Debt and (Future) Taxes — Financing Intergenerational Public Goods

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February 25, 2015

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All mistakes are my own.

Abstract

Many public goods inherently involve an intergenerational component. Groups fund projects to enhance environmental quality that help us; those projects also impact the group’s children’s livelihood. Additionally, most public projects have two funding sources: current and future incomes (taxes and debt). I construct a public goods experiment in which an agent’s contribution to the public good not only impacts her welfare, but also impacts future agents who play the game. In one treatment she may borrow from this future player. I find that, adding debt-financing as a means of funding the public good increases contributions to the project, yielding higher endowments for future agents. This gains are, however, offset by debt repayment so that economic growth is not possible for future generations without additional debt.

*I would like to thank the Texas A&M Humanities and Social Science Enhancement of Research Capacity Program and the College of Liberal Arts at Texas A&M for providing generous financial support for my research. Further, I thank my advisers Alexander Brown, Catherine Eckel, and Jonathan Meer for their encouragement and feedback as I developed my research. Thank you to the insightful comments from attendees of the 2013 Annual ESA World Meetings and the IHS Scholarship in a Free Society Symposium. I also like to thank Xiaoayuan Wang for aiding me in running the experimental sessions. The experimental research team at Texas A&M has been instrumental as well and I could not have done this research without their continual support and feedback.

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1 Introduction

Each generation inherits many things from the previous generation. One of those things which should be of concern is the economic climate and its influence on current and future economic activity. Generations begin with a set of wealth (or potential economic frontier) which is due, in large part, to the choices made by the generation(s) which came before them. Most large scale factors which influence the wealth of entire generations are the public investment choices of a previous generation(s). These include pollution and environmental quality, establishing and supporting a court system, infrastructure, the development of knowledge/science, and a plethora of other potential societal investments. Investing in these public goods whose impact extends beyond the current generation indicates a version of collective, intergenerational altruism exists. In this paper, I consider an environment of intergenerational linkage via public goods games and test using a laboratory experiment. I test if those intergenerational preferences are present and if public debt and private saving between individuals across generations impacts welfare.

I specifically study a public goods environment because most large investments made by societies have elements of public goods. For example, consider a large government research grant that create knowledge which, once discovered, is non-rivalrous and non-excludable. This knowledge changes not just the groups who discovered it, but also alters the state of the world for future individuals; when future individuals stand on the shoulders of giants, they can reach higher and the production possibility frontier is expanded for them and future player as well. Thus, society’s investment into these types of public goods helps the current generation and can lead to further gains for the younger generation. These large undertakings are normally group decisions, furthering increasing the appeal of studying these types of economic situations in a public goods setting.

Investments into group projects, however, face many obstacles; the free-rider problem is likely the most studied and important in economics. The free-rider problem captures the idea that an individual’s optimal choice is likely counter to the socially optimal. Nevertheless, Fischer et al. (2004) show that if the group’s actions alter future individuals’ welfare then

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1 I can make a similar argument that investments in higher environmental quality make healthier, future workers. This increase their productivity and moves resources, on the margin, from helps sick people to investments in other goods, further improving welfare.
current decision makers behave less selfishly; actions are closer to the Pareto optimal set than without the intergenerational linkages in their common pool resource environment.

I design an experiment in which individuals are members of a group. Each of the groups can be thought of as a generation in a dynasty of generations. The current generation’s investment in a public good directly determines both their payoffs and the starting endowments/wages of the next generation. My experiments has two treatments. In one treatment, subjects are able to borrow from their progeny and another that serves as a control where that action is not possible. I find that debt negatively impacts future players. Further, I decompose this into separate causes: underinvestment in the public goods and insufficient savings.

My paper, to the best of my knowledge, is the first paper to investigate intergenerational linkages in a public goods setting where the actions of one group impact a future group’s economic well-being. My experimental design also allows for the possibility of infinite generations in a dynasty as each generation has a known and constant probability of being the last one. As my experiment considers intergenerational debt and private savings between generations, the results of the experiment add to lineage of papers concerned with Ricardian Equivalence (Barro, 1974). Additionally, I can study different behavioral theories regarding fairness and reciprocity between generations in the laboratory. This research helps inform discussions regarding public projects, growth theory, and debt versus tax financing of various government projects.

I have organized the paper in the following way. In Section 2, I discuss the related literature. Section 3 details the theoretical background and predicts agent choices in those environments. I discuss the experimental design used to investigate intergenerational public goods games in Section 4. Section 5 provides the results of the experiment and in Section 6 I discuss implications of those results on public policy and potential extensions to my work.

2 Literature Review

There is rich history of studying public goods in an experimental laboratory. Much of the literature focuses on the impacts group size, returns from contributions, number of repetitions, and heterogeneity of endowments on subject behavior. For an extensive literature review of early work see Ledyard (1995); Zelmer (2003) provides a meta-analysis linear public goods games which expands our understanding of these environments.

A recent addition to the public goods literature are experimental studies of dynamic
public goods. Noussair and Soo (2008) study a public goods game where members of a group can influence their own future MPCR. They find that in this environment, contributions do not, on average, decline consistently over time as the future payoff from the public good is a function of current contributions to it. This result is counter to standard, repeated public goods findings in which contributions approach zero over time (Ledyard, 1995). Cadigan et al. (2011) study a two period public goods problem in which the outcome of the first period determines the state of the world in the second period; subjects play the second period public goods game with their earnings from the first period. This carryover leads to increased contribution, in general, in the first of the two periods. There is not, however, significantly increased efficiency overall compared to a two-period public goods setting without carryover.

A related line of literature is recent experimental investigations on intergenerational common pool resources (CPR). The tragedy of the common plagues CPR similarly to the way the free-rider problem hampers efficient provision in a public goods environment; each agent faces personal maximization versus group maximization. Chermak and Krause (2002) use a overlapping generations environment to investigate which observable characteristics identify various types of players (conditionally cooperative, Nash/selfish, etc.) in the CPR setting. They find that roughly one-fifth of subjects employed the socially optimal, altruistic action consistently.

Fischer et al. (2004) conduct an intergenerational CPR experiment whose design is most closely related to mine. In their paper, subjects are in groups of three and play the game only once knowing that they are part of a lineage of fixed length; they do not know where in that lineage they lie. They find that the intergenerational linkage does alter behavior from standard CPR experiments as consumption of the common pool resource slows; it does not, however, slow enough to reach the socially optimal level. One might conjecture from this outcome that similarly more pro-social behavior (increased contributions and higher net savings) could exist in an intergenerational public goods environment with debt.

In addition to public goods, my environment includes intergenerational debt and savings. These two components are often studied in Macroeconomics. (Barro, 1974) discusses a model in which debt is neutral (i.e., does not impact consumption of current and future generations); this model is known as Ricardian Equivalence. The crux of the model is that individuals care about their children, and set savings equal to the government debt; this bequest level ensures their children do not bear the burden of those encumbrances. This model has mixed empirical evidence using field data (Benheim, 1987; Seater, 1993; Stanley, 1998).

There is a growing literature of experimental macroeconomics. Duffy (2008) provides an
overview of this literature. Within this literature, there are subset of papers that investigate aspects of Ricardian Equivalence. Cadsby and Frank (1991) provides the first experimental test of intergenerational Ricardian Equivalence in their model of government debt and savings. They find, for the most part, individuals’ savings are enough to offset future debt repayments. In further studies, Slate et al. (1995) and DeLaurea and Ricciuti (2003) each find that savings behavior is sensitive to the level of certainty in the economy. In each of these studies, debt is exogenously imposed and cannot be leveraged to produce anything of value for future players. Further, all these Ricardian Equivalence experiments monetarily induce subjects to care about the other (future) player in the room. My research diverges from those paper on both of these issues and will be further discussed in the Section 4 on the design of the experiment.

3 Theory

3.1 Game Structure with Neo-Classical Predictions

I begin by examining a classic public goods situation depicted in Equation 1. Agents are members of a group of size $N$. Each group plays a version of the voluntary contribution mechanism. I consider the standard linear public goods environment; selfish, Nash equilibrium is zero contribution contrasted to the Pareto optimal solution of full contribution by all $N$ members of the group.

$$\pi_i = w_{it} - g_i + \gamma \sum_{j=1}^{N} g_j$$

where $\gamma < 1$ and $N\gamma > 1$. Any $\gamma$ with those criteria allows for the classic free-rider problem discussed in public goods literature. The models predictions for Nash and socially optimal play are $g^{NE} = 0$ and $g^{SO} = w_i$ for all $i$, respectively.

Agents play this game one time. Additionally, the contribution to the public good by an agent not only has positive externalities for her contemporaneous players, but also a positive spillovers on future players. I present a Nash dynamic model, an intragenerational optimal set of actions, and the dynamic socially optimal solutions below.

I assume that $w_{it}$ evolves in the following way

$$w_{it+1} = w_{it} + \theta(G - Nw_{it}a)$$

4 J. Forrest Williams (2013)
where \( \alpha < 1 \) and \( G \equiv \sum_{i=1}^{N} g_i \). One can think of \( N w_{it} \alpha \) as a public goods threshold. Investments under the thresholds lower the next generations starting wealth whereas investments over the threshold increase it. The parameter \( \theta \) can be thought of as an inter-generational marginal per capital return from investment into the public good. Because I consider positive spillovers from investment in this paper, it is necessarily the case the \( \theta > 0 \). It is important to note that both \( w_{it=1} \) and \( w_{jt=1} \) are monotonically increasing in \( g_{it} \); the spillovers are public goods for the future agents.

Each agent agent lives once and so plays the game once. They know that their heirs can receive the impact of these contributions (Equation 2). The timeline of the agent’s actions are seen below.

<table>
<thead>
<tr>
<th>Generation ( t ) Begins</th>
<th>( w_{it}, b_{it-1} )</th>
<th>( s_{it-1}, G_{t-1} )</th>
<th>( B_t )</th>
<th>( G_t )</th>
<th>Generation ( t ) Ends</th>
</tr>
</thead>
<tbody>
<tr>
<td>( b_{it} )</td>
<td>( g_{it} )</td>
<td>( s_{it}, c_{it} )</td>
<td>( s_{it} - b_{it} )</td>
<td>( s_{it} - b_{it} )</td>
<td>( s_{it} - b_{it} )</td>
</tr>
</tbody>
</table>

where \( b_{it} \) and \( s_{it} \) are the borrowing and savings of agent \( i \) in generation \( t \), respectively. There is never more than one generation of decision makers at a time, but agents can observe the actions of the previous generation and their own income before making any choices. Items on the top of the timeline are information that is gathered by the agents before making the next set of choices. Choice variables are located below the timeline. For instance, before determining the amount of savings, subjects observe the group contribution \( G_t \) even though it is not a choice variable.

As illustrated in the timeline, agents can borrow against their heir’s endowment to help fund their contribution and consumption.\(^2\) This detail is a normalization which captures that debt financing leads to higher taxes being issued on future players for debt repayment. I assume that there is a limit \( \delta w_{it} \) with \( \delta < 1 \) that player \( i \) can attempt to withdraw from her heir’s endowment. This modified public good setting setting becomes

\[
\pi_{it} = \underbrace{w_{it} - b_{it-1} + s_{it-1}}_{\text{Net Starting Endowment}} - \underbrace{(s_{it} - b_{it})}_{\text{Net Savings for Next Gen.}} - g_{it} + \frac{\gamma}{N} \sum_{j=1}^{N} g_{jt} \tag{3}
\]

where \( b_{it} \) and \( s_{it} \) are the amounts borrowed and saved by agent \( i \) in period \( t \), respectively.

\(^2\)I assume there is no population growth in this environment.
3.2 Nash Equilibrium

In this more expanded environment there is a profile of actions which constitute a Nash Equilibrium. This profile is $g^{NE} = 0$, $b^{NE} = \delta w_{it}$, and $s^{NE} = 0$. Note, this strategy severely hurts future generations of agents. Note only do incomes fall by $(1 - \alpha)\theta$ each generation, but endowments are additionally suppressed by $\delta w_{it}$ which falls over time as $w$ does. This baseline of the Nash equilibrium indicates that private transfers between generations (debt and savings) could lead to a collapsing outcome in which all players are worse than those before them. If players, however, have any of a variety of other-regarding preferences, it is not necessarily the case that such devolution to the worst outcome will happen.

3.3 Intragenerational Optimality

Agents who only care about their own generation have no reason to save and every reason to borrow. Each token an agent borrows is one more token that can be invested in the public good; this investment helps every member of her generation. Assuming that her and members of her cohort’s generations consumption is all that enter her utility function (i.e., $U(c_{it}, c_{js})$ for all $t = s$ and $i \neq j$) and that her utility is increasing in the consumption of her peers, then she will choose to borrow all that she can ($b_{it} = \delta w_{it}$) and invest all of it ($g_{it} = (1 + \delta)w_{it}$). Because her utility function does not include future players’ consumption, saving for those agents offer her no benefit and appropriately chooses $s_{it} = 0$.

4 Experimental Design

4.1 Subject Pool

All subjects in my experiments are undergraduate students at Texas A&M University. Members of Texas A&M, known more generally as Aggies, are a unique population on which to conduct a study where other-regarding preferences could matter. This curiosity arises because Aggies, more than most other undergraduates at large institutions, are taught that there is a deep and meaningful connection between each of them; each member chose to be an Aggie and that means something. There are numerous traditions at Texas A&M. To ensure that incoming freshmen know them all, they attend a three day camp where they learn the traditions, how they originated, why they are important, and what their responsibility is to carry them on. Many of these traditions focus on aiding or showing support for other
Aggies. In this way, I believe I can harness the naturally existing connection between the subjects to induce intergenerational preferences, rather than monetarily do so.

4.2 Design

Experiments were conducted in the Economic Research Laboratory at Texas A&M University using undergraduate students who were recruited using ORSEE (Greiner, 2004). Sessions were conducted in the summer of 2013. Sessions had between ten and twenty subjects each and all lasted less than two hours. Experiments were conducted using zTree (Fischbacher, 2007).

Subjects were brought into the lab and assigned a seat. Each seat corresponded to membership to a particular lineage. Once seated, subjects were given a set of instructions detailing the game environment and the structure of their possible actions. Subjects then took a quiz to ensure they understood the structure of the experiment and the outcomes of various actions. The results of the quiz did not influence payments and all subjects were required to answer every question correctly before the experiment would begin. If a subject incorrectly answered a question, a message would appear on her screen explaining why she missed it and what the correct answer was. In this way, I assured that all subjects would have the important aspects of the game reinforced during the quiz. Once all participants answered every question correctly on the quiz and all questions regarding the experiment were answered, subjects proceeded to play the game.

Subjects played the same game with different parameters for ten rounds. One of the rounds would be randomly selected for payment. Each round had multiple stages: debt voting (treatment only), public goods investment, and savings choices. I will discuss each of these stages individually and then how they piece together to determine payment for subjects. For both the control and treatment, subjects were assigned to groups of five. Subjects played the game with tokens; each token was worth twenty cents and was converted to US Dollars at the conclusion of the experimental session.

4.3 Debt Voting Stage (Treatment Only)

Subjects in the treatment had the option to use future players’ tokens for their own investment of consumption. To capture group debt-financing, debt creation and its level are

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3 A copy of the quiz subjects took is available in the Appendix with the instructions.
4 The instructions and quiz regarding the game can be found on my research webpage.
determined by the subjects; they were asked to place a bid to withdraw tokens from a future player’s set of tokens. Each subject submitted the their bid simultaneously knowing that the median bid would be used.\textsuperscript{5} The selected bid was then added to each players tokens. For example, subjects’ bids of 5, 6, 9, 12, and 19 yield 9 as the winning bid and all subjects have nine tokens added to their current available tokens. Correspondingly, future subjects would have nine tokens removed from their starting endowment capturing lump-sum taxes to repay the debt. For simplicity, there is no interest on debt.

Subjects were also given information about past play. I gave subjects this information to see how reciprocity might influence their actions. They were told the amount withdrawn and deposited by previous players as well as those players’ group’s investment in the public good and how it impacted them. The debt limit used for the experiment was 40% of the subject’s starting tokens.

\textbf{4.4 Public Goods Investment}

The next stage (which is the first stage for the control) is the public goods game. Subjects were told their current amount of tokens (net starting plus withdrawals, when applicable).

\textsuperscript{5}Groups can achieve no debt by having three or more members select zero as their debt withdrawal bid.
Once again, subjects could see past play and how it impacted them when making the contribution decision. A subject could invest any amount of tokens she wanted (i.e., zero to her current tokens) into the public good. The intragenerational marginal per capita (MPCR) return on investment was 0.3.\(^6\)

![Figure 2: Screen Shot of Public Goods Investment](image)

The intergenerational MPCR spillover is 0.08 tokens. That is, each token that a subject invested would raise the starting balance of the tokens for each player in the next generation by .08 tokens; the impact from investment in monotonically increasing for the next generations' starting tokens. To capture the idea that there can be insufficient investment in public goods, subjects had a threshold where the spillover would go from negative to positive. For saliency I used fifty percent of starting tokens.\(^7\) Subjects were told that each token under half of the token endowment would lower a future Aggie’s starting tokens by .08 and for each token above their starting tokens would increase by .08 tokens.

All choices were made simultaneously in each of the rounds.

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\(^6\)Subjects were told all tokens invested were multiplied by 1.5 and divided back out equally.

\(^7\)One can think of this as 50% of GDP needs to be invested into this public good to break even on the impact for the next generation. Though that percentage is may be too high, fifty was selected because it is focal and salient.
4.5 Savings Choices

Subjects make savings choices after the public goods game. To ensure that a subject could not update on how selfish or altruistic her group members were, she was given five possible outcomes from the public goods game. One of these outcomes was real and the other four were randomly determined conditional on her contribution. This process has an additional benefit beyond allowing for multiple rounds — it also provides another set of counterfactuals within a subject and a round.

For each possible group contribution amount, subjects were told how it impacted the next group, what their current tokens were at that time, and what the next person’s tokens would be before any deposits to their account. By giving the subjects all of this information I can test if subjects decided to save just enough so that the next generation is no worse off than they were (net impact), if they have a minimum threshold of tokens they wish to keep, or employ other behavioral heuristics.

The random number was drawn uniformly from the range of the subject’s contribution to the maximum possible conditional on her contribution. This technique was implemented to ensure that numbers on the extremes which would obviously be fake were never shown to subjects.

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**Figure 3: Screen Shot of Savings Choices**
5 Results

I find a strong treatment effect; debt negatively impacts the next generation. This result is robust to a variety of empirical controls. Summary statistics can be found in Table 1. Each of the sessions lasted under two hours and was conducted in the Economic Research Laboratory at Texas A&M during the summer of 2013. Average payment was $18.23.\(^9\)

Table 1: Summary Statistics

<table>
<thead>
<tr>
<th></th>
<th>Control: No Debt</th>
<th>Treatment: With Debt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Starting Tokens</td>
<td>50.07</td>
<td>49.73</td>
</tr>
<tr>
<td>Previous Debt</td>
<td>N/A</td>
<td>9.37</td>
</tr>
<tr>
<td>Previous Savings</td>
<td>9.67</td>
<td>9.95</td>
</tr>
<tr>
<td>Tokens Borrowed</td>
<td>N/A</td>
<td>16.1</td>
</tr>
<tr>
<td>Invested Tokens</td>
<td>26.91</td>
<td>28.95</td>
</tr>
<tr>
<td>Tokens Saved</td>
<td>4.4</td>
<td>10.11</td>
</tr>
<tr>
<td>Total Impact on Next Cohort</td>
<td>6.04</td>
<td>-2.07</td>
</tr>
</tbody>
</table>

I find that the availability of debt hurts the next generation, on average, by two tokens whereas the counter-factual control has a positive impact on the next generation of six tokens. Figure 4 highlights this graphically. Additionally, Figure 4 illustrates the average externality from one generation to the next for each of the various channels (debt, savings, spillovers from public goods) for the control and treatment.

From Table 1 and Figure 4, we can see that debt leads to larger positive spillovers from one generation to the next (higher investments and savings). These additional gains, however, are more than offset by the existence of debt. These analysis, though interesting, is cursory; information gleaned from Figure 4 are unconditional on many factors which could alter play. To control for more details I conduct a regression analysis. I now decompose the treatment effect to investigate the channels by which debt is harming the next generation.

\(^9\)The treatment’s average was $18.92 and the control’s was $17.55
5.1 Underinvestment in Public Good

The optimal outcome for both the current and future generation requires that all debt is fully invested in the public good. This action creates the most extra surplus for both the current generation and has the largest positive spillover for the next generation. I conduct a regression analysis to test how different characteristics and sources of income impact a subject’s investment in the public good.\footnote{This analysis is only looking at the Treatment, because they are the only subjects with access to debt.}

Table 3 illustrates the empirical determinants of investment into the public good. The coefficient on debt is less than one and is not statistically significantly different from zero using standard analysis.\footnote{Using a one-tailed test, one could argue that it is statistically different at the $\alpha = .1$ level.} I feel this is strong evidence that many subjects are not optimally investing the debt they borrow. This behavior leads to smaller group earnings for their group and the future group which plays after them.
Table 2: Regressions on Total Change in Tokens for Next Generation

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Debt</td>
<td>-8.111***</td>
<td>-8.273***</td>
<td>-7.862***</td>
<td>-7.858***</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Starting Tokens</td>
<td>0.0685</td>
<td>0.0558</td>
<td>0.0577</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.089)</td>
<td>(0.122)</td>
<td>(0.108)</td>
<td></td>
</tr>
<tr>
<td>Previous PG Impact</td>
<td>-0.292***</td>
<td>-0.285***</td>
<td>-0.296***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>0.739</td>
<td>0.735</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.664)</td>
<td>(0.666)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>-1.453</td>
<td>-1.456</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.457)</td>
<td>(0.456)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Econ Major</td>
<td>-2.720</td>
<td>-2.728</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.196)</td>
<td>(0.195)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subjects</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Rounds</td>
<td>10</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Round Dummies</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Additional Demographics</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>adj. $R^2$</td>
<td>0.086</td>
<td>0.107</td>
<td>0.151</td>
<td>0.161</td>
</tr>
</tbody>
</table>

$p$-values in parentheses, Clustered by Subject

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Table 3: Determinants of Tokens Invested in the Public Good

<table>
<thead>
<tr>
<th></th>
<th>First Group</th>
<th>Second Group</th>
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</thead>
<tbody>
<tr>
<td>Debt</td>
<td>0.632</td>
<td>0.633</td>
</tr>
<tr>
<td></td>
<td>(0.159)</td>
<td>(0.174)</td>
</tr>
<tr>
<td>Net Starting Tokens</td>
<td>0.432**</td>
<td>0.460**</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
<td>(0.008)</td>
</tr>
<tr>
<td>Female</td>
<td>0.587</td>
<td>0.750</td>
</tr>
<tr>
<td></td>
<td>(0.935)</td>
<td>(0.917)</td>
</tr>
<tr>
<td>Caucasian</td>
<td>3.277</td>
<td>3.225</td>
</tr>
<tr>
<td></td>
<td>(0.680)</td>
<td>(0.690)</td>
</tr>
<tr>
<td>Voter</td>
<td>3.999</td>
<td>4.062</td>
</tr>
<tr>
<td></td>
<td>(0.565)</td>
<td>(0.565)</td>
</tr>
<tr>
<td>Econ Major</td>
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<td>8.982</td>
</tr>
<tr>
<td></td>
<td>(0.425)</td>
<td>(0.438)</td>
</tr>
<tr>
<td>Texan</td>
<td>3.535</td>
<td>3.683</td>
</tr>
<tr>
<td></td>
<td>(0.640)</td>
<td>(0.634)</td>
</tr>
<tr>
<td>CRT Fail</td>
<td>-2.931</td>
<td>-2.965</td>
</tr>
<tr>
<td></td>
<td>(0.713)</td>
<td>(0.714)</td>
</tr>
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<table>
<thead>
<tr>
<th></th>
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<tr>
<td>Subjects</td>
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<td>30</td>
</tr>
<tr>
<td>Rounds</td>
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<td>10</td>
</tr>
<tr>
<td>Round Dummies</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>adj. $R^2$</td>
<td>0.190</td>
<td>0.175</td>
</tr>
</tbody>
</table>

p-values in parentheses, Clustered by Subject

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5.2 Insufficient Savings

Dynamic optimal play also requires that subjects save to offset the next generation’s debt repayment burden. This is related to the notion of Ricardian equivalence. Barro (1974). Ricardian equivalence states that individuals are save for their children to offset the debt burden they will face. Barro uses dynastic preferences to in an overlapping generations model to show how this result would occur. Specifically, parents care about their children; those children in turn care about their own children. These dynastic preferences lead parents to save for their progeny. Parents do not want their children’s livelihood to be significantly worsened by debt-repayment because it would hurt themselves. To avoid this they save exactly equal to the debt repayment.

I find savings to be significantly less than this prediction. Figure 5 shows the empirical distribution of savings to debt and the Ricardian prediction. The large under-savings are the principal reason the next generation is negatively impacted with debt.
6 Discussion

Many public goods are not static in their returns; often the impact in these types of investments, especially large scale ones, have impacts which span generations. I create a laboratory experiment to test if different methods of financing the public good can impact the welfare of agents dynamically. I observe two, at first, contradictory findings. The ability to borrow leads higher natural endowments for the next generation through higher contributions and corresponding spillovers. When debt is available, the next generation, however, has a lower net endowment (endowment plus savings minus debt repayment) than the generation before them. This lower endowment occurs because the debt repayment is higher than the gains from the previous generation’s investment in the public good. The failings of using debt to finance the public goods comes from two separate avenues. Subjects both under invest the debt they get and do not sufficiently save to offset the debt repayment of the future players.
This paper is one of the first articles which investigates the a potential second-order effect of a group decision on another group. To my knowledge, this is the first paper which experimental investigates the dynamic impact of public goods in an infinite generations setting in which each generation lives, and therefore plays only once. Given my results, there are a set of possible extensions which I think are worthwhile. One is varying the marginal returns per capita, both for the current and future players. It is well established within the public economics literature that the higher the MPCR is, the more contributions will be given to the group account. We can test this robustness, even to players outside the room (future generations). Additionally, I would like to vary the debt limit. Currently, I have used forty percent of current endowments. By varying the debt limit I can answer the understand the relation between debt limits and damages from debt; perhaps damage is not monotonically increasing in debt availability. Lastly, I would like to see a condition where subjects were tied to use their borrowing for the public good. In general I feel that, though the literature on experimental public goods papers is voluminous, there is more that can be added when considering the second-order effects of investments such as this paper does.
References


Appendix – Additional Graphs

Additional Figures representing the data.

![Kernel-weighted Polynomial Estimation](image1)

![Testing Ricardian Equivalence](image2)
Kernel-weighted Polynomial Estimation

Net Change in Tokens vs. Net Starting Tokens

- Treatment -- Real Outcomes
- Treatment -- Randomly Generated Outcomes

kernel = epanechnikov, degree = 0, bandwidth = 4.47

Kernel-weighted Polynomial Estimation

Net Change in Tokens vs. Net Starting Tokens

- Control -- Real Outcomes
- Control -- Randomly Generated Outcomes

kernel = epanechnikov, degree = 0, bandwidth = 5.08
Appendix – Experimental Instructions and Quiz

All instructions were conducted using zTree Fischbacher (2007) and were read aloud to the subjects. For convenience, I include the text from the zTree program instead of a set of screen captures.

Instructions for Debt Treatment

Today you will be participating in an economics laboratory experiment. Please pay attention to these instructions so that you will understand how you can earn money. Do not look at other people’s work. Please do not talk, laugh, exclaim aloud, etc. Doing so will result in removal from the experiment and you will not be paid.

If you have any questions, please raise your hand, and the experimenter will quietly answer your question.

You have been randomly assigned to be a member of a group. Each group consists of five members. Your group is connected to a set of other groups who have played the game before you and some who may play after you. You, along with the four other members of your group will make a set of decisions. These choices will influence your earnings and may impact a future set of Aggies. Likewise a previous group’s choices could have impacted your endowment for the game and potential income.

Outline of the Session

You will participate in 10 rounds of the same game. Each round you are assigned to a group. Each round may have different starting values. One round will be selected for payment. That round’s position in the ten rounds (second, ninth, etc.) is randomly determined. Because any one round may be selected, you should play each round as best as you can.

Each round will consist of three phases which we will discuss in depth.

- Group Withdrawal Bidding Stage
- Investment Decision Stage
- Deposit Allocations Stage

In every round you will be given information, when applicable, about past players’ actions and how those actions impacted your current token amount. For instance, you will be told:

- Previous group’s tokens withdrawn from your starting balance.
- How much the previous group invested in Account A and how it impacted your starting tokens.
- Previous player’s deposit of tokens back into your starting balance.
In rounds that are not used for payment, this information may be randomly generated. Remember, you do not know which round will be used for payment, so it is in your best interest to make your best choices given the information in each of the rounds. The information will be displayed in a table for you to help you make any choices. Remember, not only did a past group (when applicable) impact your position, but your choices may impact a future group of students as well.

**Group Withdrawal Bidding Stage**

In every round the first decision you are asked to make is how much you wish to bid to withdraw from future students who will play this game. You, and everyone in your group will input a number of tokens you wish to withdraw.

The middle bid of the five submitted is the selected bid. For instance, if the five bids are: 3, 5, 8, 10, and 19 then 8 is the middle, and therefore, is the selected bid. The amount of the winning bid is added to everyone’s token account. So, if you had X tokens before, now you will have X + 8 tokens in the above example. This is regardless of if you bid 8 or a different value. All group members get the middle bid added to their account and this withdrawal is taken from a future group’s tokens.

**Investment Decision Stage**

After withdrawal decisions are made, your current amount of tokens will be updated. You and your group members will play an investment game with these tokens.

You will be able to invest any amount of your current tokens (including withdrawals) into an investment called Account A. Investments in Account A work in the following way: Each token from any group member in Account A is multiplied by 1.5 and divided out equally to all members in your group. Any token you choose to not invest is kept.

Additionally, your investment choice not only impacts you and the people in your group, but it impacts the next group of students who will play this game. For each token in Account A under half of starting tokens, future students will start with .08 less tokens. Investments over half of total beginning tokens result in an increase of .08 for each token for the future students playing after you.

**Deposit Allocation Stage**

After you make you and your group make your investment decisions, you will be asked if you would like to deposit any tokens to a future player who will play after you. This future play will be impacted already by the group’s withdrawal and investment choices.

You will be given five withdrawal choices to make based on the possible outcomes of the group’s investment choices. One of these values is the actual one your group made and the other four are randomly generated values. When a round is selected for play, the real investment and savings choice will be paid. Because you do not know which is real and
which are randomly generated, it is in your best interest to treat each as if it could be real in case it were to be selected for payment.

Any tokens you do not deposit for a future player are kept by you and will be used to determine the cash you earn at the end of the session. The next slide discusses how tokens are converted to cash.

Cash Payment = .20 * Tokens Remaining — Each token is worth twenty cents.

Summary

One round of the ten is randomly selected for payment. You will paid based on the tokens you have remaining in your account. Your choices in one round do not impact the value of later round tokens for you or your group – Each round is independent. To recap:

- You will start with a set of tokens which may have been impacted by previous players.
- You and your group bid to withdraw tokens from future players not in the room. The middle bid wins and all players in your group get that many tokens added to their tokens (and taken from the future students’ tokens).
- You may then make an investment into Account A. The amount invested by any member is the group is multiplied by 1.5 and divided back out equally between all group members.
- Your investment in Account A impacts the next group of students’ tokens as well. Investments under half the starting tokens lower their tokens and investments over half increase the tokens of those Aggies.
- You will make a set of Deposit choices. One is real and the others are random. The tokens you don’t deposit for the next student are kept by you.
- There is a 60% chance that a future set of Aggies plays after you.

Instructions – Debt-Free Baseline

Today you will be participating in an economics laboratory experiment. Please pay attention to these instructions so that you will understand how you can earn money. Do not look at other people’s work. Please do not talk, laugh, exclaim aloud, etc. Doing so will result in removal from the experiment and you will not be paid.

If you have any questions, please raise your hand, and the experimenter will quietly answer your question.

You have been randomly assigned to be a member of a group. Each group consists of five members. Your group is connected to a set of other groups who have played the game before you and some who may play after you. You, along with the four other members of your group will make a set of decisions. These choices will influence your earnings and may
impact a future set of Aggies. Likewise a previous group’s choices could have impacted your endowment for the game and potential income.

Outline of the Session

You will participate in 10 rounds of the same game. Each round you are assigned to a group. Each round may have different starting values. One round will be selected for payment. That round’s position in the ten rounds (second, ninth, etc.) is randomly determined. Because any one round may be selected, you should play each round as best as you can.

Each round will consist of three phases which we will discuss in depth.

- Investment Decision Stage
- Deposit Allocations Stage

In every round you will be given information, when applicable, about past players’ actions and how those actions impacted your current token amount. For instance, you will be told:

- How much the previous group invested in Account A and how it impacted your starting tokens.
- Previous player’s deposit of tokens into your starting balance.

In rounds that are not used for payment, this information may be randomly generated. Remember, you do not know which round will be used for payment, so it is in your best interest to make your best choices given the information in each of the rounds. The information will be displayed in a table for you to help you make any choices. Remember, not only did a past group (when applicable) impact your position, but your choices may impact a future group of students as well.

Investment Decision Stage

You and your group members will play an investment game with your available tokens.

You will be able to invest any amount of your current tokens into an investment called Account A. Investments in Account A work in the following way: Each token from any group member in Account A is multiplied by 1.5 and divided out equally to all members in your group. Any token you choose to not invest is kept.

Additionally, your investment choice not only impacts you and the people in your group, but it impacts the next group of students who will play this game. For each token in Account A under half of starting tokens, future students will start with .08 less tokens. Investments over half of total beginning tokens result in an increase of .08 for each token for the future students playing after you.
Deposit Allocation Stage

After you make you and your group make your investment decisions, you will be asked if you would like to deposit any tokens to a future player who will play after you. This future play will be impacted already by the group’s withdrawal and investment choices.

You will be given five withdrawal choices to make based on the possible outcomes of the group’s investment choices. One of these values is the actual one your group made and the other four are randomly generated values. When a round is selected for play, the real investment and savings choice will be paid. Because you do not know which is real and which are randomly generated, it is in your best interest to treat each as if it could be real in case it were to be selected for payment.

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- You will start with a set of tokens which may have been impacted by previous players.

- You may then make an investment into Account A. The amount invested by any member is the group is multiplied by 1.5 and divided back out equally between all group members.

- Your investment in Account A impacts the next group of students’ tokens as well. Investments under half the starting tokens lower their tokens and investments over half increase the tokens of those Aggies.

- You will make a set of Deposit choices. One is real and the others are random. The tokens you don’t deposit for the next student are kept by you.

- There is a 60% chance that a future set of Aggies plays after you.