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"An Experimental Dynamic Public Goods Game with Carryover"

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Abstract: We examine voluntary contributions in a two-stage public good experiment with 'carryover.' In two treatments, each subject's second stage endowment is determined by the return from the public good in the first stage. We manipulate payoffs across these treatments so that, relative to our no-carryover baseline, earnings from either Nash play or Pareto Optimal play are held constant. The remaining two treatments maintain a constant endowment in each stage, but vary the marginal per capita return (MPCR) to contributions in the second stage. Our results indicate that carryover increases first stage contributions. Our implementation of carryover enables us to examine the effects of changing endowments and MPCR's with a wider variety of parameter values than in the existing literature. Consistent with these studies, we find that MPCR and endowment effects are important determinants of subject contributions to the group account. While stage 1 contributions tend to increase in the presence of carryover, efficiency levels across both stages fall relative to the baseline due to the high potential payoffs from complete contribution in the second stage (due to higher endowments or MPCR levels).

JEL classification: C72; C90; H41

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1. Introduction

There is a vast experimental literature on the Voluntary Contributions Mechanism (VCM) as a means of public goods provision (for surveys see Davis and Holt (1993); Ledyard (1995); and Holt (2007)). Typically, subjects are endowed with a number of tokens to be allocated either to a private or a group account. The return from the group account is non rival and non excludable, but the marginal per-capita return (MPCR) to the group account is typically lower than the return to the private account; this induces the common free riding problem associated with public goods provision. A benefit of the VCM approach is the sharp contrast between self interested play (the Nash equilibrium has zero contribution to the group account) and socially optimal play (the Pareto optimum has each subject contribute all tokes to the group account).

Several authors have investigated the impact of variation in endowment levels (for examples, see (Rapoport (1988), Laury, Walker, and Williams (1999), Clark (2002), Cherry, Kroll, and Shogren (2005), Muehlbacher and Kirchler (2009), De Cremer and van Dijk (2009)), MPCR (for examples, see Marwell and Ames (1979); Isaac, Walker, and Thomas (1984); Isaac and Walker (1988), and Fisher et. al (1995)), and the effects of repeated play (in which a stage VCM game is repeated several times, see for examples Isaac, Walker, and Thomas (1984); Isaac, McCue and Plott (1985); Banks, Plott and Porter (1988)). Results from this research suggest that increases in endowment or MPCR lead to higher contribution levels and that repeated play leads to decay in contributions to the group account over time. The results are similar to those in experimental studies of the prisoner's dilemma (which can be viewed as an extreme version of the VCM game) that find repeated play leads to decreased rates of cooperation (see for example Kreps et al (1982)). Some authors have investigate the impact of group size (Isaac, Walker, and Williams (1994)) or sanctioning (Ostrom, Walker, and Gardner (1992), Gürerk, Irlenbusch, and Rockenbach (2006), and Galbiati and Vertova (2008)) or other methods to overcome the collective action problem (for examples see Fehr and Gächter (2000), Egas and Riedl (2005), Cinyabuguma, Page, and Putterman (2005), Page, Putterman, and Unel (2005), Gurerk , Irlenbusch, and Rockenbach (2006), Sefton, Shupp, and Walker (2006), Ones and Putterman (2007), and Ertan, Page, and Putterman (2009)).

A limitation to existing research, particularly in repeated settings, is the lack of connection between decision-making across periods. In repeated interactions associated with public goods provision, contributions to a group account may 'carryover' from one period to the next, as would occur if the return from the public good in an early period was made available for use in successive periods. Alternatively, experience with public goods provision may lead to 'learning by doing' that lowers costs of provision, a form of carryover that effectively increases the MPCR. While the introduction of carryover in endowment levels or MPCR does not affect the equilibrium predictions associated with the VCM game, carryover can sharpen the contrast in payoffs between self interested and socially optimal play. The main contribution of our paper is the analysis of these effects. While Castro (2005) utilizes a two stage framework in which subjects have the option of contributing to two separate public goods, we are not aware of any prior work that implements carryover between stages within a period.

In particular, we examine a two stage VCM game where the second stage endowment or MPCR is linked to decisions from the first stage. In our *varying endowment* treatments, a subject's payoff from the first stage (which includes their return from both the private and group account) becomes their endowment in the second stage. Relative to our no carryover baseline, in one of these treatments the payoff from Nash play is held constant (while the payoff to socially optimal play increases), and in a second treatment the payoff from socially optimal play is constant (while the payoff to Nash play decreases). In our *varying MPCR* treatments, the second stage MPCR is linked to first stage contributions to the group account. Our baseline utilizes a four person VCM game with an MPCR of 0.5. In the MPCR treatments (in the absence of first stage contributions to the group account), the second stage MPCR is set to a reference point of either 0.3 (in the low treatment) or 0.5 (in the high treatment). Importantly, the second stage MPCR increases with the level of first stage contributions to the group account. These changes do not affect the payoff to Nash play, but do increase the payoff to socially optimal play. Although we introduce carryover in a way that does not affect the predictions associated with Nash play, our basic behavioral hypothesis is that linking the first and second stage decisions with carryover should increase first stage contributions. Because the second stage endowment and MPCR levels are determined as part of the experiment, our approach also allows us to examine the impact of these variables on second stage contributions with a wide range of parameter values.

The experimental data are broadly consistent with our behavioral hypothesis. Relative to the baseline, first stage contributions were higher in three of our four carryover treatments. Our analysis of second stage contributions is consistent with the robustness of the endowment and MPCR effects in the existing (no carryover) literature. Our results also provide limited support for a within period end game effect. We repeated our two stage VCM game for five periods, and while in most cases contributions decreased from one stage to the next, subject contributions rebounded at the beginning of the next period. This result suggests a limited ability on the part of our subjects to overcome the decay typically associated with multi-period VCM games. The remainder of the paper is organized as follows: section 2 introduces our experimental design and procedures, section 3 provides a discussion of the results, and section 4 concludes.

2. Experimental Design and Procedures

2.1 Baseline

All treatments were conducted via computer using the z-Tree software (Fischbacher 2007). Subjects were undergraduate student volunteers from the United States Naval Academy. In the baseline treatment, subjects were randomly and anonymously placed in groups of 4, and given a per period endowment of 10 experimental dollars (ED) to be placed in a private account (earning 1 ED for that subject alone) or a group account (generating ½ an ED for each group member). Subjects stayed in the same group for each of 10 periods. The group account can be viewed as a public good, with each subject's per period ED earnings given by:

$$ED_i = \left(w_i - m_i\right) + .5\sum_i m_i \qquad \textbf{(1)}$$

where w_i is the initial ED endowment per period, m_i is individual i's contribution to the group account for that period, $\sum_i m_i$ represents the sum of contributions to the group account and ($w_i - m_i$) represents individual i's contribution to the private account. The Nash equilibrium prediction for this decision problem has each subject ‘free ride’ in each period, contributing 0 ED to the group account. In the Pareto optimal outcome, each subject contributes 10 ED to the group account in each period. Over the course of the 10 periods, earnings for each subject under Nash play are 100 ED, while under Pareto Optimal play earnings are 200 ED. At the end of the experiment, EDs are converted to cash at an exchange rate of $0.10 for each ED.

2.2 Varying Endowment Treatments: Constant Nash Equilibrium Payoffs (NE) and Constant Pareto Optimal Payoffs (PO)

To study the effects of carryover in endowments, we utilized two treatments in which a subject’s ED earnings from a ‘first stage’ VCM game (using baseline parameters) became the subject’s endowment in a second stage. Each of these treatments consisted of 5 two stage periods—in the first stage of each period, subjects played the baseline VCM game with an endowment of 10 ED. In the second stage, each subject’s endowment was determined by their ED payoff from the first stage. Varying the second stage endowment does not change the prediction associated with Nash play (zero contributions to the group account) or Pareto Optimal play (full contribution to the group account) in either stage. It does, however, change the payoffs under these strategies. In the constant NE treatment, subjects accumulated ED in each stage of each period. Thus, similar to the baseline, Nash play by all subjects would result in a payoff of 10 ED in each of the 10 stages, for an aggregate of 100 ED. Pareto Optimal play by all subjects in each stage, however, would result in the accumulation of 20 ED in each of the five first stages and 40 ED in each of the five second stages, for an aggregate of 300 ED.

To control for the level of payoffs under Pareto optimal play, subjects in the constant PO treatment accumulated ED only in the second stage of each period. In other words, while the outcomes of the first stage had an impact on the second stage endowments, subjects were not ‘paid’ for their first stage decisions. This does not affect the predictions associated with Nash play (free riding remains a dominant strategy in both stages) or Pareto optimal play. Note, however, that the payoff when all subjects utilize the Nash strategy is 10 ED in each of 5 periods, for a total of 50 ED. Under Pareto Optimal play, subjects accumulate 40 ED in each of 5 periods, for a total of 200 ED. As such, relative to the baseline, the constant NE treatment keeps payoff under Nash play constant but increases payoffs under Pareto optimal play, while the constant PO treatment lowers the payoff to Nash play and keeps the payoff to Pareto optimal play constant.

2.3 Varying MPCR Treatments: Low and High

To study the effects of carryover in the marginal per capita return (MPCR), we utilized two treatments in which a group's total contributions to the public good from a 'first stage' VCM game (using baseline parameters) influenced the MPCR associated with contributions to the group account in the second stage. Both treatments consisted of 5 two stage periods—in the first stage of each period, subjects played the baseline VCM game with an endowment of 10 ED and an MPCR = 0.5. In the second stage of each period, each subject's endowment was 10 ED and the MPCR was linked to total contributions to the group account in the first stage of that period. In the High treatment, each group's second stage MPCR was equal to 0.5 + .01*total group contributions from stage 1. In the Low treatment, each group's second stage MPCR was equal to 0.3 + .01*total group contributions from stage 1. In each of these treatments, a subject's ED earnings in each period is the sum of their first and second stage earnings. Linking second stage MPCR to group contributions from stage 1 in this way does not affect the predictions associated with Nash or Pareto optimal play (zero and full contribution to the group account, respectively). Under Nash play in both the High and Low treatments, a subject earns 10 ED in each of the ten stages, for a total of 100 ED. Under Pareto optimal play, the second stage MPCR for the High (Low) treatments is 0.9 (0.7), resulting in payoffs of 56 (48) ED in each of five stages for a total of 280 (240) ED.

3. Experimental Results

3.1 First Stage Contributions

Although the Nash prediction of free riding in each period is consistent across treatments, our basic behavioral hypothesis is that introducing carryover, either through endowment or MPCR, should increase first stage contributions. Figures 1 and 2 display the average contribution, as a percent of endowment, in the first stage of the varying endowment and MPCR treatments, respectively. For comparison purposes, the figures also include average contributions (as a percent of endowment) from the odd periods of the baseline.

(**Insert Figure 1 and Figure 2 here**)

While Stage 1 contributions were similar in the baseline and constant NE treatment, contributions in the constant PO and varying MPCR treatments were higher in each period. Similar to the results from many experimental studies of VCM games that utilize multiple periods, contributions to the group account appear to decay in all but the high MPCR treatment. We utilize random effects regression estimates to assess whether these differences in contributions are statistically significant (where each subject is the group variable, to control for interdependence. Table 1 reports the results.

(Insert Table 1 here)

The coefficient estimates on the constant PO, varying MPCR treatment variables, and the period variable are statistically significant and in the expected direction. We conclude that in most cases, introducing carryover increases contributions to the group account in stage 1. Our intuition for these results is straightforward. Relative to the baseline, the varying MPCR treatments provide an additional benefit to stage 1 contributions to the group account. In the high treatment, this takes the form of raising second stage MPCR above the MPCR available in the first stage. In the low treatment, the second stage MPCR is increased from a lower reference point. In this case, group contributions of 20 ED (half of each subject's endowment) would result in a stage 2 MPCR equal to that available in stage 1. In a sense, failing to meet this aggregate contribution level cost the group by reducing the MPCR relative to stage 1 (and the baseline). Our results suggest that the additional benefit to contributions in stage 1 of the varying MPCR treatments had a statistically significant and positive impact on contributions to the group account.

The intuition underlying the varying endowment treatments is slightly different. Relative to the baseline, inability to overcome the stage 1 collective action problem in the constant NE treatment has a higher 'opportunity cost' in the sense that payoffs from socially optimal play in both stages are much higher. While our behavioral hypothesis suggests this would increase stage 1 contributions, the empirical results indicate that this did not have a statistically significant impact on contributions to the group account. Relative to the baseline, the payoffs from Nash play were lower in the constant PO treatment. In a sense, this lowers the cost associated with socially optimal play in the first stage (as subjects did not realize their ED payoff until the completion of the second stage). Our empirical results suggest that the reduction in payoffs to Nash play in the constant PO treatment had a significant and positive impact on stage 1 contributions.

3.2 Second Stage Contributions

Prior research has shown that MPCR and endowment levels have significant impacts on behavior in VCM games (see Van Dijk and Grodzka (1992) or Van Dijk and Wilke (1994)). Figure 3 and Figure 4 display average stage 2 contributions (as a percent of endowment) for the varying endowment and MPCR treatments, respectively, by period. For comparison purposes, we also include average contributions (as a percent of endowment) for the even periods of the baseline.

(**Insert Figure 3 and Figure 4 about here**)

As a percentage of endowment, stage 2 contributions to the group account appear to be lower in the constant NE treatment than in the baseline, while they are higher (in particular in the final periods) in the varying MPCR treatments. In all treatments, there appears to be significant decay in contributions over time. We use random effects regression analysis to assess whether these differences are statistically significant. Based on prior research that shows MPCR, endowment, and period influence subject decision making, we include controls for these variables. Following Dickinson (1998), we also include a control, ‘lagdeviate,’ for a subject’s deviation from average contribution to the group account in the prior stage. A subject who contributed more than the group average in stage 1 might respond by lowering their contribution in the next stage. Alternatively, decay in subject contributions to the group account for those contributing more than the group average might be slower than the rate of decay for low contributors. If this is the case, the estimated coefficient on the lagdeviate variable would be positive. Tables 2 and 3 report the random effects regression results.

(Insert Table 2, Table 3 here)

Consistent with prior research, the regression estimates indicate that endowment and MPCR have positive and statistically significant impacts on a subject's contribution to the group account. Importantly, our analysis of the endowment and MPCR effects utilizes a wider range of values than previously available, establishing the robustness of these effects. The coefficient estimate for the period variable is negative and statistically significant, an indication of the decay in contributions typically associated with multiple period VCM games. The estimate for the lagdeviate variable is positive and statistically significant, which we interpret as evidence that decay in contributions is faster for subjects whose stage 1 contributions are lower than average. With these controls in place, we find that second stage contributions to the group account were lower for the varying MPCR treatments and the constant NE treatment, although the estimate on the NE treatment is not statistically significant. The coefficient estimate on the PO treatment is positive and statistically significant. We interpret the coefficient estimates and significance results for the treatment dummies as limited evidence for a within period 'end game' effect. Linking the stage 1 and stage 2 contribution decisions with carryover increased first stage contributions, but (controlling for endowment and MPCR effects) reduced stage 2 contributions. This issue is discussed further below.

We also use a lagdeviate2 variable to examine a subject's deviation from average contribution to the group account in the prior period (same stage), thus keeping endowment and/or MCPR constant and eliminating any impact on the carryover decision. A subject who contributed more than the group average in stage 1 (2) of period 1 might respond by lowering their contribution in the stage 1 (2) of period 2 and so forth. Again, decay in subject contributions to the group account for those contributing more than the group average might be slower than the rate of decay for low contributors, making the estimated coefficient on the lagdeviate2 also positive. Tables 4 and 5 report the random effects regression results.

(Insert Table 4, Table 5 here)

Consistent with prior research, the regression estimates indicate that endowment and MPCR have positive and statistically significant impacts on a subject's contribution to the group account. Importantly, our analysis of the endowment and MPCR effects utilizes a wider range of values than previously available, establishing the robustness of these effects. The coefficient estimate for the lagdeviate2 variable is also positive and statistically significant, thus decay in contributions is faster for subjects whose stage 1 contributions are lower than average.

3.3 Efficiency Calculations

In addition to analyzing the effects of carryover on individual contributions, we are interested in whether carryover influences the efficiency of public goods provision. Given the variation in payoffs associated with Nash and Pareto Optimal play in our treatments, we use the following efficiency index:

$$Efficiency = \left(\frac{Actual\ Earnings - Earnings\ \ at\ NE)}{Pareto\ Optimal\ Earnings - Earnings\ \ at\ NE)}\right)*100\ .$$

The denominator is a measure of the maximum gain associated with cooperative as opposed to self interested play. As such, we interpret our efficiency measure as the share of maximal gains from cooperation captured by the subjects. The results are displayed in Table 6.

(**Insert Table 6 here**)

The results regarding the effects of carryover on efficiency are mixed. Relative to the baseline, the constant NE and varying MPCR treatments had higher earnings under socially optimal play, and thus larger potential gains from cooperation. While subjects in the constant NE treatment did not capture as high a share of these gains as those in the baseline, subjects in both of the varying MPCR treatments fared better. The remaining treatment, constant PO, also had a larger surplus available than the baseline, but this was due to a reduction in payoffs to Nash play rather than an increase in Pareto optimal payoffs. Subjects in the constant PO treatment captured approximately that same share of the gains from cooperation as those in the baseline. We conclude that carryover, while stimulating stage 1 contributions, has a significant impact on efficiency only in cases where the costs of provision (as reflected in the MPCR), are affected.

3.4 *Contributions across Stage and Period*

Decay in contributions across periods in a VCM game is well documented, with the general finding that once cooperation breaks down it is difficult to reestablish. While our empirical results show decay in both stage 1 and stage 2 contributions across periods, subject contributions in our carryover treatments (in particular the varying endowment treatments) displayed a 'sawtooth' pattern. That is, while subject contributions to the group account tended to be lower in stage 2 of a period, contributions to the group account rebounded in the first stage of the following period. Figure 5 displays average contributions to the group account (as a percentage of endowment) for the varying endowment treatments.

(Insert Figure 5 here)

In connection with the regression results reported in Tables 2 – 5, this pattern provides evidence of a within period endgame effect. While subject contributions decayed over the course of the experiments, groups showed a limited ability to rebound from coordination failure. In our view, this is related to the differential contribution incentives associated with the carryover treatments—although cooperation fell in stage 2, stage 1 of the following period 'started the game over,' and in connection with the additional benefits associated with stage 1 contributions in the carryover treatment, this led to higher contributions.

4. Conclusions and Directions for Future Work

We examine the impact of carryover on contributions to a group account in a two stage VCM game. Although there is a significant literature examining the determinants of VCM contributions, we are not aware of any other papers that study carryover in endowment or MPCR in this framework. We believe this is an important omission because in many environments the payoff from a public good may be available for use in future periods. Also, the process of organizing and implementing public goods provision may impact the costs of future projects that have similar characteristics.

We conducted two varying endowment treatments in which the returns from the first stage of the game became the second stage endowment. We manipulated payoffs so that in one of these treatments the returns from Nash play were constant and in the other returns from Pareto play were constant. Our experimental results regarding the impact of carryover in endowment are mixed. Relative to the baseline, first stage contributions were higher in the constant PO treatment, but there was not a statistically significant difference in first stage contributions for the constant NE treatment. Alternatively, second stage contributions were similar in the baseline and Constant PO treatments, with the constant NE treatment having significantly lower contributions.

We also conducted two treatments to examine the impact of carryover in MPCR on subject decision making. In these treatments, the second stage MPCR was increasing the level of first stage contributions to the group account, with either a low (0.3) or high (0.5) starting point. Our experimental results suggest that carryover in MPCR increases contributions in both the first and second stages. This result, while not consistent with the comparative statics associated with the Nash prediction, supports our behaviorally based hypothesis that carryover should increase contributions.

Our results are consistent with the existing VCM literature in the sense that two important forces determining second stage contributions were the endowment and MPCR. Our regression estimates and significance results indicate that these variables are positively correlated with contributions. We also find that lagged deviations from the group average contribution and period have a significant impact on contributions. While the coefficient estimate on the period variable indicates decay in contributions, subjects in our varying endowment treatments showed a limited ability to rebound from decay in contributions from the second stage of a period to the first stage of the next period.

While carryover appears to have had a significant impact on subject contributions to the group account, it does not appear to have significantly affected efficiency levels relative to our baseline. Given the characteristics of our design, in which earnings under Pareto play are higher for the MPCR and constant NE treatment, this may not be surprising. In summary, our results suggest that carryover in endowment and MPCR have important impacts on subject decision making in VCM frameworks.

However, while carryover leads to increases in contributions in most cases, the dampening of the free rider incentive is not sufficient to alter aggregate efficiency levels because carryover, in particular in MPCR, raises the payoffs associated with cooperative play.

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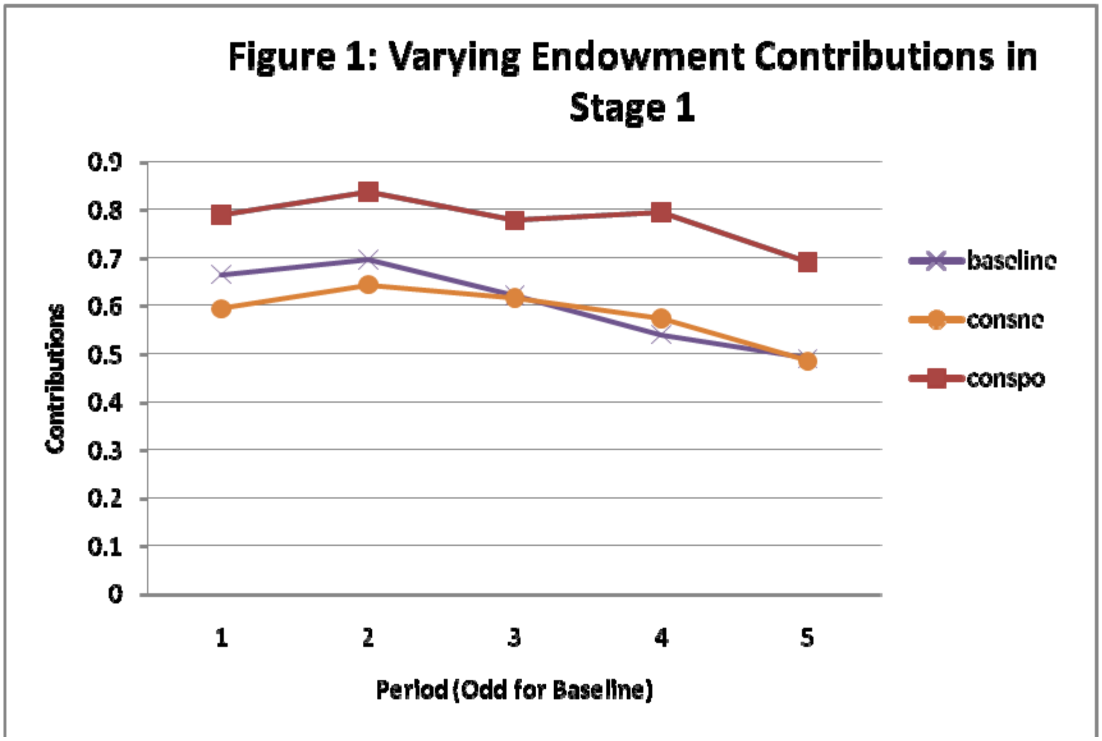
Figure 1: Varying Endowment Contributions in Stage 1
Contributions
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
Period (Odd for Baseline)
baseline
consne
conspo

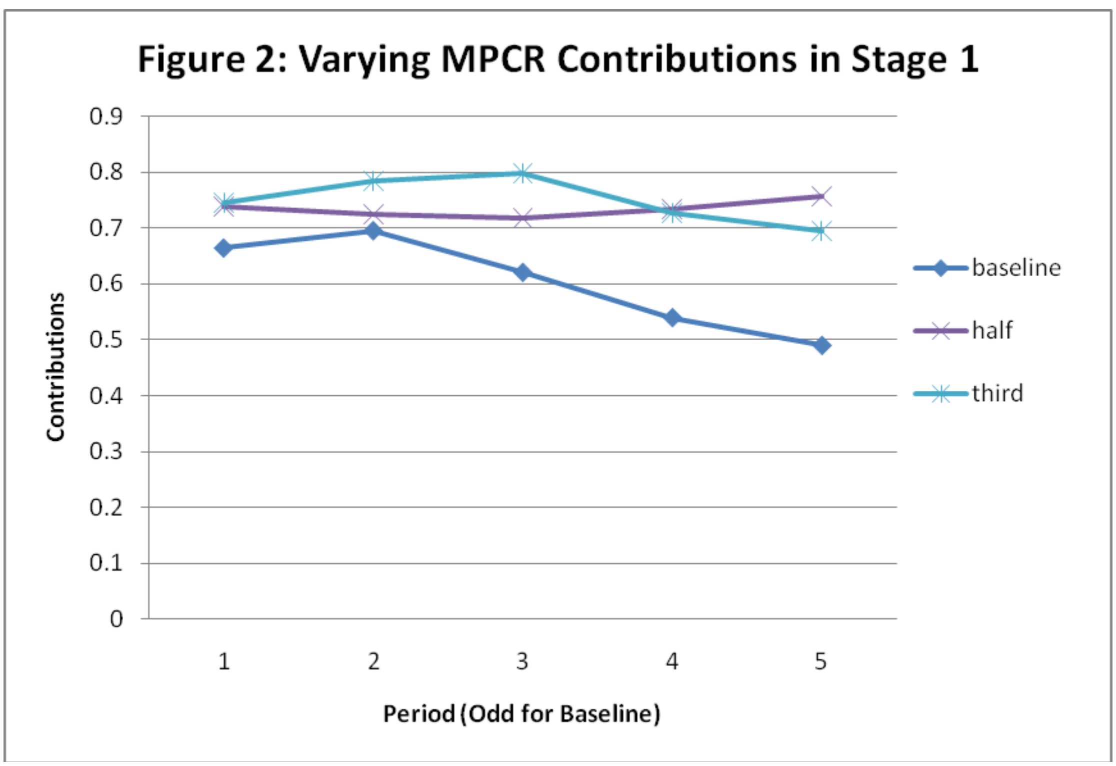
Figure 2: Varying MPCR Contributions in Stage 1
Contributions
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
Period (Odd for Baseline)
baseline
half
third

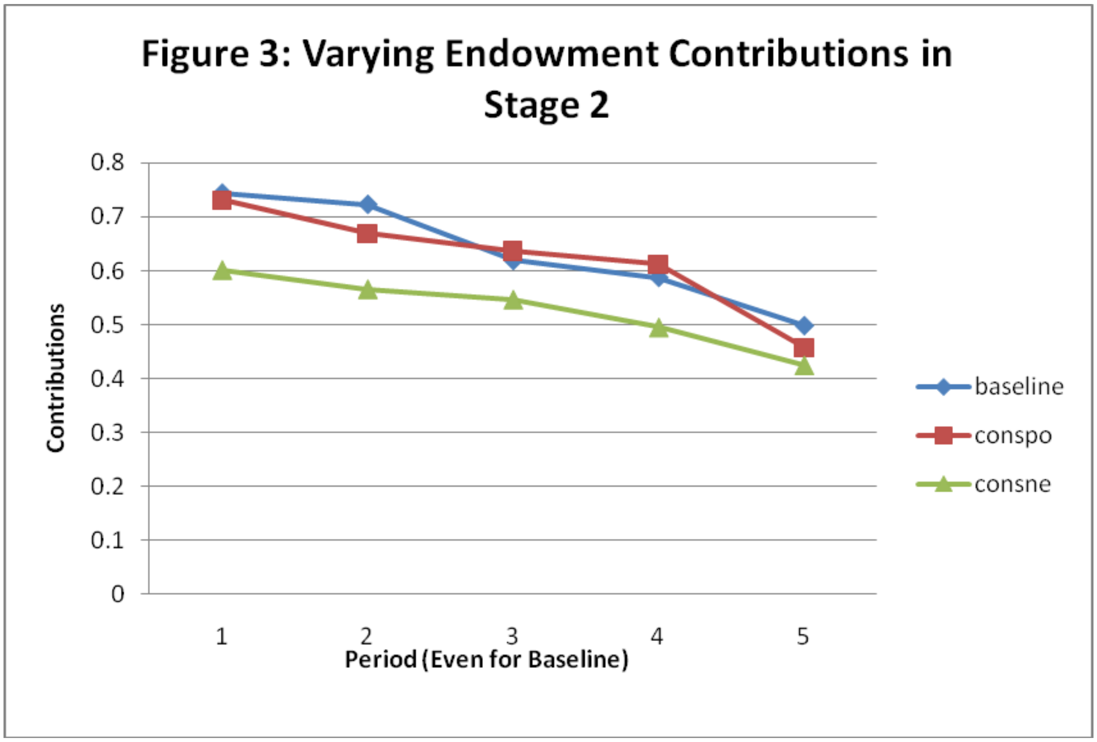
Figure 3: Varying Endowment Contributions in Stage 2
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Contributions
1
2
3
4
5
Period (Even for Baseline)
baseline
conspo
consne

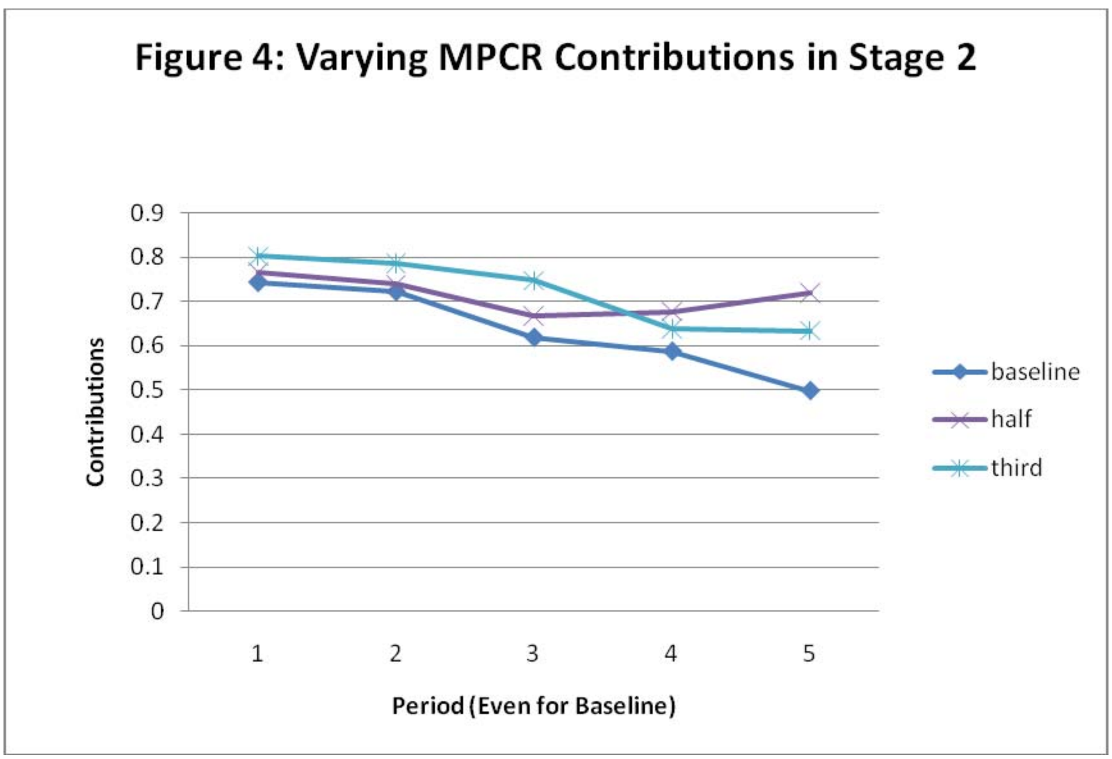
Figure 4: Varying MPCR Contributions in Stage 2
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Contributions
1
2
3
4
5
Period (Even for Baseline)
baseline
half
third

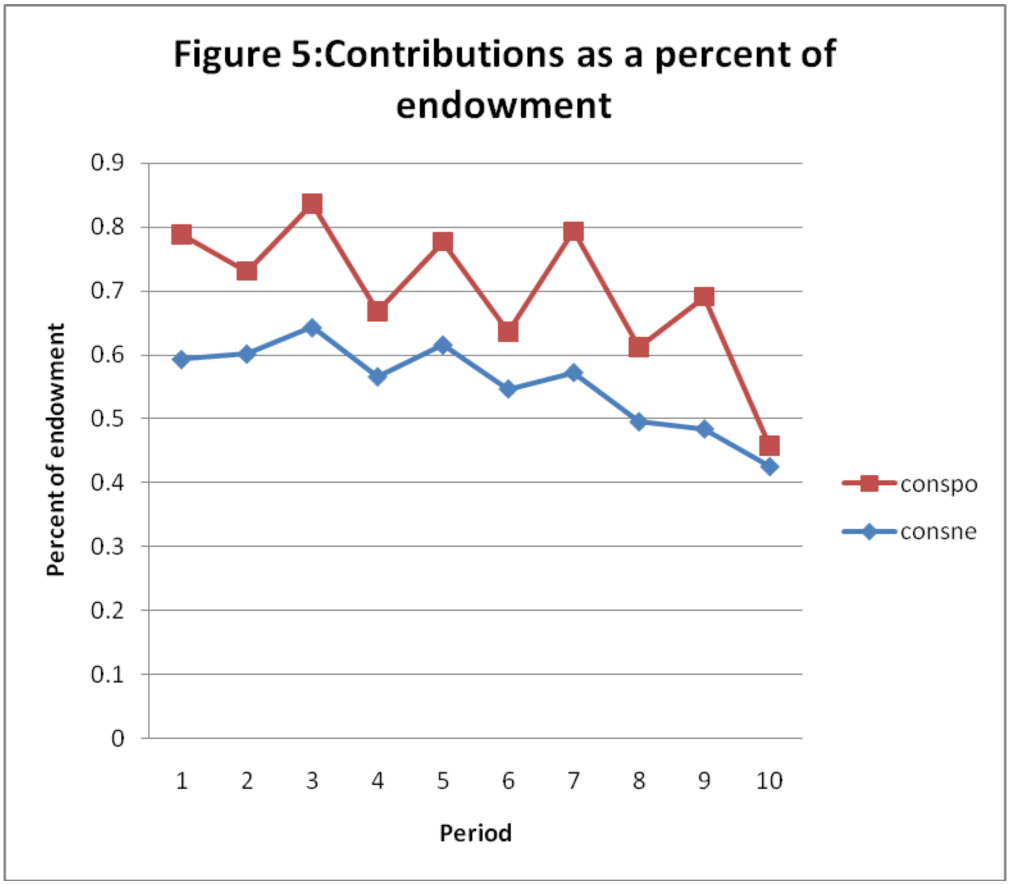
Figure 5:Contributions as a percent of endowment
Percent of endowment
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
7
8
9
10
Period
conspo
consne

Table 1: Random Effects regression results for individual contributions (two-tailed p-values in parentheses), robust standard errors

Independent Variable	
PO	1.643
	(0.012)
NE	-0.203
	(0.758)
High	1.325
	(0.034)
Low	1.480
	(0.015)
Period	-0.122
	(0.000)
Constant	6.632
	(0.000)
R^2 overall	0.0516
Wald $Chi^2(6)$	1313.37
Prob > Chi^2	0.0000
N	1120

Table 2: Random Effects regression results for individual contributions for varying endowment treatments (two-tailed p-values in parentheses), robust standard errors

Independent Variable	
PO	2.281
	(0.013)
NE	-0.319
	(0.683)
Endowment	0.322
	(0.001)
Lagdeviate	0.235
	(0.002)
Period	-0.391
	(0.000)
Constant	5.421
	(0.000)
R^2 overall	0.2267
Wald $Chi^2(5)$	108.28
Prob > Chi^2	0.0000
N	611

Table 3: Random Effects regression results for individual contributions for varying MPCR treatments (two-tailed p-values in parentheses), robust standard errors

Independent Variable	
MPCR	25.056
	(0.000)
Lagdeviate	0.368
	(0.000)
High	-6.508
	(0.000)
Low	-1.566
	(0.000)
Period	-0.212
	(0.000)
Constant	-4.944
	(0.000)
R^2 overall	0.3667
Wald $Chi^2(5)$	285.34
Prob > Chi^2	0.0000
N	613

Table 4: Random Effects regression results for individual contributions for varying endowment treatments (two-tailed p-values in parentheses), robust standard errors

Independent Variable	
PO	2.305
	(0.014)
NE	-0.179
	(0.827)
Endowment	0.309
	(0.001)
Lagdeviate2	0.183
	(0.040)
Period	-0.392
	(0.000)
Constant	5.412
	(0.000)
R^2 overall	0.2076
Wald $Chi^2(5)$	91.31
Prob > Chi^2	0.0000
N	534

Table 5: Random Effects regression results for individual contributions for varying MPCR treatments (two-tailed p-values in parentheses), robust standard errors

Independent Variable	
MPCR	24.352
	(0.000)
Lagdeviate2	0.278
	(0.000)
High	-6.227
	(0.000)
Low	-1.335
	(0.007)
Period	-0.222
	(0.000)
Constant	-4.719
	(0.000)
R^2 overall	0.3349
Wald $Chi^2(5)$	183.74
Prob > Chi^2	0.0000
N	530

Table 6: Efficiency Results

$$Efficiency = \left(\frac{Actual\ Earnings - Earnings\ at\ NE)}{Pareto\ Optimal\ Earnings - Earnings\ at\ NE)}\right)*100$$

Baseline	61.81
PO	62.67
NE	50.28
High	65.53
Low	65.4