more in contributions and improve welfare. This result is due to a compensating (negative) externality that occurs among the ticket holders - the purchase of tickets by one player decreases the likelihood that another player wins.

If the random prize allocation mechanism inherent in a lottery is forgone and, instead, the prize is allocated to the largest contributor then we have the all-pay auction. As Goeree et al. (2005) demonstrates, this change improves efficiency, which in turn increases total contribution. Similar theoretical predictions of all-pay auctions outperforming lotteries are described in Orzen (2008), Corazzini et al. (2010), and Faravelli (2011).

Importantly, the advantages of all-pay auctions over lotteries do not extend to every auction mechanism. Engers and McManus (2007) reveals the very important result for auctions in charity settings that different mechanisms will raise different amounts of revenue in expectation. The loss of revenue equivalence is due to the assumptions made regarding bidders' preferences toward the auctioneer (i.e. charity). Typically, two marginal benefits are assumed on behalf of

bidders: 1) bidders receive indirect benefits from the amount of revenue generated *by all bidders* for the charity, and 2) bidders feel good (i.e. "warm glow") for personally contributing to the charity. In this context, Engers and McManus (2007) shows that winner-pay auctions and all-pay auctions leverage bidders' preferences toward the auctioneer (i.e. charity) to different degrees. Specifically, they show that the all-pay auction will raise more than the second price winner-pay auction, which in turn raises more than the first price winner-pay auction.

The intuition of the revenue discrepancy in winner-pay and all-pay auctions rests on the source of revenues: in winner-pay auctions the revenue is generated from a single bidder (the winner), while in all-pay auctions the revenue is generated by all bidders. This differences incentivizes relatively larger contributions in all-pay auctions. Goeree et al. (2005) shows this in their theoretical model where bidders have independent private values over the unit interval for a prize (with incomplete information). Due to the charity setting, they assume that bidders receive a fractional benefit for each dollar raised in the auction. Their paper reports that revenue in the first price auction is greater in a charity setting than it is in a for-profit auction setting. However, revenue is relatively less in winner-pay auctions because winning the auction comes at the cost of no longer being able to free ride (i.e., winning the auction means one now must pay their bid). As a result, this causes bids to be somewhat suppressed. In an all-pay mechanism, one's ability to free ride is eliminated because, win or lose, a bidder must always pay their bid. In other words, an all-pay auction outperforms a winner-pay auction because the mechanism itself removes the ability for bidders to free ride off the winner.

Nonetheless, much of the theoretical and empirical has given consideration to a variety of winner-pay auction mechanisms, as these are the most commonly used mechanisms used by organizations. For instance, Isaac and Schnier (2005) examine bidding behavior in silent auctions for charity. In this study, field data and experimental data are collected. Generally in silent

auctions there are many items being auctioned off simultaneously. In fact, one of the valuable

characteristics of silent auctions is that many bidders can participate in many auctions

simultaneously without the need for one (or many) auctioneers to facilitate them. Moreover, the

auctions typically rely on an publicly ascending mechanism as an English auction does.

Despite its benefits, there are several downsides that typically lead to poor performances in terms

of revenue. The first is that the silent auction is very susceptible to being "gamed". Namely, it is

easy for a bidder to surreptitiously overbid using a false identity while also submitting the

second highest bid. While the overly high bid discourages others from participating, the

"winner" is never determined and the second highest bidder claims the prize for relatively little

money. The second issue with silent auctions is the simultaneity of auctions, which makes it

difficult for each auction to be efficient or raise as much money as it could if there were not

multiple auctions operating simultaneously.

In fact, Isaac and Schnier (2005) find that the silent auction tends to perform very poorly. Their

paper reveals that there is virtually no over-bidding in silent auctions are only about half of

auction ever exceed the minimum bidding increment. Their paper also considers what revenue

would be in the presence of pure altruism, in which case bidders do not care about the source of

the revenue. This is done computationally, and it is reported that there is little difference in

expected revenue. In light of these results, the authors suggest what may be the more substantial

source of charitable behavior is the act of donating items to be auctioned. However in a similar

study, Carpenter et al. (2011) shows that silent auctions can perform nearly as well as an English

auction if the auctioneers make some minor adjustments, such not using a pre-determined

deadline for bids which will discourage sniping.

In a very interesting comparison of the English auction and a lottery for their abilities to

incentivize and solicit contributions to public good, Davis et al. (2006) finds that a sufficiently

high marginal per capita return (MPCR) lead to larger revenues in the lottery than in the English auction. This result is largely dependent on the assumption that bidders' values are common knowledge. Their paper's primary conjecture (Conjecture 1) is that any positive MPCR will motivate bidders in the English auction to inflate the payment made by the individual with the highest valuation. This result is also predicted in an early version of Engers and McManus (2007).[1] Theoretically, the knowledge of others' valuations gives an advantage to the English auction over a lottery for relatively small MPCRs. To the contrary, controlled laboratory experiments reveal that lotteries uniformly raise more revenue than English auctions, even at small MPCRs. This advantage, however, is more pronounced and more persistent through time when MPCR is higher. Moreover, this result is rather robust across different distributions of private values.

In a study from the field, Elfenbein and McManus (2007) compares revenues generated in for-profit auctions and charity auctions on eBay. The charity auctions associated with eBay are run by Giving Works where nearly all auctions donate 10-100% of the revenue to a disclosed organization. On average, there is a 6% revenue premium in auctions for charity. In addition, the paper reports that bidders typically refrained from "sniping" in charity auctions - a bidding strategy involving last-minute topping bids that allow the bidder to win. Sniping also tends to decrease the final bid in the auction. The fact that bidder tend to refrain from the strategy in charity auction suggests that bidders are actively trying to increase the final bid, even if they do not win. In a similar field experiment, Popkowski and Rothkopf (2006) run charity and for-profit auctions for identical products online. In this study they find bid levels increase by more than 40% in charity auctions donating at least 25% of revenue. They also find that bid levels respond to contribution levels in a consistent manner (i.e., the larger the contribution level the larger the

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[1]This discussion was removed in the published version of the paper, though I have a copy of the working paper for reference.

bid level).

Not all experiments of charity auctions show revenues surpassing those of for-profit auctions. In Isaac et al. (2008), a theoretical model is proposed wherein bidders receive proportional benefits with respect to how much revenue is generated. The theoretical predictions for revenue for the first price winner-pay and second price winner-pay auctions don't exceed a for-profit auction by a substantial amount. This is due largely to the assumptions made about who receives the proportional benefits. In their paper, it is assumed only half of the bidders are capable of receiving these benefits, and even these bidders do not receive the benefit if they do not win the auction. This is referred to "See and Be Seen," where the assumptions reflect how bidders may behave if they only care about being acknowledged for their contribution. Their paper also provides evidence in support of this prediction with a hybrid lab-field experiment. The experiment examines behavior in an induced laboratory environment (where revenue does not go to a real charity) as well as in a setting where bidders were allowed to send the revenue to a charity of their choice. There was no substantial difference in revenue between the treatments. In light of these results, it may be natural for practitioners to treat auctions simply as a mechanism that converts donated items into cash, rather than an opportunity to incentive donations (Orzen 2008). In fact, this already occurs with some regularity. According to Giving USA, a public service foundation, 23 million itemized personal tax returns listed a non-cash donation. Despite their economic value, many of these in-kind donations do not have mission-oriented value, which necessitates an auction mechanism. These in-kind donations can also take unusual forms that would not be captured in tax returns. For instance, in 2011 a charity auctioned off the ability to job shadow Bill Clinton for a day that which raised $255,000. While the theoretical literature on charity auctions uniformly touts the superior fund-raising capacity of all-pay auctions, the empirical findings are certainly mixed. In field studies,

Carpenter et al. (2008) and Onderstal et al. (2013) find that all-pay auctions under-perform relative to the first price winner-pay (in the former) and the VCM (in the latter), both of which conclude a lack of participation was the source of the shortfall. On the other hand, Carpenter et al. (2013a) found the all-pay auction to raise more revenue than the first price winner-pay and the second price winner-pay in a laboratory setting. Compared to lotteries, Shram and Onderstal (2009) and Carpenter et al. (2013b) suggest all-pay auctions raise more revenue, however Orzen (2008) and Corazzini et al. (2010) find the opposite result.

Resolving this empirical discrepancy on the all-pay auction's ability to generate revenue has important policy implications for fund-raisers and charitable organizations. One explanation for these contradicting results is that the competition between bidders in the all-pay auction may be negatively overshadowing the theoretical benefits of the mechanism. If so, heterogeneity in competitiveness between bidders may be an important factor to consider. However, a preponderance of the experimental findings on all-pay auctions (in for-profit contexts) reports over-bidding, many of which consider competitiveness, or the "utility of winning," to be an explanation.[2]

Since all-pay auctions for charity occasionally fail due to a lack of participation, endogenous entry into competitive environments is a relevant consideration. For instance, Morgan et al. (2012) reports that there is over-entry in contests with relatively small prizes and under-entry with relatively large prizes.[3] In Eriksson et al. (2009), risk aversion tends to keep subjects out of competitive environments (i.e. tournaments). But perhaps most interestingly, Bartling et al. (2009) finds that inequality-averse subjects often opt-out of competitive environments. This result seems particularly relevant in the context of charity auctions where bidders are more likely to be

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[2]See Gneezy and Smorodinsky (2006), Ernst and Thoni (2009), Lugovskyy et al. (2010), Fehr and Schmidt (2011), Klose and Sheremeta (2012), Ong and Chen (2012).

[3]The evidence in Morgan et al. (2012) is from a Tullock lottery contest, which is different than the all-pay auction.

inequality-averse, and may explain why participation can fall short in these settings.

While the context of early studies make it seem as though the value of charity auctions to be primarily as a way to turn in-kind donations into cash - and there is certainly value there - more recent empirical studies demonstrate that certain auction mechanisms can be overwhelmingly successful in certain settings. In particular, mechanisms that require all bidders to pay a positive amount that is less than or equal to their bid (i.e., all-pay auctions) are more successful than those mechanisms where only the winner pays an amount less than or equal to their bid. While this advantage of all-pay auctions over winner-pay auctions, it extends to lotteries in many circumstances as well.

With respect to revenue, a new mechanism called the "bucket auction" (formally introduced in Carpenter et al. 2013a) has the promise of harnessing the theoretical benefits of all-pay auctions without its success requiring much at all on participation. The bucket auction is essentially a sequential-move war of attrition (WoA), which is equivalent to a second price all-pay auction.[4] In the auction, bidders are endowed with auction currency, denoted by "tokens," which have a monetary value and are used for bidding. The auctioneer randomly arranges bidders in a circle with one bidder being chosen to start the bidding process. This bidder has the choice to publicly place one, and only one, of her tokens in a "bucket," which will be referred to as bidding, or not place a token in the bucket, which will be referred to as exiting. If she chooses to bid a token then she loses the monetary value of the token but stays in the auction. If she chooses to exit then she forfeits the auction and may not participate further.

The bucket auction has theoretical properties that improve revenue over even the first price

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[4]A war of attrition is typically described as a competition among n participants each vying for one of $k < n$ prizes. It is costly to maintain one's status as an "active" participant, but may exit at any time - thereby forfeiting their claim to one of the k prizes. This competition continues (and costs continue to accrue for active bidders) until $n - k$ participants choose to exit. When modeled with open loop strategies, the war of attrition is equivalent to the second price all-pay auction.

all-pay auction. By imposing the assumptions associated with a charity setting to the generalized framework in Bulow and Klemperer (1999), Carpenter et al. (2013a) shows that a bidder choosing to delay exit generates a positive externality for other bidders. Namely, the act of staying in the auction a little bit longer forces others to stay in a little bit longer than they otherwise would have. This generates more revenue for the charity, which is assumed to also benefit all bidders indirectly. While the bucket auction is predicted to outperform the first price all-pay, as well as several varieties of winner-pay auctions, the empirical difference is staggering. In a laboratory experiment where preferences for revenue generation were induced, Carpenter (2013a) reports the bucket auction raised one and a half times as much revenue as the next best mechanism (the first price all-pay). Very similar results are reported in Carpenter et al. (2013b), a field study involving nearly 100 charity auctions across the United States. Because a war of attrition with open-loop strategies is essentially a second price all-pay auction (Krishna and Morgan 1997), this theoretical result is corroborated in Goeree et al. (2005), where the revenue generated in all-pay auction increases as the prices paid by winners approaches the "last price" all-pay auction.

Bidder-specific characteristics are explored in Carpenter et al. (2013a) as potential explanations for the extraordinary revenues generated from the bucket auction, such as sunk cost sensitivities (also considered in Eyster 2002) and competitiveness. While these characteristics are consistent with behavior driving revenues up in charity settings, Horisch and Kirchkamp (2007) find under-bidding to be prevalent in wars of attrition in a for-profit context. This chapter continues to explore bidder-specific characteristics, but also explores mechanism-specific characteristics (e.g., incremental vs. lump-sum bidding) as potential explanations. By manipulating the exchange value of unused auction currency (i.e. the monetary value of tokens that were never bid) the bucket auction can be revenue equivalent to the first price all-pay auction or to the war of attrition. This manipulation allows for the testing of mechanism-specific effects on bidding

behavior.

3.2 Theoretical Motivation

3.2.1 Bucket Auction Description

The bucket auction is a sequential-move war of attrition (WoA). The war of attrition is a well understood form of competition that requires participants to pay a cost to continue until only k participants are willing to continue paying said cost for the right to one of k prizes. In the bucket auction, bidders (participants) are endowed with auction currency ("tokens") which have a monetary value and are used for bidding. In this variation, the amount of tokens a bidder brings to the auction is privately and individually determined before the auction begins. The auctioneer randomly arranges bidders in a circle with one bidder being chosen to start the bidding process. This bidder has the choice to publicly place one, and only one, of her tokens in a "bucket," which will be referred to as bidding, or not, which will be referred to as exiting. If she chooses to bid a token then she loses the monetary value of the token but stays in the auction. If she chooses to exit then she forfeits the auction and may not participate further.

Once the first bidder bids or exits, the bucket is moved to the next bidder who must also choose to bid or exit. This process continues until there are as many bidders who have not exited as there are prizes, and these remaining bidders claim them. Regardless of the outcome of the auction, all bidders must pay the monetary value of the tokens they personally placed in the bucket. The bucket auction deviates from typical wars of the attrition in timing; bidders must choose to bid or exit sequentially rather than simultaneously. This variation has little impact on equilibrium behavior, however it does cause the bidding process to take longer. To make deriving analytical predictions more straight-forward, the intra-circle sequential moves will be abstracted from in the model.
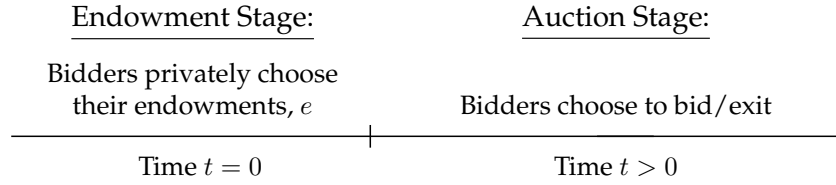
This theoretical design bridges the gap between the first price all-pay and the bucket auction through the variation of an unused token's redemption value. By setting the redemption value of unused tokens equal to zero (i.e., tokens only have value in the auction for which they were purchased) we can make direct comparisons to the more familiar first price all-pay auction. The ability to create revenue-equivalence the all-pay and this variation of the war of attrition allows for a clean analysis of mechanism-specific effects, such as incremental vs.lump-sum bidding. It also allows for analysis on bidder-specific "sensitivities" that are may be exploited by a mechanism design, such as loss aversion, competitiveness, risk-taking attitudes, or sunk cost sensitivities.

3.2.2   Preliminaries

In this auction there are $n = 2$ risk-neutral bidders looking to claim a single prize with a *pure common value* v. Figure 3-1 outlines the timing of the decision stages of this auction. Bidders incur a cost to compete for the prize at a normalized rate of 1 per unit time, t. Let $t = 0$ be the pre-auction stage where bidders privately choose an endowment $e \in [0, \bar{e}]$ of auction currency they will draw from during the auction. It is assumed $t = 0$ is the only time bidders can contribute to their endowment for the auction. Let e be drawn independently and identically from the distribution F where $F(0) = 0$ and $F(\bar{e}) = 1$. It is also assumed that $F(\cdot)$ is differentiable everywhere, and this probability density function will be denoted by f. This distribution describes the probability with which a bidder chooses a particular endowment z such that $f(z) = \Pr(e = z)$.

To simulate a charity setting, it is assumed that bidders receive benefits from the revenue generated by the auction. Following Engers and McManus (2007) and Carpenter et al. (2013), two constant marginal benefits will be added to the model. The first benefit α will measure the

Figure 3-1: Timing of Decision Stages

Endowment Stage:	Auction Stage:
Bidders privately choose their endowments, e	Bidders choose to bid/exit
Time $t = 0$	Time $t > 0$

constant marginal indirect benefit a bidder receives from the total amount of revenue raised. This is benefit is independent of where the revenue originates (i.e. it does not depend on which bidder(s) contributed to the total revenue). On the other hand, the second constant marginal benefit assumes γ measures the benefit a bidder receives from personally contributing to the auction revenue. Another way to think about γ is to imagine that bidders get "warm glow" from contributing to the charity through the auction.

If, after the auction is over, a bidder has any endowment remaining (i.e. not spent in the auction) it may be redeemed for cash at an exogenously determined rate $\theta \in [0, 1]$ per unit of e. Bidders may have unused tokens at the end of the auction for two reasons: 1) bidders may choose to exit without using their entire endowment or 2) a bidder may win the auction before her endowment is fully exhausted. In the following subsections, I will demonstrate that when $\theta = 0$ this variation of the war of attrition is equivalent to the first price all-pay auction, and when $\theta = 1$ it is equivalent to the original war of attrition.

3.2.3   Equilibrium Analysis: Auction Stage

Wars of attrition have a well understood solution concept as described in Bulow and Klemperer (1999): at time t, the cost of delaying an exit until $t + dt$ must equal the expected benefit of winning a prize at time $t + dt$. In the setup proposed by this chapter, bidders have privately chosen their endowments before the auction begins. Each unit of currency has a redemption value of θ, thus the cost of staying in the auction dt longer is reduced to θdt. This also means for

an endowment of e a bidder brings to the auction she automatically forfeits $(1 - \theta)e$ of it.

Let $b(r)$ denote the bid function of a bidder with an endowment of e, who behaves as though they have an endowment of r. Table 3.1 defines the costs and benefits to bidder i from winning the auction.[5] The first column labeled "Auction-based" describes the payouts attributed to bidding the bucket auction without considering the social preferences captured in α and γ. The second column labeled "Indirect Benefit" captures the benefits associated to α, the amount of revenue that is raised. Note that this benefit is generated from the amount contributed through bidding *and* through the unredeemable portion of bidder's auction currency. Since the auction currency purchased by others is never revealed, the contribution from their unredeemable currency is based in expectation. In the last column, the payouts associated with "warm glow" are captured by γ. Rows break down payouts based on bidders' strategies. The first row is based on one's bidding strategy, while the second and third rows break down payouts by each bidder's endowment strategy.

Table 3.1: Payout from Winning

	Auction-based	Indirect Benefit	Warm Glow Benefit
Bidding Strategy:	$v - \theta b(r)$	$+2\alpha\theta b(r)$	$+\gamma\theta b(r)$
Endowment Strategy:	$-(1 - \theta)e$	$+\alpha(1 - \theta)e$	$+\gamma(1 - \theta)e$
Other's Endowment Strategy:		$+\alpha(1 - \theta)\int zf(z)dz$	

[5]The only modification to Table 3.1 needed to describe the payout to losing the auction is to remove the value of the item, v.

The terms in Table 3.1 are combined into the bidder's payout function,

$$u(r, e) =$$

$$\int_0^r \left[v - (1 - 2\alpha - \gamma)\theta b(x) - (1 - \alpha - \gamma)(1 - \theta)e + \alpha(1 - \theta)\int zf(z)dz \right] f(x)dx$$

$$- \left((1 - 2\alpha - \gamma)\theta b(r) + (1 - \alpha - \gamma)(1 - \theta)e - \alpha(1 - \theta)\int zf(z)dz \right) \left[1 - F(r) \right] \qquad (3.1)$$

$$s.t.\ b(r) \le e,$$

which also reflects the constraint that one's bid may not exceed their endowment, $b(r) \le e$. By setting the first-order condition of (3.1) with respect to r equal to zero we find

$$0 = vf(r) - \theta(1 - 2\alpha - \gamma)[1 - F(r)]b'(r).$$

Imposing the revelation principle (Myerson 1981) and rearranging for $b'(e)$ reveals

$$b'(e) = \frac{v}{(1 - 2\alpha - \gamma)\theta} \frac{f(e)}{1 - F(e)}.$$

Integrating over $b'(e)$ gives

$$b(e) = b(0) + \frac{v}{(1 - 2\alpha - \gamma)\theta} \int_0^e \frac{f(x)}{1 - F(x)}dx = \frac{v}{(1 - 2\alpha - \gamma)\theta} \int_0^e \frac{f(x)}{1 - F(x)}dx \qquad (3.2)$$

where the constant of integration $b(0) = 0$, a result of the participant with an endowment of zero being forced to submit a bid of zero. Also, when $\theta = 1$, we find the same theoretical result reported in Carpenter et al. (2013) where $\theta = 1$ is an implicit assumption in their model.[6]

It can be shown that if the constraint $b(e) \le e$ is ignored then the optimal bidding strategy leads

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[6]The only difference here is that this model assumes a pure common value while Carpenter et al. (2013) assumes a distribution of private values.

to a negative payout when $\theta < 1$. By substituting (3.2) into (3.1), the expression reduces to $u = -2\alpha(1-\theta)(1-F(e))\int zf(z)dz < 0$. Only when $\theta = 1$ is there a non-negative expected payout to participants ($u = 0$). In addition, it can be shown that the F associated with the optimal bidding function must first-order stochastically dominate a distribution F' that has an expected payout of zero for all θ. This reveals that the constraint $b(e) \leq e$ must be binding so that $b(e) = e$. Another way to interpret this result is to say participants choose their endowments probabilistically and only exit when they have exhausted it.

3.2.4 Equilibrium Analysis: Endowment Stage

Being able to backward induct the optimal behavior in the auction stage allows us to define the optimal strategy for choosing auction currency. Using the bid function $b(e) = e$, which implicitly imposes the revelation principle, and substituting it into (3.1) yields

$$u(e) =$$

$$\int_0^e \left[v - (1 - 2\alpha - \gamma)\theta x - (1 - \alpha - \gamma)(1-\theta)e + \alpha(1-\theta)\int zf(z)dz\right]f(x)dx$$

$$- \left((1 - 2\alpha - \gamma)\theta e + (1-\alpha-\gamma)(1-\theta)e - \alpha(1-\theta)\int zf(z)dz\right)\left[1 - F(e)\right]$$

$$=$$

$$\int_0^e \left[v - (1 - 2\alpha - \gamma)\theta x - (1 - \alpha - \gamma)(1-\theta)e + \alpha(1-\theta)\int zf(z)dz\right]f(x)dx$$

$$- \left((1 - (1+\theta)\alpha - \gamma)e - \alpha(1-\theta)\int zf(z)dz\right)\left[1 - F(e)\right].$$

Taking the first order condition and setting it equal to zero yields the differential equation

$$0 = vf(e) + (1 - 2\alpha - \gamma)\theta F(e) - (1 - (1+\theta)\alpha - \gamma).$$

Solving the differential equation above and imposing $F(0) = 0$ leads to Proposition 5.

Proposition 1. For $n = 2$ and $\theta \in (0, 1)$ there is a unique symmetric perfect Bayesian Nash equilibrium where

$$F(e) = \frac{1 - (1 + \theta)\alpha - \gamma}{(1 - 2\alpha - \gamma)\theta} \left[1 - \exp\left(-\frac{(1 - 2\alpha - \gamma)\theta}{v} e \right) \right], \text{ and} \tag{3.3}$$

$$b(e) = e.$$

It can be shown that we return to the solutions of the first price all-pay auction and war of attrition when we set $\theta = 0, 1$, respectively. In the former, this is due again to $\lim_{\theta \to 0^{>}} F(e) = \frac{1 - \alpha - \gamma}{v} e$, which is equivalent to an all-pay auction (Baye et al. 1996) extended to a charity setting; in the latter, this is due to $F(e)$ being equivalent to the war of attrition in a charity setting when $\theta = 1$.

Because this is an all-pay auction, and because revenue is determined by the bidder who exits first, we must rely on the first order statistic to determine expected revenue. In general, the kth order statistic is the value of the kth smallest value drawn from a sample of size greater than or equal to k. Because we are interested in the bidder who drops out first we would like to know the probability an endowment of e is the first smallest endowment. This is why we are interested in the first order statistic.

For this war of attrition, when bidders draw their endowments let $f_{(1)}(e)$ define the probability e is the smaller of two independent draws from F, thereby describing the 1st order statistic. There are two ways an endowment of e can be the smallest value drawn from f. The first is if $e_i < e_j$, and the second is if $e_j < e_i$. The probability a bidder chooses an endowment of e is $f(e)$, and the probability the other bidder has an endowment greater than e is $[1 - F(e)]$. Therefore, the first order statistic of this distribution is $f_{(1)}(e) = f(e_i)[1 - F(e_j)] + f(e_j)[1 - F(e_i)] = 2f(e)[1 - F(e)]$. Revenue in this charity setting does not adhere to revenue equivalence. In particular it can be shown using (3.4) that expected revenue is strictly increasing in θ according to the F in (3.3).

Revenue is most easily identified by two separate sources. The first source is the *unredeemable* fraction of bidders' endowments, $(1 - \theta)e$. This source of revenue is independent of bidding strategies as it is determined when bidders choose their endowments at time $t = 0$. The second source is the amount of their endowment bidders choose to bid, which has a remaining per-unit value of θ. This, along with bidders only exiting when their entire endowment is exhausted, leads to the revenue function

$$R = \underbrace{2(1 - \theta) \int_0^{\bar{e}} edF(e)}_{\text{Revenue from Endowments}} + \underbrace{2\theta \int_0^{\bar{e}} edF_{(1)}(e)}_{\text{Revenue from Bidding}} \tag{3.4}$$

where $\bar{e} \Rightarrow F(\bar{e}) = 1$.

The value of $\bar{e}$ increases with the charity parameters, which means that bidders are willing to take larger endowments as their benefits rise and this amount is greater than the value of the item v. A restriction of non-negative values for α and γ leads to $\bar{e} = -\frac{v}{(1-2\alpha-\gamma)\theta} \ln \left[1 - \frac{(1-2\alpha-\gamma)\theta}{1-(1+\theta)\alpha-\gamma}\right]$. While the expected revenue function does not reduce into a compact or interpretable solution, the loss of revenue equivalence is illustrated in Figure 3-2 for given values for v, α, and γ. This is a representative illustration of how revenue changes with θ as long as $\alpha > 0$. For cases where $\alpha = 0$ and $\gamma > 0$ we find revenue equivalence to hold and expected revenue to increase with γ.

3.3 Experiment Design

In this study, a total of 120 subjects were recruited to participate in one of ten sessions. Using a between subjects design, sessions were equally split to test one of following five auction settings: discrete all-pay auction; bucket auction (pre-purchase, $\theta = 0$); bucket auction (pre-purchase, $\theta = 0.5$); bucket auction (pre-purchase, $\theta = 1$); bucket auction (no pre-purchase, WoA). Sessions took place in the Behavioral Business Research Laboratory at the University of Arkansas in

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Figure 3-2: Expected Revenue Increases with the Redemption Value (θ)

$$v = 20$$
$$\alpha = 0.1$$
$$\gamma = 0.05$$

Redemption Value of Unused Endowment (θ)
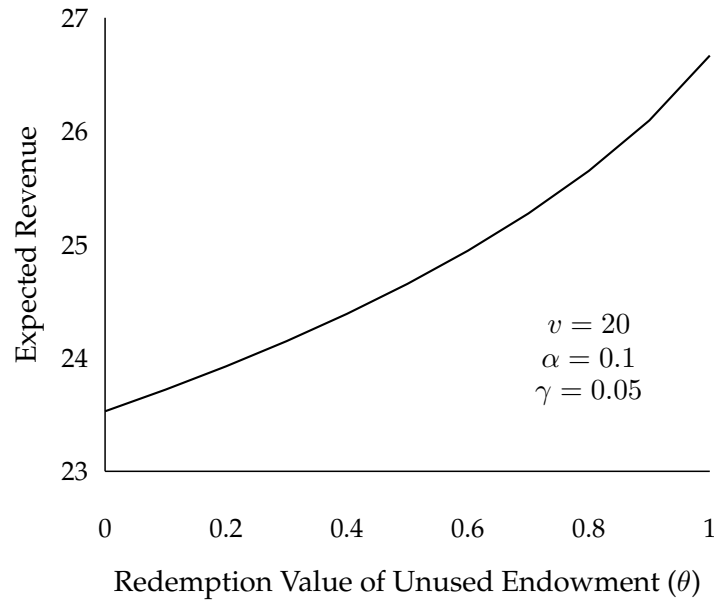
groups of twelve subjects. With the use of the computer software, z-Tree (Fischbacher 2007),

subjects were seated at partitioned computer workstations to ensure private decision-making

and given computerized instructions about the experiment, at which point they were allowed to

ask procedural and clarifying questions.[7] The entire experiment lasted approximately eighty

minutes, and subjects earned $20.95 on average.

The experimental design in this chapter employs features from Carpenter et al. (2013) that assist

in strengthening the external validity of laboratory charity auctions. The first such feature

involves subjects completing a task, where successfully doing so earns them money. This money

is then used during auctions later in the experiment. This feature discourages the risk seeking

behavior that can result from being given an endowment for auction participation (cf. Ackert et

al. 2006). The second feature is the ability for subjects to opt out of an auction, if they preferred

not to participate. This is an important feature also, as field experiments comparing participation

in charity auctions across mechanisms (e.g. Carpenter et al. 2008; Onderstal et al. 2013) have

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[7]Instructions for a treatment of the bucket auction can be found in the appendix.

demonstrated that differences in participation can explain the differences in revenue.

The instructions explained that the experiment consisted of two phases, each of which had an undisclosed number of periods. In Phase 1, subjects were given multiple opportunities to earn cash. This task consisted of counting how many numbers (0-9) there were in a series of 120 random characters that included both digits (0-9) and letters (A-Z) within 60 seconds (similar to Foster 2013). Each of the 120 characters was equally likely to be one of the 36 alphanumeric characters. If the subject reported the correct number or was off by at most 3 in absolute value then she received \$2, otherwise she received nothing. Table 3.2 shows an example of this effort task.[8] A relatively large margin of error was allowed in this task because the purpose of the task was principally to avoid risk seeking behavior that may occur with unearned endowments. Subjects were given eight opportunities to complete this task for a maximum possible endowment of \$16.

Table 3.2: Effort Task Example

8	3	P	2	M	9	L	K	V	5	W	9	G	5	2	X	M	E	G	P
6	E	Y	R	4	D	S	S	9	L	V	X	3	Q	S	M	O	H	B	A
R	9	Y	Y	P	2	4	A	V	0	D	R	L	Z	X	8	3	A	L	J
7	Q	7	M	I	2	D	Z	V	6	W	Z	U	P	L	2	G	P	Q	J
F	N	N	L	Y	J	N	N	G	D	X	J	L	Q	7	5	4	T	F	Q
V	R	H	R	D	8	R	0	7	C	G	P	P	X	3	L	C	X	9	0

In Phase 2, subjects were given multiple opportunities to participate in an auction using the money they earned in Phase 1. Though the auction mechanism varied by session, the prize in the auction was always a fictitious item worth \$10. In the first 10 periods of Phase 2, bidders participated in two bidder auctions, and it the last 10 periods bidders participated in six bidder auctions for a total of 80 auctions per session. Bidders were randomly rematched in each auction. During the two bidder auctions, the computer placed the 12 subjects in a given session into

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[8]This example has 32 numbers in it. If the subject reported 29, 30, 31, 32, 33, 34 or 35 then she earned \$2.

groups of four, and randomly rematched within that fixed group. This allowed for sufficient randomness to avoid collusion, and also allowed for the isolation of dynamic session effects (cf. Fréchette 2012). During the six bidder auctions, the computer randomized all 12 subjects from that session into two groups. This is summarized in Table 3.3.

Table 3.3: Session Groups for Auctions

Auction Rematching by Period		
Auctions	Bidders per Auction	Groups of
1-10	2	4 | 4 | 4
11-20	6	12

Two features were employed to maintain the fixed financial position of subjects for each auction. First, at the beginning of each auction, bidders' endowments were reset to the amount they earned in Phase 1. This allows subjects to participate in an auction each period without affecting their ability to participate in future auctions. Second, one of the twenty auctions was randomly selected to determine the payoffs from Phase 2. As a result, a subject's final earnings consisted of her cumulative earnings from Phase 1, one randomly selected auction in Phase 2, and a show up payment of $5.

In accord with the theoretical literature on charity auctions (e.g. Engers and McManus 2007; Carpenter et al. 2013), two constant marginal benefits were induced in the auction to simulate a charity setting. The particular parameters for these marginal benefits were chosen to be the same as Carpenter et al. (2013). The first marginal benefit $\alpha = 0.1$ is the indirect benefit associated to the revenue generated by the auction. In the experiment, subjects were informed that for every dollar of revenue generated, each of them would receive $0.10. The second marginal benefit $\gamma = 0.05$ is the "warm glow" from personally contributing to the auction. As a result, for each dollar a bidder personally contributed, she received $0.05.

After each auction, bidders were shown a break down of their earnings, which consisted of 1) the

cost of tokens purchased for the auction, 2) the outcome of the auction (claimed the item or not), 3) the total revenue generated by the auction and their indirect benefit earnings from revenue, and 4) the amount of money they personally contributed to the auction and their warm glow earnings from their contribution. Table 3.4 outlines the theoretical predictions over revenue for the parameters of this experiment. To make theoretical predictions the cost of a token ($0.50) must be normalized to 1, which makes the item's value $v = 20$. With respect to endowment predictions, when $\theta \to 1, \bar{e} \to \infty$. As a result, for $\theta = 1$ it is a weakly dominant strategy for bidders to convert their entire effort task earnings $\tilde{e}$ into auction currency for each auction. On the other hand, in *WoA*, the bidders' endowments are automatically converted into currency for them.

Note that revenue predictions do not change within a mechanism when the number of bidders increases, with the exception of $\theta = 0.5$ which has yet to be explicitly defined. In the case of the *All-pay* and $\theta = 0$ mechanisms this is due to the theoretical predictions in Baye et al. (1996), which shows that risk-neutral bidders will adjust their mixed bidding strategies as n changes.[9] In the case of the $\theta = 1$ and *WoA* mechanisms, this is due to the theoretical predictions in Bulow and Klemperer (1999), which shows that all but two bidders should exit the auction instantaneously. In other words, it should be that at most only two bidders spend any tokens at all, and these two bidders are instantaneously coordinated upon. This prediction is verified theoretically for the charity setting in Carpenter et al. (2013).

Following Phase 2, subjects were asked to answer survey questions regarding their experience in the auction as well as questions regarding hypothetical scenarios that could address their

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[9]In particular, Baye et al. (1996) shows that the unique symmetric mixed strategy Nash equilibrium is $F(x) = \left(\frac{x}{v}\right)^{\frac{1}{n-1}}$. In the presence of α and γ, it is relatively straight forward to show this result becomes $F(x) = \left(\frac{1-\alpha-\gamma}{v}x\right)^{\frac{1}{n-1}}$.

Table 3.4: Endowment & Revenue Predictions by Mechanism (in $)

Parameters

$v = \$10$	Token Cost = \$0.50	$\alpha = 0.1$	$\gamma = 0.05$

Predictions of Average Auction Currency Endowments

	All-pay	$\theta = 0$	$\theta = 0.5$	$\theta = 1$	WoA
$n = 2$	5.88	5.88	7.55	$\tilde{e}$	$\tilde{e}$
$n = 6$	1.96	1.96		$\tilde{e}$	$\tilde{e}$

Predictions of Average Revenue

	All-pay	$\theta = 0$	$\theta = 0.5$	$\theta = 1$	WoA
$n = 2$	11.76	11.76	11.82	13.33	13.33
$n = 6$	11.76	11.76		13.33	13.33

Notes: $\tilde{e}$ represents the bidder's entire effort task earnings.

susceptibility to the sunk cost fallacy and competitive behavior.[10] Many of these questions were selected from a survey in Carpenter et al. (2010). It is often thought the reason why the bucket auction performs so well is because sequential move auctions allow more latitude for competitive types to bid more aggressively than simultaneous move auctions. In addition to this proposed behavioral result, the bucket auction could invoke the sunk cost fallacy in some bidders due to the reiterative bidding process and the notion of throwing "good money after bad."

3.4 Experimental Results

The results reported here will primarily focus on three areas of analysis. The first area of analysis will cover how auction currency endowments varied across mechanisms. The second area of analysis will cover how individual contributions varied across mechanisms, which will also address the issue of participation. Finally, the third area of analysis will cover whether survey data indicates any behavioral factors influencing bidding behavior across mechanisms.

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[10]These questions are included in the instructions found in the appendix.

3.4.1 Auction Currency Endowment Strategies

Optimal endowment strategies were heavily influenced by the rate at which unused currency could be redeemed. In particular, it was predicted that as the redemption value of currency increased there would be greater demand of it for the auction. For the $\theta = 0$ mechanism, it was predicted that bidders would purchase currency in a manner equivalent to submitting a bid in a sealed bid all-pay auction. In the two bidder auctions this was equivalent to each bidder taking $5.88 US worth of currency on average. In the six bidder auctions this prediction decreased to $1.96 US of currency on average. Figure 3-3 shows the average currency endowments for all mechanisms along with the 95% confidence intervals of those averages. This table also includes the theoretical predictions for currency endowments, and the average effort task earnings each bidder had to draw from for a given auction.

In comparing the endowment strategies of bidders in the *All-pay* and $\theta = 0$ mechanisms, Figure 3-3 shows that the average endowment in a two bidder $\theta = 0$ auction is statistically significantly greater than the prediction of 5.88 ($p < 0.041$), while it is not in the *All-pay* mechanism. However, average endowments are statistically significantly greater in the six bidder auctions for both mechanisms. Because six bidder auctions always followed two bidder auctions, it is not clear why bidders are taking so much currency, as conceivably it could be due to a behavioral effect or, perhaps more simply, because bidders fail to adjust their strategies to the presence of additional bidders. The survey addressed at the end of this section partially addresses this concern.

With respect to the $\theta = 0.5$ mechanism, it was predicted that bidders would be willing to take more currency on average than the *All-pay* or $\theta = 0$ mechanisms, since unused currency was partially redeemable after the auction. Indeed, the average currency endowment did increase relative to these other mechanisms, and it did so in a way similar to what was predicted. For two bidder auctions, the average currency endowment was not statistically significant from the

Figure 3-3: Auction Currency Bought in $
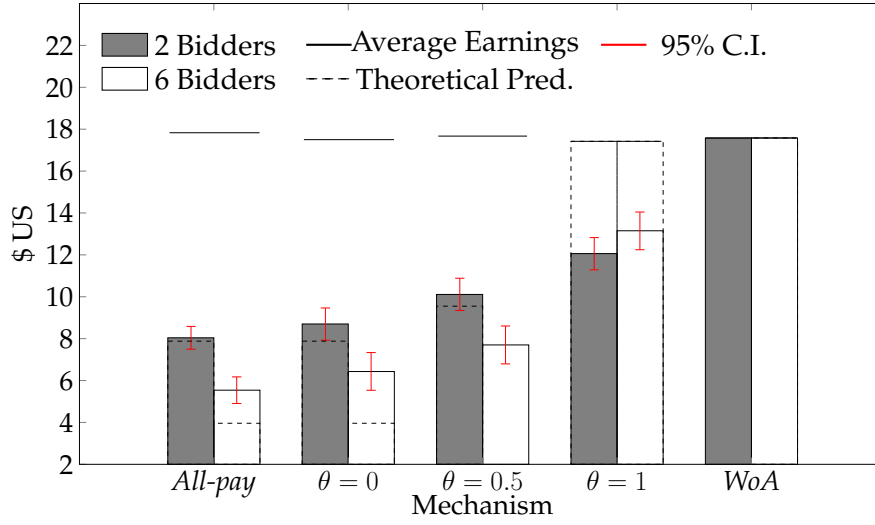
predicted average. With respect to the six bidder auctions, there is no comparison of the empirical average to a theoretical prediction because there is no model that addresses a setting with $n > 2$ bidders.

In the $\theta = 1$ mechanism, it was predicted that bidders would convert their entire effort task earnings into auction currency for each auction, as this is the weakly dominant strategy regardless of the number of bidders. This is opposed to the *WoA* mechanism, where each bidder was forced to convert their entire effort task earnings into auction currency (i.e., this step was performed for them automatically by the computer). Within the $\theta = 1$ mechanism, bidders took statistically significantly less currency than was predicted ($p < 0.001$ for two bidder auctions and $p < 0.001$ for six bidder auctions). While there is a weakly dominated endowment and bidding strategy involving a mixed strategy over endowments and then bidding the realized endowment until it is exhausted, this is not the case in the data. In this treatment only 41% of bidders who lost an auction (i.e., did not claim the item) bid until they ran out of currency. More information regarding bidding strategies is provided in the next subsection. It is arguable that bidders used the currency endowment stage to curb their contribution in the auction, essentially setting a

self-enforced bidding limit.

3.4.2   Bidding Behavior, Individual Contributions & Participation

In the $\theta = 0$ and $\theta = 0.5$ mechanisms, bidders are predicted to choose their currency endowments

probabilistically and bid until they've exhausted their realized endowment. This is almost

always the case in $\theta = 0$ auctions where 91% of bidders had no currency left when they exited.

However, this was much less likely to happen in the $\theta = 0.5$ mechanism where only 71% of those

who exited a given auction had no tokens left. While it is possible for bidders to exhaust their

entire endowment in the $\theta = 1$ mechanism, this should happen very infrequently (less than 5% of

the time) since they are predicted to convert all of their effort task earnings into auction currency.

The actual frequency of this happening in the $\theta = 1$ mechanism, as previously mentioned, was

41%. This result is partly due to bidders curbing their currency endowments back, and partly

due to too many bidders exiting too late in the auction (i.e., bidding too aggressively).

From whom did the contributions come? In particular, were the results in revenue due to a few

bidders contributing a lot, or were contributions well distributed? It turns out the concentration

of contributions were well distributed across bidders for all mechanisms. In aggregate (for all

twenty auctions combined), 80% of the total contributions came from the top 54% to 66% of

contributors, depending on the mechanism. The distribution of contributions tended to be more

concentrated in the *All-pay* and $\theta = 0$ mechanisms, which saw 80% of contributions come from

the top 54% and 62% of bidders respectively. In $\theta = 0.5$ it was 62% as well. This concentration

lessened slightly as the redemption value of tokens increased. For the $\theta = 1$ and *WoA* 80% of

contributions came from the top 62% and 66% contributors respectively. This suggests that larger

redemption values encouraged moderately high participation from many individuals.

One of the primary findings of this experiment is the "bucket premium" revealed in the

comparison of contributions between the *All-pay* and $\theta = 0$ mechanisms in Figure 3-4. It was

predicted that these two mechanisms should be identical with respect to endowment strategies,

and since currency has no redemption value here this means choosing an endowment is

equivalent to choosing a contribution amount in the auction. However, the bucket premium

shows that using a incremental bid mechanism leads to statistically significantly greater

contributions beyond what was theoretically predicted ($p < 0.054$). On the other hand, the *All-pay*

mechanism's average contribution is not statistically significantly different from the theoretical

prediction, and moreover it is actually quite close to the point prediction. This premium is

equivalent to an 11% increase in expected revenue according to the average contributions in these

mechanisms, though these averages are not statistically significantly different. Contributions in

six bidder auctions were much greater than theoretical predictions for both mechanisms, and

revenues were exceedingly high as a result. In particular, the *All-pay* mechanism raised $21.18 US

on average for an item worth $10 US, while the $\theta = 0$ mechanism raised $26.52 US on average.

The bucket premium grew with the number of bidders in the auction, as contributions in the

$\theta = 0$ mechanism were 25% greater on average than they were in the *All-pay* mechanism.

Figure 3-4: Average Contribution by Mechanism in $
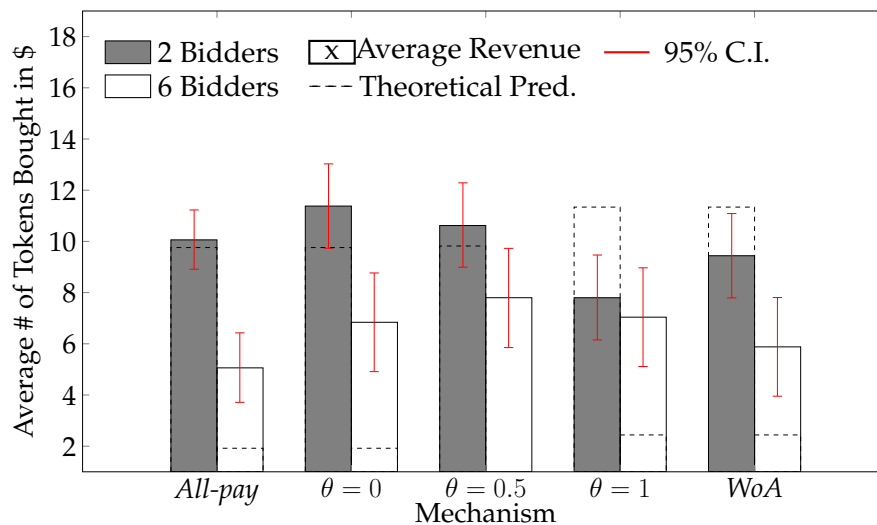
The average contribution made by bidders in the $\theta = 0.5$ mechanism is predicted to be slightly less than the average endowment, as winners will redeem half of their remaining endowment at the end of the auction, should they have any. Figure 3-4 shows that the average contribution in this mechanism was slightly greater than the point prediction of $5.91 US, however not statistically significantly so. The average revenue for this two bidder mechanism was $12.62 US, which is slightly less than the $\theta = 0$ mechanism. On the other hand, the six bidder mechanism was the most successful in terms of revenue among those tested, which raised $29.40 US - nearly three times the item's value. Behavioral considerations discussed in the next subsection suggest that the success of this mechanism may be related to bidders' sunk cost sensitivities, which makes those who are sunk cost sensitive to delay exit longer than they should by taking too large of an endowment. This corroborates the results in Carpenter et al. (2013).

Another primary finding of these experiments is the (relatively) underwhelming performance of the bucket auction in the $\theta = 1$ and *WoA* mechanisms. Figure 3-4 shows in these mechanisms bidder contributions in two bidder auctions are statistically significantly less than theoretically predicted ($p < 0.001$ for $\theta = 1$ and $p < 0.026$ for *WoA*). Though the bucket auction has never previously been tested in a two bidder setting, this result is somewhat surprising given its success with a handful more bidders (Carpenter et al. 2013; Carpenter et al. 2014). On the other hand, Hörisch and Kirchkamp report systematic underbidding in traditional two bidder wars of attrition (no charity preferences assumed). As the next subsection will reveal, there is not much in to gleam from the survey data to help understand what may be causing the underbidding from a behavioral standpoint. Notwithstanding the contributions in two bidder auctions, contributions again were much higher on average than predicted in the six bidder auctions. The $\theta = 1$ mechanism raised $27.12 US in six bidder auctions, where the average contribution is strikingly similar to its two bidder counterpart. The *WoA* mechanism raised $23.64 US on average.

What about participation in these mechanisms? In this chapter, "participating" in an auction will be defined as making any positive contribution to the auction. This means different things in different mechanisms. For instance, to participate in a $\theta = 0$ auction, one need only choose a positive endowment to have participated (and need not bid any of it). On the other hand, in a $\theta = 1$ auction, choosing a positive endowment is a necessary but not sufficient condition to participate in an auction - one must also choose to bid at least one token of said endowment to have participated. Figure 3-5 summarizes participation rates by mechanism. Reiterating their equivalence, there should be no difference between participation rates in the *All-pay* and $\theta = 0$ mechanisms. However, the results show that participation in the two bidder auctions is statistically significantly greater in the $\theta = 0$ mechanism ($p < 0.032$). This result may give some insight into why the bucket auction typically performs so well: the incremental bidding design encourages participation, perhaps because it is more interesting to bidders relative to submitting a sealed, lump-sum bid.

Figure 3-5: Participation Rates
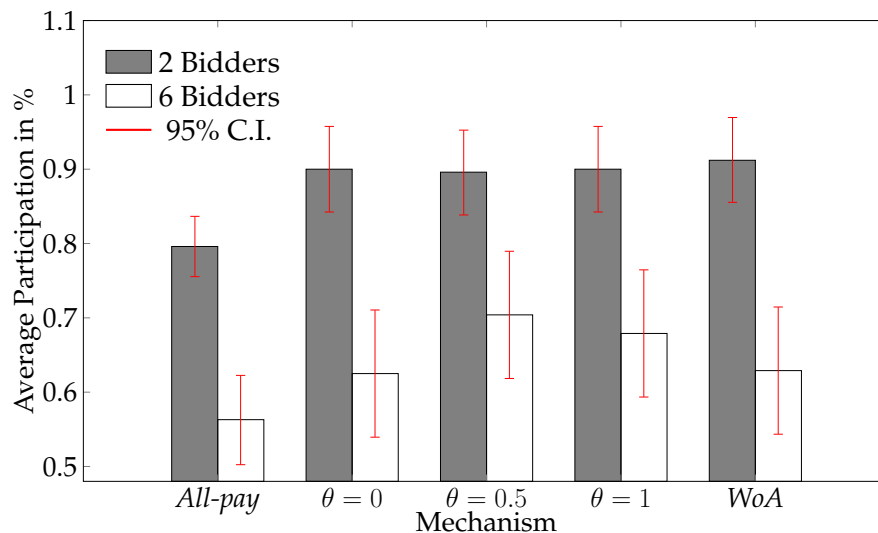
Among the two bidder bucket auctions there is little variation in participation with approximately 90% of bidders making some positive contribution. On the other hand, six bidder

auctions see some variation in participation with a low of approximately 55% in the *All-pay* mechanism to a high of approximately 70% in the $\theta = 0.5$ mechanism. Participation rates in the six bidder auctions are correlated with the average revenue across mechanisms. Furthermore, the participation rates in the $\theta = 1$ and *WoA* mechanisms are much greater than predicted. The participation rates of these mechanisms are approximately 68% and 63% respectively. However, all but two bidders should be willing to exit the auction before making any contribution, which puts expected participation rates at 33% - a rate far below what is observed.

Finally, it is worth noting that for the bucket auctions the likelihood that a bidder won (i.e. did not exit) the auction was significantly impacted by the position she had in circle. Namely, those who were able to bid last intra-period were more likely to win an auction. These effects are highlighted in Tables 3.7 and 3.8, which report probit estimates on bidder exits (exit=1) in two and six bidder auctions respectively. The effect was relatively small in two bidder auctions, where the bidder in position 2 won 55% of the time (as opposed to 50%). However, the benefit become more exaggerated in the six bidder auctions, where the bidder in position 6 won 42% of the time (as opposed to 17%).

3.4.3 Behavioral Factors

Following the completion of stage two, the auction portion of the experiment, subjects were asked to respond to a thirteen question survey. This survey can be found in the appendix, and many of the questions were identical to a subset of those in Carpenter (2010) (or only slightly modified). Table 3.5 summarizes those questions that were used in the analysis of this subsection. Subjects' responses to these questions defined their individual characteristics in many dimensions. One's response to the measure labeled Competitive was based on a Likert scale (1-5) of how competitive one views them self, where 1 indicated "Not at All" and 5 indicated "Very

Table 3.5: Summary of Survey Responses

Bidder Characteristics					
	All-pay	$\theta = 0$	$\theta = 0.5$	$\theta = 1$	*WoA*
Competitiveness (1-5)	3.83	4.21	4.08	4.29	4.17
Risk Response (1-5)	2.25	2.71	2.58	2.50	2.63
Loss Response (1-5)	4.29	4.00	4.46	4.04	4.33
Sunk Cost Response (0-1)	0.29	0.29	0.38	0.25	0.29
Subjects	24	24	24	24	24

Competitive". The characteristic Risk Response indicated whether someone was willing to take risks in financial situations where a 1 was not very likely and a 5 is very likely. Note that this measure should not be conflated with the notion of risk aversion, as this survey question is not an adequate measure of that. Instead, the interpretation of one's response to this question can be better understood as a more general attitude toward financial risks. The characteristic Loss Response, which is also based on a Likert scale, measures how much an individual worries about possible losses in financial situations where a 1 indicates that they do not at all and a 5 indicates that they do very much. Finally, the characteristic labeled Sunk Cost Response measures one's sunk cost sensitivity. In the survey, subjects were given two hypothetical scenarios regarding sunk costs and asked how they would behave, where their response was an indicator variable for being sensitive to sunk costs. If a subject's responses to these scenarios both indicated a sunk cost sensitivity then they were labeled in the Table 3.5 as being sunk cost sensitive (1), otherwise they were not labeled sunk cost sensitive (0).

Table 3.6 summarizes a series of ordinary least squares estimates of the sum of a subject's contributions from all twenty auctions. This aggregate measure of one's contributions for the entire experiment is regressed on each of the subject's characteristics as measured by their survey responses. Here, we can see the only characteristic that has a significant effect on the aggregate

contributions a bidder made throughout the experiment is their risk response. In the *All-pay* and $\theta = 0.5$ mechanisms this effect is significant and positive, although only marginally so in the case for *All-pay*.

Table 3.6: OLS Estimate of Survey Responses on Aggregate Contributions

Dependent Variable: Sum of All Contributions in $						
	Pooled	*All-pay*	$\theta = 0$	$\theta = 0.5$	$\theta = 1$	*WoA*
Competitiveness	7.08	15.03	15.84	0.87	11.72	-21.55
	(5.36)	(11.71)	(14.15)	(13.81)	(14.18)	(15.06)
Risk Response	12.26***	24.86*	7.24	25.68**	-3.29	-1.27
	(4.45)	(13.70)	(10.43)	(10.15)	(11.11)	(7.81)
Loss Response	5.31	-22.97	4.63	-4.06	17.50	-23.67
	(5.84)	(18.05)	(10.33)	(23.43)	(11.70)	(17.37)
Sunk Cost Response	-8.42	28.20	-5.64	-29.33	0.72	-6.67
	(10.47)	(31.49)	(27.43)	(24.36)	(22.73)	(18.97)
Observations	120	24	24	24	24	24

Notes: clustered standard errors are in parentheses.
*,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

These subject-specific characteristics are also used to analyze the likelihood one exits in an auction (i.e., whether or not they win or lose the auction). Tables 3.7 and 3.8 report of series of probit estimates for each mechanism in two bidder and six bidder auctions respectively. Marginal effects are reported. The variable Period is also included in these regressions, which measures their relative placement in the bidding circle with 1 being first. In these regressions more nuanced results appear that may speak to certain behavioral biases influencing their bidding strategies. In the two bidder auctions, one's bidding position had a significant effect on whether they chose to exit. Namely, as one was able to bid later in the circle the more likely it was that they won the auction. As was discussed in the previous subsection, this effect is even stronger in the six bidder auctions. There was a strong effect from one's competitiveness on the likelihood of one exiting an

$\theta = 0$ auction in the direction one would intuitively expect; more competitive individuals were less likely to exit the auction. In the *All-pay* mechanism, bidders who were more likely to take financial risks were also less likely to exit the auction (significant at the 5% level). Finally, there is a very strong effect from one's sunk cost sensitivity on the likelihood they will exit a *WoA* auction; if someone is sunk cost sensitive they are less likely to exit the auction. This result corroborates that of Carpenter et al. (2013) where one's sunk cost sensitivity was also found to increase the duration one stayed in the auction.

Table 3.7: Probit Estimate of Auction Exits on Survey Responses in 2 Bidder Auctions

	Dependent Variable: Exited (Lost) the Auction (1=Exit)					
	Pooled	*All-pay*	$\theta = 0$	$\theta = 0.5$	$\theta = 1$	*WoA*
Position	-0.09*	0.03	0.04	0.06	-0.18***	-0.37***
	(0.05)	(0.06)	(0.08)	(0.07)	(0.02)	(0.13)
Competitiveness	-0.05*	-0.02	-0.17***	0.03	-0.03	-0.03
	(0.02)	(0.03)	(0.06)	(0.05)	(0.08)	(0.04)
Risk Response	-0.06***	-0.12**	0.03	-0.07	-0.05	-0.01
	(0.02)	(0.05)	(0.03)	(0.04)	(0.07)	(0.03)
Loss Response	-0.05	-0.03	-0.03	-0.14*	-0.08	-0.1
	(0.03)	(0.05)	(0.03)	(0.08)	(0.08)	(0.10)
Sunk Cost Response	0.01	0.06	-0.02	0.09	0.06	-0.27***
	(0.01)	(0.13)	(0.09)	(0.16)	(0.05)	(0.04)
Observations	1200	240	240	240	240	240

Notes: clustered standard errors are in parentheses. Marginal effects are reported. *,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.

In the six bidder auctions, many of the measured characteristics have more exaggerate effects relative to the two bidder auctions. For instance, while one's competitiveness was the only characteristic that positively influenced the likelihood a bidder won for the two bidder $\theta = 0$ auction, this characteristic also had a positive effect in the *All-pay*, $\theta = 0$ and $\theta = 1$ mechanisms for six bidder auctions. One's willingness to take financial risks also increases the likelihood they

won the six bidder *All-pay*, $\theta = 0$ and $\theta = 0.5$ auctions. Because these are the auctions that require

some upfront cost to participate, this result suggests that bidders correctly perceived most of the

risk in these auctions was in the endowment stage. The more worried bidders became about

potential losses the more likely they were to exit the six bidder *All-pay* and $\theta = 0.5$ auctions.

Finally, there is a strong effect of one's sunk cost sensitivity on the likelihood they won the six

bidder $\theta = 0.5$ auctions. Interestingly, the effect is strongly in the opposite direction of that found

in the two bidder auctions for the *WoA* mechanism and for previous studies.

Table 3.8: Probit Estimate of Auction Exits on Survey Responses in 6 Bidder Auctions

	Dependent Variable: Exited (Lost) the Auction (1=Exit)					
	Pooled	*All-pay*	$\theta = 0$	$\theta = 0.5$	$\theta = 1$	*WoA*
Position	-0.05***	0.04***†	-0.02***	-0.04	-0.11***	-0.12***
	(0.02)	(0.01)	(0.00)	(0.03)	(0.01)	(0.04)
Competitiveness	-0.04***	-0.08***	-0.04***	0.02	-0.09***	-0.03
	(0.01)	(0.02)	(0.00)	(0.01)	(0.01)	(0.03)
Risk Response	-0.03***	-0.06***	-0.04***	-0.05***	0.03	-0.02
	(0.01)	(0.01)	(0.00)	(0.02)	(0.03)	(0.04)
Loss Response	0.00	0.10***	-0.02	0.10**	-0.02	0.05
	(0.02)	(0.02)	(0.02)	(0.05)	(0.02)	(0.05)
Sunk Cost Response	0.02	-0.13	-0.02	0.17***	-0.03	0.06
	(0.04)	(0.13)	(0.16)	(0.06)	(0.07)	(0.08)
Observations	1200	240	240	240	240	240

Notes: clustered standard errors are in parentheses. Marginal effects are reported.
*,**, and *** denote significance at the 10%, 5%, and 1% level, respectively.
† This significance in Period for *All-pay* is due to how the computer broke ties
(based on position). One's position was not known when endowment decisions
were made.

3.5 Conclusion

This chapter adds to a growing literature on the ability of all-pay auctions to raise money for charity. The theoretical literature on charity auction design uniformly touts the superior fund-raising capacity of all-pay auctions, as they eliminate the free-riding associated with winner-pay auctions. In winner-pay auctions, losing bidders accrue benefits proportional to the winning bid at a cost of zero, and this subsequently suppresses bids. Among the empirical evidence on all-pay auctions for charity, however, there are mixed results regarding their ability to generate contributions as predicted. The inconsistency of the all-pay auction can largely be traced back to participation rates.

Given that participation rates typically constrain all-pay auctions from reaching their theoretical potential with respect to revenue, an all-pay mechanism that theoretically requires relatively little participation among potential bidders may help stabilize all-pay revenues. This led to the consideration of the "bucket auction," which is essentially a war of attrition. Theoretically, this mechanism requires at most two bidders to participate if the auctioned item has a pure common value. Moreover, Carpenter et al. (2013) shows that the bucket auction should raise more than a first price all-pay auction in expectation, which also increases its desirability as the preferred mechanism. Furthermore, they show that the bucket auction performs extraordinarily well relative to the first price all-pay auction.

This chapter builds from Carpenter et al. (2013) to address the bidder-specific and mechanism-specific characteristics of the bucket auction that may be leading to its overwhelming success. This is done through an innovative theoretical model that bridges the gap between the first price all-pay auction and the second price all-pay auction (i.e., the war of attrition). Charity auctions are induced in the laboratory to test the performance of the first price all-pay auction

alongside several variations of the bucket auction.

One of the primary experimental findings of this chapter is the "bucket premium," which identifies that an incremental bidding mechanism like the bucket auction can statistically significantly increase contributions beyond their theoretical predictions. Moreover, there is no such benefit from a lump-sum bidding mechanism like the first price all-pay auction. Exit survey data suggests that the bucket auction is capable of raising contributions by exploiting the bidders' degree of competitiveness better than the first price all-pay auction.

Contrary to our theoretical understanding that the bucket auction only requires two bidders in a pure common value setting, the experiments of this study reveal that contributions are not sufficient enough in this setting to generate the level of revenue theoretically predicted by the traditional war of attrition. However, in the presence of six bidders, contributions are much more than sufficient to generate the revenue theoretically predicted - even after a reasonable amount of exposure to the mechanism with six potential bidders. While this study fails to support the bucket auction's ability to perform well in the presence of very few bidders, it does continue to provide support for its ability to sustain very large revenues in the presence of a handful or more bidders.

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A   Putting Social Preferences to Work

A.0.1   Subject Directions

You have been asked to participate in an economics experiment. In addition to the $5 dollars you will receive for showing up today, you may earn an additional amount of money, which will be paid to you at the end of the experiment.

In today's experiment the computer will randomly place you in one of two roles for the entire study, either Role A or Role B.

There will be several rounds of decision making, each of which consists of 3 parts.

In the first part of each round, each person in Role A will be asked to make a decision about how money will be allocated between him/herself and a randomly selected person in Role B. You will not know who this other person is, and he or she will not know who you are at any point either during or after the experiment. The person in Role A will be presented with 2 options of how to split the money, and they will be labeled "Option A" and "Option B". These options will be different in each round.

People in Role B will be asked to make hypothetical decisions at the same time, but the choice made by those in Role B will not influence anyone's payout. On the next screen you will be told which Role you are in.

You will be in Role A (B) for the entire experiment.

This means that you will be making real (hypothetical) payout decisions for you and another person here in Role B (A).

In the 2nd part of each round, each person in Role A will be presented with an alternative to the option he or she chose in part 1.

The alternative way of splitting the money is randomly generated by the computer, and will be labeled "Alternative".

Ultimately, whether the money is split via Role A's choice in part 1 or via the Alternative generated by the computer in part 2 will depend on Role A's performance in part 3 of the round.

In part 3 of each round Role A will be asked to complete a task.

Role A's performance of this task will determine which allocation option (Role A's choice from part 1 or the alternative generated by the computer in part 2) will be used to split the money between Role A and the other person in Role B.

If the person in Role A successfully completes the task, the option he or she chose in part 1 will be used to split the money.

If the Person in Role A fails at the task, the alternative generated by the computer in part 2 will be used to split the money.

Instructions for this task are provided on the next screen.

Instructions for the task are as follows:

Role A will be shown a sequence of 120 random characters consisting of numbers (0-9) and letters (A-Z). The task is to count how many numbers (0-9) there are in the 120 characters. Role A will have 90 seconds to complete this task. The Option Role A chose in Part 1 will determine the payout if he or she counted how many numbers are in the sequence correctly within 1. In other words, Role A can still be off by 1 and still keep the Option he or she chose in Part 1. Otherwise, the payout will be determined by the Alternative.

After Role A has completed the task in part 3, the computer will tell Role A whether he or she succeeded or failed at the task, and the computer will also tell Role A how the money was split. This will be the case for every round.

At the end of the experiment, the computer will randomly choose one of these allocation decisions to determine the payouts for the person in Role A and the person in Role B.

Just to recap, the experiment involves several rounds in which:

1. Role A will choose between 2 options for how money will be split between him/herself and someone in Role B. Role B will choose between 2 hypothetical options of how to split money. The decisions by those in Role B will not influence anyone's payouts.

2. Those is Role A will be presented with a randomly generated alternative to the option he/she chose in part 1.

3. Those in Role A will complete a counting task, where successfully completing the task will cause the money to be split according to the option he/she chose in part 1 and failing the task will cause the money to be split according to the alternative generated by the computer in part 2.

If you have any questions, please raise your hand and the experimenter will come over to your computer station. If you fully and completely understand these directions, please click the button that says BEGIN to start a PRACTICE round.

We are now ready to begin the experiment. If you have any questions, please feel free to ask them now. Otherwise, please click the button that says "BEGIN" to start the experiment.

A.0.2 Screenshots

Dictator chooses between Option A and Option B:

Part I
You are Role A.
Below are two options of how to split money between you and the person in Role B. You have two options: Option A and Option B. Please click the option you prefer below.

Option A	$14 for you; $6 for Role B	Choose A
Option B	$13 for you; $10 for Role B	Choose B

Dictator is shown their choice and the alternative (in this case, A):

Part II
In the next screen you will find a series of characters consisting of both numbers (0-9) and letters (A-Z). Count how many numbers are displayed in the series and enter it into the computer. You have 90 seconds to complete this task. If your count is correct (or only off by one) you will be assigned the payout you chose, which is displayed below here. If you count incorrectly you will be assigned the randomly selected alternative payout that is displayed below here. If you do not complete the task within 90 seconds you will be assigned the randomly selected alternative payout. To begin, click the button below that says "BEGIN".

You chose	$13 for you; $10 for Role B
Alternative	$13 for you; $10 for Role B

BEGIN

Dictator is shown their choice and the alternative (in this case, B):

98

Part II
In the next screen you will find a series of characters consisting of both numbers (0-9) and letters (A-Z). Count how many numbers are displayed in the series and enter it into the computer. You have 90 seconds to complete this task. If your count is correct (or only off by one) you will be assigned the payout you chose, which is displayed below here. If you count incorrectly you will be assigned the randomly selected alternative payout that is displayed below here. If you do not complete the task within 90 seconds you will be assigned the randomly selected alternative payout. To begin, click the button below that says "BEGIN".

You chose	$13 for you; $10 for Role B

Alternative	$14 for you; $6 for Role B

BEGIN

Dictator is shown their choice and the alternative (in this case, C):

You chose	$13 for you; $10 for Role B

Alternative	$15 for you; $0 for Role B

BEGIN

Dictator is shown their choice and the alternative (in this case, D):

Part II
In the next screen you will find a series of characters consisting of both numbers (0-9) and letters (A-Z). Count how many numbers are displayed in the series and enter it into the computer. You have 90 seconds to complete this task. If your count is correct (or only off by one) you will be assigned the payout you chose, which is displayed below here. If you count incorrectly you will be assigned the randomly selected alternative payout that is displayed below here. If you do not complete the task within 90 seconds you will be assigned the randomly selected alternative payout. To begin, click the button below that says "BEGIN".

You chose	$13 for you; $10 for Role B

Alternative	$12 for you; $5 for Role B

BEGIN

Dictator completes the effort task:

Remaining time [sec]: 85

8 3 P 2 M 9 L K V 5 W 9 G 5 2 X M E G P

6 E Y R 4 D S S 9 L V X 3 Q S M O H B A

R 9 Y Y P 2 4 A V 0 D R L Z X 8 3 A L J

7 Q 7 M I 2 D Z V 6 W Z U P L 2 G P Q J

F N N L Y J N N G D X J L Q 7 5 4 T F Q

V R H R D 8 R 0 7 C G P P X 3 L C X 9 0

How many numbers are in the 120 characters above? [   ]

CONTINUE

Dictator is shown the result of their effort task:
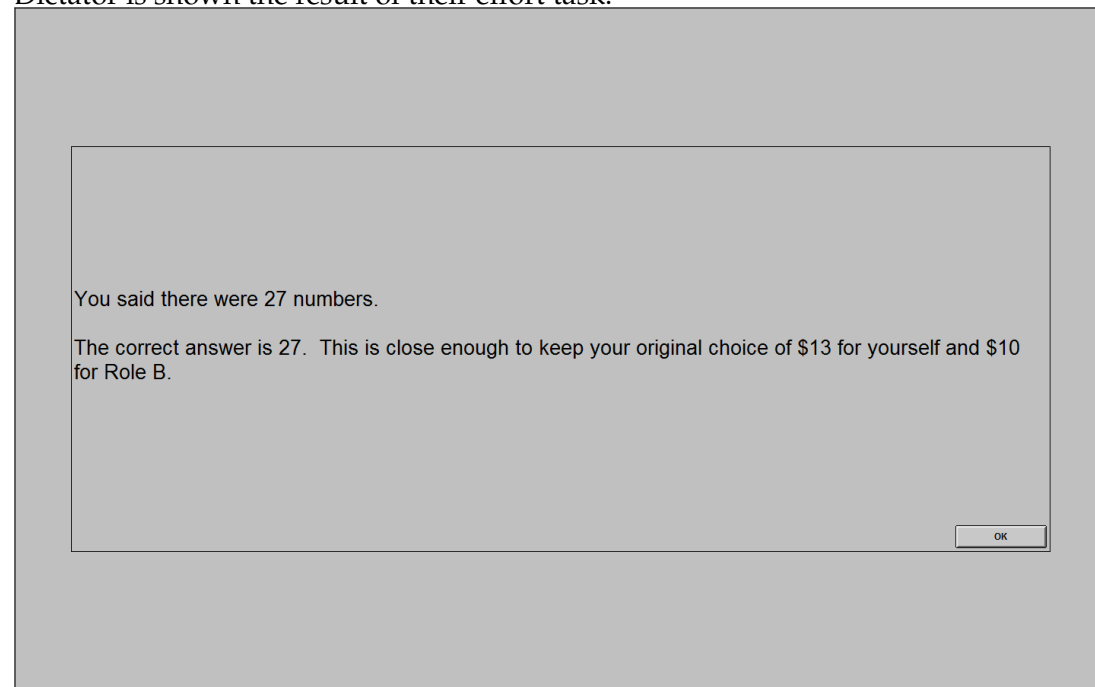
You said there were 27 numbers.

The correct answer is 27. This is close enough to keep your original choice of $13 for yourself and $10 for Role B.

OK

A.0.3   IRB Approval Notification

UNIVERSITY of ARKANSAS
1871 ®

Research Support and Sponsored Programs
Institutional Review Board

February 4, 2010

MEMORANDUM

TO:	Joshua Foster Salar Jahedi
FROM:	Ro Windwalker IRB Coordinator
RE:	New Protocol Approval
IRB Protocol #:	09-12-337
Protocol Title:	*Strategic Ignorance*
Review Type:	☒ EXEMPT ☐ EXPEDITED ☐ FULL IRB
Approved Project Period:	Start Date: 02/04/2010 Expiration Date: 02/03/2011

Your protocol has been approved by the IRB. Protocols are approved for a maximum period of one year. If you wish to continue the project past the approved project period (see above), you must submit a request, using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. This form is available from the IRB Coordinator or on the Compliance website (http://www.uark.edu/admin/rsspinfo/compliance/index.html). As a courtesy, you will be sent a reminder two months in advance of that date. However, failure to receive a reminder does not negate your obligation to make the request in sufficient time for review and approval.   Federal regulations prohibit retroactive approval of continuation. Failure to receive approval to continue the project prior to the expiration date will result in Termination of the protocol approval. The IRB Coordinator can give you guidance on submission times.

If you wish to make *any* modifications in the approved protocol, you must seek approval *prior to* implementing those changes.   All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 120 Ozark Hall, 5-2208, or irb@uark.edu.

B   Bidder Behavior in All-pay Auctions for Charity

B.0.4   Subject Directions for the Bucket Auction

Welcome! You have already earned $5 for showing up on time. It is important that you read
these instructions carefully and understand them, so that you can make good decisions, and
potentially make a considerable amount of money today.

If you have any questions during the experiment, please raise your hand, and an experimenter
will come to assist you. Otherwise, please do not talk or communicate with anyone.

Overview:

This experiment has two phases, each of which involves a repeated activity.

> Phase 1: In this phase all participants here today will have multiple opportunities to
> complete a task. Each time you complete the task successfully you will earn $2. If you
> do not complete the task successfully you will earn $0.

> Phase 2: In this phase all participants here today will have multiple opportunities to
> participate in an auction. The item being auctioned is a fictitious item worth $10. At
> first, each of you will be randomly and anonymously matched with one other bidder
> (participant in this experiment) for each auction. Later, each of you will be randomly
> and anonymously matched with five other bidders for each auction. However, only
> one of you may claim the $10 item in a given auction.

Phase 1: The Task

Instructions for the task are as follows:

You will be shown a sequence of 120 random characters consisting of numbers (0-9) and letters
(A-Z). The task is to count how many numbers (0-9) there are in the 120 characters. You will have
60 seconds to complete this task and report the number to the computer.

If you count how many numbers are in the sequence correctly within 3 then you will receive $2.

In other words, you can be off by at most 3 (over or under) and still receive $2.

To the left is an example of the task in Phase 1 [shown on screen]. Take a moment to see what this

task is like. (The "REPORT" button does not work right now because this is just an example.)

Hint: in this example there are [actual] numbers. If you had reported [actual-3], [actual-2], [actual-1],

[actual], [actual+1], [actual+2] or [actual+3] you would have received $2.

Note that zeros (0) and Os look very similar. Because the example here was randomly generated,

it may or may not have zeros or Os.

Phase 2: The Auction

In Phase 2 you will have the opportunity to participate in auctions using the money you earned

in Phase 1.

To participate in an auction you must have Tokens. Tokens can be purchased, using the money

you earned in Phase 1, for $0.50 each *before the auction begins*. You cannot buy more tokens than

you can afford, and you cannot buy tokens once the auction begins.

Bidders will take turns Bidding (i.e. contributing) their Tokens, one Token at a time. The last

bidder to Bid a Token will claim the auctioned item, which is a fictitious item worth $10.

If at any point you prefer to not Bid, you may choose to Exit, and forfeit the auction. If you

choose to Exit you will not claim the item. A bidder can claim the item only if they are the last to

Bid (at least one) Token. If, when the auction ends, you have Tokens left over, these Tokens will

be redeemed for $0.25 each.

Important Aspects of this Auction:

1. Each auction you will be randomly and anonymously matched with 1 or 5 other

   participants for the auction. So, you will never know who the other bidders are.

2. No one will ever know how many Tokens you buy, and you will not know how many

Tokens other bidders buy.

3. Tokens are purchased at the beginning of each auction only, and cannot be transferred from one auction to the next.

4. One of you will be randomly chosen to start bidding. This will be revealed after all bidders have bought their Tokens and has nothing to do with how many Tokens were purchased.

5. You may choose to buy 0 Tokens at no cost, if you like.

6. If no one chooses to Bid a Token, then no one will claim the item.

7. If only one bidder chooses to buy Tokens, then that bidder will claim the item by bidding their first Token.

Bidders' endowments will be reset to the amount they earned in Phase 1 at the beginning of each new auction. As a result, the decision to participate in an auction does not impact a bidder's ability to participate in future auctions.

Important Aspects of this Auction:

Furthermore, in these auctions we will be simulating charity auctions. Charity auctions are different in two ways, *both of which will impact how much money you earn*. These two ways are outlined here:

1. In charity auctions, bidders often receive benefits from how much revenue is raised (i.e. how many Tokens are contributed by all bidders combined).

2. Bidders often feel good for contributing to a charity.

The auction raises revenue through the total value of Tokens that were Bid by everyone in the auction and the unredeemable value of unused Tokens.

Because bidders often receive benefits from the total revenue raised, for every $1 the auction raises in revenue the bidders in that auction will receive $0.10 each. *Example: if all bidders combined contribute $15 to the auction, then each of them would receive $1.50 at the end of the auction.* Because individual bidders feel good for contributing to charity, for every $1 you personally contribute to the auction, you will receive $0.05. *Example: if you contribute $6 to the auction (i.e. 12 Tokens), then you would receive $0.30 at the end of the auction on top of any money received because of the total amount raised.*

Summary of the Auction

To recap, in each auction of Phase 2 you will be placed in an auction where,

1. Each period you will be randomly and anonymously paired with one or five other participants(s) for the auction. So, you will never know the other bidders.

2. All bidders will privately buy Tokens for the auction using the money earned in Phase 1.

3. One bidder will be randomly chosen to start bidding.

4. The last person to contribute a Token will claim the fictitious item worth $10.

5. Each of you, regardless of winning or losing the auction, will earn an additional $0.10 for each $1 of revenue generated by all bidders.

6. Each of you, regardless of winning or losing the auction, will earn an additional $0.05 for each $1 personally contributed to the auction.

As mentioned earlier, there will be many opportunities for you to participate in an auction. At the end of the experiment, the computer will choose one of these auctions randomly. Your payment for Phase 2 will be based on the outcome of this one randomly selected auction.

Almost Ready to Begin

Your total earnings for today's experiment will consist of your cumulative earnings from Phase 1, your earnings from one randomly selected auction in Phase 2, and your $5 show up payment for coming on time. So:

Total Earnings =

    Phase 1 Earnings +

    Phase 2 Earnings +

    Show Up Payment ($5)

If you have any questions you would like to ask at this point, please raise your hand. Otherwise, you will now go through a series of comprehension questions to make sure you understand the experiment. After everyone has correctly answered these questions, there will be one practice auction, then Phase 1 will begin.

Comprehension Questions

1. **True or False:** The other bidders in my auction are the same every period.

    (a) True.

    (b) False. [A: Bidders are randomly assigned to auctions each time.]

2. **True or False:** You must buy Tokens for every auction.

    (a) True.

    (b) False. [A: You can choose to not participate in an auction by not buying any Tokens.]

3. **True or False:** You won't know who will bid first when you buy your Tokens.

    (a) True. [A: Bidders will buy Tokens, then one bidder will be randomly selected to start bidding.]

(b) False.

4. **True or False:** If you choose not to buy any Tokens you cannot win the auction, but you will not use any money you earned in Phase 1.

    (a) True. [A: If you don't buy any Tokens, you cannot win the auction and you will not use any money you earned in Phase 1.]

    (b) False.

5. **True or False:** Your earnings for Phase 2 will be based on one randomly selected auction.

    (a) True. [A: One auction will be randomly selected, and the outcome of this auction will determine your earnings for Phase 2.]

    (b) False.

[At the beginning of Period 11]

The number of bidders in each auction has increased to 6! Bidders are still randomly assigned to auctions. (Everything else about the auction is the same.)

B.0.5 Exit Survey

The experiment is now over. Thank you for participating! Below, there are a few questions that will help us understand the decisions you've made in this experiment. Please give them your full consideration.

How difficult did you find this auction?

Very Easy	Easy	Moderate	Hard	Very Hard
☐	☐	☐	☐	☐

Briefly, explain what your strategy was for bidding. [open response]

How many auctions have you participated in over the last 2 years (including online auctions like eBay)? [numerical response]

How fair is this auction to bidders?

Very Unfair	Unfair	Neither Fair Nor Unfair	Fair	Very Fair
☐	☐	☐	☐	☐

If present at a charity auction like this in the future, how likely would you be to participate?

Very Unlikely	Unlikely	Neither Likely Nor Unlikely	Likely	Very Likely
☐	☐	☐	☐	☐

We would like to ask you a few questions about your preferences and attitudes. Please try to answer these as accurately as possible.

In general, do you see yourself as someone who is willing to take risks?

Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
☐	☐	☐	☐	☐

Financially, do you see yourself as someone who is willing to take risks?

Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
☐	☐	☐	☐	☐

In general, when you are faced with an uncertain situation, do you worry a lot about possible losses?

Strongly Disagree   Disagree   Neither Agree Nor Disagree   Agree   Strongly Agree
☐   ☐   ☐   ☐   ☐

In financial situations, when you are faced with an uncertain situation, do you worry a lot about possible losses?

Strongly Disagree   Disagree   Neither Agree Nor Disagree   Agree   Strongly Agree
☐   ☐   ☐   ☐   ☐

In general, how competitive are you?

Not at All   Usually I Am Not   Undecided   Usually I Am   Very Competitive
☐   ☐   ☐   ☐   ☐

We would like to ask you a few hypothetical questions. Please try to answer these as accurately as possible.

Imagine that you've decided to see a movie in town and have purchased a $10 ticket. As you're waiting outside the theater for a friend to join you, you discover that you've lost the ticket. The seats are not marked and the ticket cannot be recovered because the person who sold it doesn't remember you. Would you buy another $10 ticket? [Response: Yes or No]

Imagine that a month ago, you and a friend made a nonrefundable $100 deposit on a hotel room in New Orleans for the coming weekend. Since the reservation was made, however, the two of you have been invited to spend the same weekend at another friend's cabin in Colorado. You'd both prefer to spend the weekend at the cabin but if you don't go to New Orleans, the $100 deposit will be lost. Would you still go to New Orleans? [Response: Yes or No]

B.0.6 IRB Approval Notification

UNIVERSITY OF ARKANSAS

August 23, 2013

MEMORANDUM

TO: Joshua Foster
                Cary Deck

FROM: Ro Windwalker
                IRB Coordinator

RE: PROJECT MODIFICATION

IRB Protocol #:   13-05-702

Protocol Title: *The Bucket Auction: Theory and Evidence on Participation*

Review Type: ☒ EXEMPT   ☐ EXPEDITED   ☐ FULL IRB

Approved Project Period: Start Date: 08/23/2013 Expiration Date: 05/12/2014

Your request to modify the referenced protocol has been approved by the IRB. **This protocol is currently approved for 100 total participants.** If you wish to make any further modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes.   All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

Please note that this approval does not extend the Approved Project Period. Should you wish to extend your project beyond the current expiration date, you must submit a request for continuation using the UAF IRB form "Continuing Review for IRB Approved Projects." The request should be sent to the IRB Coordinator, 210 Administration.

For protocols requiring FULL IRB review, please submit your request at least one month prior to the current expiration date. (High-risk protocols may require even more time for approval.) For protocols requiring an EXPEDITED or EXEMPT review, submit your request at least two weeks prior to the current expiration date. Failure to obtain approval for a continuation *on or prior to* the currently approved expiration date will result in termination of the protocol and you will be required to submit a new protocol to the IRB before continuing the project. Data collected past the protocol expiration date may need to be eliminated from the dataset should you wish to publish. Only data collected under a currently approved protocol can be certified by the IRB for any purpose.

If you have questions or need any assistance from the IRB, please contact me at 210 Administration Building, 5-2208, or irb@uark.edu.

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