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# Experimental tests of Ricardian equivalence with distortionary versus nondistortionary taxes

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## Abstract

Previous experimental work has examined the effects of relaxing some assumptions upon which Ricardian equivalence is based. Notably, however, the impact of distortionary taxation on Ricardian equivalence has not been investigated. This paper tests the effects of distortionary versus nondistortionary taxation. Distortionary taxes are introduced in some settings by levying a “tax” on savings, so that one unit of savings does not lead to one unit of future consumption. We find that, in the presence of nondistorting (e.g., lumpsum) taxes, there is strong evidence that subjects behave according to the predictions of Ricardian equivalence; that is, an increase in debt on one generation leads to an increase in bequests to the future generation by an equal amount. However, in the presence of distorting taxes, consumption is not equalized across periods, and the predicted Ricardian equality between the change in bequests and the change in debt is not attained.

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## 1. Introduction

The effects of deficit spending on the economy remain controversial and unresolved. As summarized by Bernheim (1989) and Seater (1993), the "Neoclassical view" predicts that deficit spending will increase the interest rate and crowd out private investment, so that the burden of government bonds issued in the current period will be shifted at least partially to future generations. In contrast, the "Ricardian view" arises largely from the work of Barro (1974), who argues that this shifting of the burden of debt from current to future generations will not in fact happen. Knowing that debt will have to be repaid by their children, altruistic bondholders will not regard government debt as net wealth and will not increase their consumption in response to the use of debt rather than tax finance. Instead, they will increase their savings in anticipation of the increase in future taxation (on their children, or their children's children) needed to service the debt. In this view, tax and debt finance are equivalent, a proposition referred to as "Ricardian equivalence", after David Ricardo who first suggested this equivalence two hundred years ago.[1]

The assumptions necessary for Ricardian equivalence to hold in theory are quite restrictive: perfect capital markets, infinite horizons, certainty of future income, intergenerationally linked households, and nondistortionary taxation. If these assumptions hold, then Barro (1974) shows that rational agents will use voluntary intergenerational transfers to offset the burden of government debt that will be borne by future generations.

Following upon this theoretical literature and its conflicting predictions, an enormous empirical literature has emerged to test these predictions, with largely ambiguous results.[2] In part because of the difficulties of empirical work, there has been some interest in using experimental methods to examine the effects of deficit spending, notably the work of Cadsby and Frank (1991), Slate et al. (1995), and Ricciuti and Di Laurea (2003).[3] Experimental methods have the advantage of allowing a more direct test of behavioral assumptions and responses, an especially important advantage given that the effects of government financing policy depend on individuals' behaviors: whether individuals recognize intertemporal tradeoffs, whether they recognize any increase in future debt repayment liabilities, whether they are altruistic, whether they will actually bestow intergenerational transfers, and so on. These issues can perhaps best be investigated in a laboratory setting. Indeed, recent surveys by Ricciuti (2008) and Duffy (2009) argue compellingly for the application of experimental methods to macroeconomic issues such as Ricardian equivalence.

Previous experimental work has examined the effects of some of the main predictions of Ricardian equivalence, including the effects of relaxing some of the assumptions upon which Ricardian equivalence is based (e.g., uncertainty, imperfect capital markets). Notably, however, the impact of distortionary taxation on Ricardian equivalence has not been investigated. Given the prevalence–indeed, the dominance–of this type of taxation in the real-world tax systems of all nations, this is a notable omission. Barro himself (1996) believed that the most important theoretical objection to Ricardian equivalence was the distorting nature of real world taxes.[4] We therefore examine the effects of distortionary

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[1] A third view of deficits, the so-called "Keynesian view", assumes underemployment and predicts expansionary–and positive–effects of deficit spending. In this view, if individuals treat deficit spending as an increase in disposable income (or wealth), then individuals will raise their consumption, which in turn will increase aggregate demand and thereby reduce unemployment.

[2] See Seater (1993) and, more recently, Ricciuti (2003) for comprehensive surveys of much of this literature.

[3] For some related experimental work on intergenerational transfers (both public and private), see also van der Heijden, Nelissen, Potters, and Verbon (1997, 1998), Offerman, Potters, and Verbon (2001), and Guth, Offerman, Potters, Strobel, and Verbon (2002).

[4] Also, Abel (1986) argues that distortionary taxes (e.g., progressive wealth taxes) lead to the failure of Ricardian equivalence. In contrast, Trostel (1993) demonstrates that a non-linear tax on labor income does not necessarily generate failure.

taxation on the standard predictions of Ricardian equivalence. We find that, while the Ricardian view largely holds in the presence of nondistortionary taxes, the existence of a distortionary tax on savings generates behavior inconsistent with Ricardian equivalence and more consistent with the Neoclassical view of debt.

The rest of this paper is organized as follows. Section 2 summarizes the literature review. Section 3 describes the experimental design, the hypotheses, and the numerical predictions. Section 4 presents the analysis, and Section 5 concludes.

## 2. Previous Experimental Work

Cadsby and Frank (1991) were the first to examine Ricardian equivalence in the laboratory. In their experimental design, they assumed that the well-being of "children" entered into the utility function of the "parent", so that a parent's utility depended upon the utilities of all current–or future–descendants. Parents received government debt, which created an obligation for them or their children. Since current and succeeding generations must either pay interest on the debt or retire the debt, the issuance of debt should, according to Ricardian equivalence, affect the generation alive when the debt is issued via the intergenerational utility function. Indeed, a strict interpretation of Ricardian equivalence predicts that the current generation would save the full debt amount as a bequest for its heirs. Cadsby and Frank (1991) found that, when the equilibrium solution of intergenerational transfers was greater than zero, individuals' decisions showed a Ricardian pattern, with the parents saving close to the full amount of the debt. However, when agents were myopic (e.g., when the intergenerational linkage was weakened), a change in debt was not fully offset by a change in transfers, suggesting the Neoclassical prediction.

Slate et al. (1995) tested Ricardian equivalence under uncertainty about the likelihood of repayment. Within the same basic Cadsby and Frank (1991) framework, they relaxed the assumption of certainty on future income by setting the probability of government bonds retirement as 20 percent, 40 percent, 80 percent, and 100 percent. Their results showed that, as the probability of retirement increases, intergenerational transfers increased, as predicted by Ricardian equivalence. However, an increase in consumption occurred when the probability of bonds retirement is low, confirming the Neoclassical prediction.

Ricciuti and Di Laurea (2003) examined Ricardian equivalence under the presence of liquidity constraints and uncertainty. Again utilizing the Cadsby and Frank (1991) setting, Ricciuti and Di Laurea (2003) allowed the relaxation of the perfect capital market assumption in one treatment and the assumption of certainty on the current generation's income in another treatment. In their baseline treatment where the environment is set to represent the Ricardian economy (e.g., no liquidity constraints, no uncertainty), their results supported the Ricardian prediction, in that individuals equated consumption allocations over periods. However, in the liquidity constraint treatment, individuals no longer equated consumption across periods, although partial support for the Ricardian prediction was still found. In their uncertainty treatment, their results provided no evidence for Ricardian equivalence.

These three experimental studies focused on relaxing the Ricardian equivalence assumptions of perfect capital markets, perfect foresight, and certainty of future income. However, no studies have examined the effect of distortionary taxes on the prevalence of Ricardian equivalence. Our study focuses on this important issue. In particular, our experimental design compares the effects on savings and consumption of a baseline treatment with a nondistortionary tax versus the effects of a distortionary tax, using the standard overlapping generation setting in which the utility of the future generation enters the utility of the current generation. The next section discusses in detail our experimental design and the associated hypotheses.

## 3. Experimental Design and Hypotheses

3.1. Experimental Design

Following Cadsby and Frank (1991), Slate et al. (1995), and Ricciuti and Di Laurea (2003), our experimental design uses an intergenerational utility function in an overlapping generations setting. Two groups of subjects, the older generation and the younger generation, represent the overlapping generations. The older generation's utility function depends on the younger generation's utility, creating the standard intergenerational linkage; that is, the inclusion of the younger generation's utility in the older generation's utility captures the altruism motive of the older generation, creating an operative linkage between generations, as illustrated by Barro (1974).

Our experiment consists of two treatments. A baseline treatment conforms to the key assumptions underlying Ricardian equivalence (e.g., a lumpsum or nondistortionary tax). In a savings tax (or distortionary tax) treatment, a tax on savings/bequests is introduced, in which one unit of savings does not generate one unit of future income. Ricardian equivalence is predicted to hold in our baseline treatment, while Ricardian equivalence is predicted to fail in the presence of a distortionary tax on savings. Each subject experiences both treatments (i.e., a within-subject design). We vary the order of the treatments in order to control for potential order effects, so that half the subjects first face the baseline treatment followed by the savings tax treatment, and half the subjects face the treatments in the opposite order.

The baseline treatment consists of 12 "rounds", and the savings tax treatment consists of 18 "rounds"; after every 6 rounds, the set of parameter values changes. Within each round are 3 "periods". The older generation lives in period 1 and period 2, while the younger generation lives in period 2 and period 3. At the beginning of period 1, the computer displays private information with the various parameter values, all of which remain the same for the 3 periods of the round. At the end of period 3, the computer displays the scores, and then a new round begins. There is no linkage across the rounds. In each session, 6 practice rounds are conducted to give subjects an opportunity to learn. After the instructions are read, the subjects (or "players") are allowed to ask questions, and practice questions are administered to ensure that subjects understand the experiment. The full experiment then begins.[5]

The subjects are randomly divided into two groups, called Group A and Group B. Each subject is in the same group throughout the experiment. Each subject from Group A is randomly paired with another subject from Group B. This pairing changes in every round, so that each subject is not paired with the same person in two consecutive rounds and is not paired with the same person more than twice in a session/treatment. The currency used throughout the experiment is "franks". At the end of the experiment, the franks that the subjects earn are converted into U.S. dollars at the following exchange rates: 1 frank = 0.00000025 U.S. dollar when a subject is in Group A, and 1 frank = 0.0005 U.S. dollar when a subject is a member of Group B. The exchange rates between subjects in Group A and subjects in Group B differ so that earnings will be similar for subjects who make payoff-maximizing decisions.

Subjects in Group A play the "older" generation, referred to as the "Giver"; subjects in Group B play the "younger" generation (the "Receiver"). The Giver receives an endowment (or an income) of $\omega_{G1}$ franks at the beginning of period 1, from which he/she has to decide how much to allocate for consumption $C_{G1}$ and how much to allocate for savings $S_{G1}$. Savings that are made in period 1 are carried over to period 2. The Giver also receives an extra endowment, or "loan", of $\omega_{G2}$ franks at the beginning of period 2, at which point the Giver again has to decide how much to allocate for consumption $C_{G2}$ and how much to allocate for savings $S_{G2}$. The extra endowment is effectively a transfer payment to the Giver

[5] The instructions are given in the Appendix.

that can be viewed as being financed by debt issuance, with the debt retired after the Giver's lifetime; that is, the government debt has to be repaid by the descendants (the Receiver) at the beginning of period 3. The savings of the Giver in period 2 are given to his/her descendant as a bequest at the beginning of period 3.

Subjects in Group B are the younger generation. The Receiver is given an endowment (or income) of $\omega_{R2}$ franks at the beginning of period 2. The Receiver must decide how much of the endowment to allocate for consumption $C_{R2}$ and how much to allocate for savings $S_{R2}$ in period 2, with savings that are made in period 2 carried over to period 3. At the beginning of period 3, the Receiver receives a bequest from the Giver, in the form of saving that the Giver has made in period 2; also, at the beginning of period 3 the extra endowment given to the Giver in period 2 is subtracted from the available funds of the Receiver. If the Receiver is not able to pay back the government debt, then his/her score is set to zero. In period 3, the Receiver has no decision to make: all available funds must be allocated for consumption $C_{R3}$. Throughout, the subjects are constrained by non-negativity values both on consumption and savings allocations.

Our design uses the simple multiplicative utility function used by Cadsby and Frank (1991), Slate et al. (1995), and Ricciuti and Di Laurea (2003). Cadsby and Frank (1991) tested several other functional forms, and concluded that the multiplicative form was quite punitive to deviations from the theoretical predictions, so that it generated less noisy behavior than other utility functions. More precisely, with this utility function the score (or "utility") of the Giver $U_G$ is assumed to be a multiplicative function of his/her consumption in period 1, his/her consumption in period 2, and the Receiver's score, adjusted by a scaling factor. The Receiver's score $U_R$ is also assumed to be a multiplicative function of his/her consumption in period 2 and his/her consumption in period 3 (again adjusted by a scaling factor). For simplicity, both the rate of interest and the discount rate are assumed to be zero. The payoff to the Giver is given by $U_G = C_{G1} * C_{G2} * C_{R2} * C_{R3} * 0.00000025$, and the Receiver gets the payoff $U_R = C_{R2} * C_{R3} * 0.0005$, where (0.00000025, 0.0005) are the scaling factors, designed to ensure comparability of final payoffs.[6]

The baseline treatment consists of 12 three-period rounds with a nondistortionary tax. In all rounds of the baseline treatment, the Giver's initial period 1 endowment $\omega_{G1}$ is 100 franks. The Giver's extra endowment (e.g., "loan" or "debt") of $\omega_{G2}$ franks at the beginning of period 2 is 50 franks in rounds 1-6 of the baseline treatment, and in rounds 7-12 the loan amount is doubled to 100 franks in order to test the comparative static predictions of the theory (as discussed in the next sub-section). The distortionary or savings tax treatment consists of 18 rounds all of which impose a distortionary tax on savings; that is, a "tax" ($t$) is imposed that decreases the savings amount from $S$ to $S(1 - t)$, so that one frank of savings does not generate one frank of future consumption. In rounds 1-6 of the savings tax treatment, there is again a loan provided to the Giver ($\omega_{G2}$ = 50 franks), and there is also a tax on savings of 25 percent; the loan is doubled in rounds 7-12 ($\omega_{G2}$ = 100 franks), and the savings tax remains the same; in rounds 13-18 the tax rate on savings increases to 50 percent, and the loan remains unchanged. (Note that the Giver's initial period 1 endowment $\omega_{G1}$ is always 100 franks in the savings tax treatment. Note also that the Receiver's endowment $\omega_{R2}$ is always 100 franks, in either the baseline or the savings tax treatments.)

The parameter values are summarized in Tables 1 and 2. The experiment was programmed and conducted using software z-Tree (Fischbacher 1999). We built our code

[6] As demonstrated by Cadsby and Frank (1991), a multiplicative utility function generates especially strong incentives for giving that equalizes consumption across periods and across generations because the failure to equalize consumption is severely punished. Indeed, in the event that consumption in any period by any agent is zero, a multiplicative utility function leads to zero utility, both for the Giver and for the Receiver.

based on the code created by Ricciuti and Di Laurea (2003), and we used many of the experimental parameters of Slate et al. (1995).[7]

Thirty-two subjects, drawn from a subject pool maintained by the Experimental Economics Center at Georgia State University, participated in the experiment. The subjects were undergraduate students with various majors, and most students had taken 2-3 economic courses. After the experiments, the subjects were asked to fill out an anonymous questionnaire about basic demographic information and about what factors motivated their decisions. The subjects were paid in private in cash at the end of the experiment. Each session lasted for roughly two hours, and each subject earned on average 24.17 U.S. dollars. The subjects' payments were funded by Faculty of Economics and Business, Universitas Gadjah Mada, Yogyakarta, Indonesia.

3.2. Hypotheses

The design of the experiment requires the older generation to move first. In making his/her decision, the Giver needs to take into account the decision that the Receiver will make. Assuming agents are farsighted and rational, the objective function of the Receiver's problem is given by:

$$\underset{S_{R2}}{\ell} = C_{R2}C_{R3} = (\omega_{R2} - S_{R2})(S_{G2} + S_{R2} - \omega_{G2}), \tag{1}$$

which is maximized subject to the constraints that $C_{R2} > 0$ and $C_{R3} > 0$. The savings function of the Receiver, or the reaction function $S_{R2}$, is:

$$S_{R2} = \tfrac{1}{2}(\omega_{G2} + \omega_{R2} - S_{G2}), \tag{2}$$

which allows the consumption allocations $C_{R2}$ and $C_{R3}$ to be determined. The Giver then incorporates the reaction function of the Receiver, so that the objective function of the Giver's problem is given by:

$$\begin{aligned}\underset{S_{G1},S_{G2}}{\ell} &= C_{G1}C_{G2}C_{R2}C_{R3} = (\omega_{G1} - S_{G1})(\omega_{G2} + S_{G1} - S_{G2}) \\ &\tfrac{1}{2}(\omega_{R2} - \omega_{G2} + S_{G2})\tfrac{1}{2}(S_{G2} - \omega_{G2} + \omega_{R2})\end{aligned} \tag{3}$$

which is maximized subject to the constraints that $C_{G1} > 0$, $C_{G2} > 0$, $C_{R2} > 0$, and $C_{R3} > 0$.[8] By differentiating and substituting, the Giver's savings functions are obtained:

$$S_{G1} = \tfrac{3}{4}\omega_{G1} - \tfrac{1}{4}\omega_{R2} \tag{4}$$

$$S_{G2} = \tfrac{1}{2}(\omega_{G1} + 2\omega_{G2} - \omega_{R2}), \tag{5}$$

and from these savings functions the consumption allocations can be shown to be:

$$C_{R2} = C_{R3} = \tfrac{1}{4}(\omega_{G1} + \omega_{R2}) = C_{G1} = C_{G2}, \tag{6}$$

so that consumption is equated across periods and across individuals.

The issuance of government debt that has to be repaid by the descendants of the bond holders will have no impact on consumption in this setting. Consumption will stay constant because bond holders will not regard the debt as net wealth (Barro 1974). Instead of increasing consumption, bond holders will increase savings, thereby bequeathing the full amount of the extra endowment to their descendants. The Receiver's and the Giver's payoffs become, $U_R = [\tfrac{1}{4}(\omega_{G1} + \omega_{R2})]^2$ and $U_G = [\tfrac{1}{4}(\omega_{G1} + \omega_{R2})]^4$, respectively. The effect of deficit

[7] We are indebted to Roberto Ricciuti for the provision of his experimental code upon which our code was developed. We are also indebted to Krawee Ackaramongkolrotn, Senior Research Associate at the Experimental Center Georgia State University for his help on the programming.

[8] The Giver also faces the additional constraints that saving cannot exceed income in any period, or $S_{G1} < \omega_{G1}$ and $S_{G2} < \omega_{G2} + S_{G1}$.

spending on the Giver's bequest can easily be shown to equal $\frac{\partial S_{G2}}{\partial \omega_{G2}} = 1$. In this case, the change in deficit spending equals the change in the bequest, and there is a one-to-one correspondence between debt and bequests.

However, when savings taxes are levied at rate $t$, the Receiver's objective function becomes:

$$\underset{S_{R2}}{\ell} = C_{R2}C_{R3} = (\omega_{R2} - S_{R2})(S_{G2}(1-t) + S_{R2}(1-t) - \omega_{G2}), \tag{7}$$

which is maximized subject to the nonnegativity constraints $C_{R2} > 0$ and $C_{R3} > 0$. The Receiver's reaction function under savings taxes now becomes:

$$S_{R2} = \tfrac{1}{2}\left[\omega_{R2} + \frac{\omega_{G2}}{1-t} - S_{G2}\right]. \tag{8}$$

Consequently, under distortionary savings taxes, the Receiver will no longer equate consumption across periods, but will decrease consumption from period 2 to period 3 by (1 – $t$), or

$$C_{R2} = \tfrac{1}{2}\left(\omega_{R2} + S_{G2} - \frac{\omega_{G2}}{1-t}\right) \tag{9}$$

$$C_{R3} = \tfrac{1}{2}(1-t)\left[\omega_{R2} + S_{G2} - \frac{\omega_{G2}}{1-t}\right]. \tag{10}$$

The objective function of the Giver now becomes:

$$\underset{S_{G1},S_{G2}}{\ell} = C_{G1}C_{G2}C_{R2}C_{R3}$$

$$= \tfrac{1}{4}(1-t)(\omega_{G1} - S_{G1})(\omega_{G2} + S_{G1}(1-t) - S_{G2})\left(\omega_{R2} + S_{G2} - \frac{\omega_{G2}}{1-t}\right)^2, \tag{11}$$

which is maximized subject to $C_{G1} > 0$, $C_{G2} > 0$, $C_{R2} > 0$, and $C_{R3} > 0$.[9] The Giver's savings functions are:

$$S_{G1} = \tfrac{3}{4}\omega_{G1} - \tfrac{1}{4}\frac{\omega_{R2}}{1-t} + \tfrac{1}{4}\frac{\omega_{G2}}{1-t}\left(\frac{t}{1-t}\right) \tag{12}$$

$$S_{G2} = \tfrac{1}{2}\left[\omega_{G1}(1-t) - \omega_{R2} + \omega_{G2}\left(\frac{1}{1-t} + 1\right)\right] = \tfrac{1}{2}\left[\omega_{G1}(1-t) - \omega_{R2} + \omega_{G2}\left(\frac{2-t}{1-t}\right)\right]. \tag{13}$$

The Giver's equilibrium consumption allocations are:

$$C_{G1} = \tfrac{1}{4}\left(\omega_{G1} + \frac{\omega_{R2}}{1-t} - \omega_{G2}\left(\frac{t}{(1-t)^2}\right)\right) \tag{14}$$

$$C_{G2} = \tfrac{1}{4}(1-t)\left(\omega_{G1} + \frac{\omega_{R2}}{1-t} - \omega_{G2}\left(\frac{t}{(1-t)^2}\right)\right). \tag{15}$$

Substituting the Giver's bequest function into equations (9) and (10), the Receiver's equilibrium consumption allocations become:

$$C_{R2} = \tfrac{1}{4}(1-t)\left(\omega_{G1} + \frac{\omega_{R2}}{1-t} - \omega_{G2}\left(\frac{t}{(1-t)^2}\right)\right) = C_{G2} \tag{16}$$

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[9] Again, there are the additional constraints on the Giver that saving cannot exceed income in any period, or $S_{G1} < \omega_{G1}$ and $S_{G2} < \omega_{G2} + S_{G1}(1\text{-}t)$.

$$C_{R3} = \tfrac{1}{4}(1-t)^2\left[\omega_{G1} + \frac{\omega_{R2}}{1-t} - \omega_{G2}\left(\frac{t}{(1-t)^2}\right)\right]. \tag{17}$$

With a savings tax, agents decrease their consumption expenditures by (1- $t$). Consumption of the Giver in period 2 will be equivalent to consumption of the Receiver in period 2, which is less than consumption of the Giver in period 1 by the amount of taxes. Similarly, consumption of the Receiver in period 3 is less than consumption of the Receiver in period 2 by the amount of taxes. Distortionary taxes therefore give a different result than the one under no taxes, and the one-to-one relationship between changes in debt and changes in bequests disappears in the presence of savings taxes.

Note also that the effect of a change in the distortionary tax on the Giver's period 2 savings is in general ambiguous; that is, $\frac{\partial S_{G2}}{\partial t} = -\tfrac{1}{2}\omega_{G1} + \tfrac{1}{2}\omega_{G2}(1-t)^{-2}$, which is greater than 0 if $\omega_{G1} > \omega_{G2}(1-t)^{-2}$, less than 0 if $\omega_{G1} < \omega_{G2}(1-t)^{-2}$, and equal to 0 if $\omega_{G1} = \omega_{G2}(1-t)^{-2}$.[10] However, when the Giver's endowments are equal (or $\omega_{G1}$=$\omega_{G2}$), then an increase in the tax rate will always increase the Giver's period 2 savings: the higher tax rate increases the relative size of the period 2 endowment (since period 1 savings are taxed), and the Giver responds by increasing period 2 savings. Even when $\omega_{G1}$>$\omega_{G2}$, there exists a high enough tax rate such that an increased tax rate will make the relative size of the period 2 endowment higher than the period 1 endowment, which again means that the Giver's period 2 savings will increase.[11]

In sum, under Ricardian equivalence with nondistortionary taxes, it is expected that the older generation will bequeath the whole amount of the debt (or the loan) to the younger generation. Ricardian equivalence also predicts that consumption decisions will be equated across agents and across periods. In the presence of distortionary taxes, these predictions no longer hold. Specifically, in the baseline treatment, Ricardian equivalence is predicted to hold: the Giver will save the full amount of the loan in period 2 and give it to the Receiver in period 3. However, when distortionary taxes are levied, Ricardian equivalence is predicted to fail: consumption of the Giver will decrease, and the equivalence between debt and bequests will no longer hold.

Tables 1 and 2 summarize the equilibrium consumption and savings predictions based on the parameters of the experimental design.

## 4. Results

Table 3 presents the mean observed values for the choice variables in the last rounds of each set of experimental parameters. The results are nearly identical if we instead pool observations from the last two rounds. (Recall that in the baseline treatment there are no distortionary taxes and that in rounds 7-12 the loan amount is doubled; in the savings tax treatment there are always distortionary taxes, the loan is doubled in rounds 7-12, and the tax rate on savings is increased from 25 to 50 percent in rounds 13-18.)

Our main result relates to Ricardian equivalence in the two treatments. Ricardian equivalence in each treatment implies $\frac{\partial S_{G2}}{\partial \omega_{G2}}$ = 1. Table 4 summarizes the response of

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[10] Remember that, with a tax on savings, the actual bequest of the Giver to the Receiver is not the period 2 savings of the Giver (or $S_{G2}$) but savings reduced by the tax, or $S_{G2}(1-t)$.

[11] We are grateful to an anonymous referee for this observation and this argument. Indeed, for the particular parameter values that we use in our experimental design, the theoretically predicted sign of $\partial S_{G2}/\partial t$ is positive, except in the cases when endowments are unequal ($\omega_{G1}$=100 and $\omega_{G2}$=50) and the tax rate is "small" ($t$=0 or $t$=0.25).

bequests with respect to the change in deficit spending from round 6 to 12 of both treatments. In rounds 7-12, the period 2 loan (e.g., deficit spending) for the older generation increased in both treatments by 50 franks relative to the loan in rounds 1-6. Strict Ricardian equivalence requires that the bequest from the Giver to the Receiver ($S_{G2}$) should always increase by the full amount of the loan, or by 50, regardless of the presence or absence of taxes. In the baseline treatment, the average value of the change in bequests from round 6 to round 12 is 46.94 (or 102.88 – 55.94), and the null hypothesis that $\frac{\partial S_{G2}}{\partial \omega_{G2}}$ equals 1 cannot be rejected at the 5 percent level. Under the distortionary or savings tax treatment, however, the null hypothesis is rejected, invalidating Ricardian equivalence. The average value of the change in bequests in round 6 versus round 12 is clearly positive, but is only 36.07. The levy of taxes on savings distorts individuals' consumption-savings decisions, leaving deficit spending unmatched by an increase in bequests.

Figures 1 and 2 demonstrate the impact of the various policy changes on the average observed bequests for each treatment, and compare the average observed bequests with the bequests as predicted by the theoretical derivations of subsection 3.2. As shown in Figure 1, the average observed bequests follow quite closely the predicted values for all 12 rounds of the baseline treatment (e.g., bequests of 50 in rounds 1-6 and 100 in rounds 7-12). There is somewhat more noise in the savings tax treatment. Even so, the average observed bequest clearly increases (as predicted) when the loan amount increases in rounds 7-12 and then decreases (as predicted) when the tax rate increases in rounds 13-18, even though the observed values do not match perfectly the predicted values.

Ricardian equivalence also implies equality of inter-period consumption in a round. Table 5 presents the results of t-tests of the null hypothesis of equality across periods. We fail to reject the null hypothesis for the baseline treatment, which is consistent with Ricardian equivalence. In contrast, under the distortionary or savings tax treatment, we reject the null hypothesis of equality across rounds.

More broadly, we fail to reject the joint equality of consumption of the four consumption decision choices (e.g., that $C_{G1} = C_{G2} = C_{R2} = C_{R3}$ in each treatment) in the baseline treatment using a Friedman test, which is a nonparametric test to compare three or more matched groups. In the baseline treatment, the p-value is 0.5656. In contrast, we reject the null hypothesis of equal consumption in the savings tax treatment, with a p-value less than 0.0001.

Note that our theory also predicts that changing the tax rate from 0.25 to 0.50 (round 12 versus round 18) in the savings tax treatment should (given our experimental parameters) cause the Giver's period 2 savings to increase. Table 6 summarizes the response of bequests with respect to the change in tax rates, or $\frac{\partial S_{G2}}{\partial t}$; see also Figure 2. Somewhat surprisingly, the mean change in bequest is -2.07; that is, the older generation apparently chooses to consume slightly more and bequeath slightly less as result of the tax change. However, this change (while negative) is not significantly different from zero.

## 5. Conclusions

Our experimental results indicate that, in the presence of nondistorting taxes, subjects behave according to the predictions of Ricardian equivalence; that is, as predicted by Ricardian equivalence, there is equality across consumption in an intergenerational setting, and any increase in debt on one generation leads to an increase in bequests to the future generation by an equal amount. However, in the presence of distorting taxes, consumption is not equalized across periods, and the predicted Ricardian equality between the change in bequests and the change in debt is not attained. Thus, while the Ricardian view holds in the absence of distortionary taxes, the existence of a distortionary tax in our laboratory experiment generates behavior more consistent with the Neoclassical view of debt.

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**Table 1. Baseline Treatment: Experimental Parameters and Theoretical Predictions**

| | Parameters | | | Predictions | | | |
|---|---|---|---|---|---|---|---|
| **Round** | $\omega_{G1}$ | $\omega_{G2}$ | $\omega_{R2}$ | $C_{G1} = C_{G2} = C_{R2} = C_{R3}$ | $S_{G1}$ | $S_{G2}$ | $S_{R2}$ |
| 1-6 | 100 | 50 | 100 | 50 | 50 | 50 | 50 |
| 7-12 | 100 | 100 | 100 | 50 | 50 | 100 | 50 |

**Table 2. Savings Tax Treatment: Experimental Parameters and Theoretical Predictions**

| | Parameters | | | | Predictions | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Round** | $\omega_{G1}$ | $\omega_{G2}$ | $\omega_{R2}$ | t | $C_{G1}$ | $C_{G2} = C_{R2}$ | $C_{R3}$ | $S_{G1}$ | $S_{G2}$ | $S_{R2}$ | $S_{G1}(1\text{-}t)$ | $S_{G2}(1\text{-}t)$ | $S_{R2}(1\text{-}t)$ |
| 1-6 | 100 | 50 | 100 | 0.25 | 52.78 | 39.58 | 29.69 | 47.22 | 45.83 | 60.48 | 35.42 | 34.38 | 45.36 |
| 7-12 | 100 | 100 | 100 | 0.25 | 47.22 | 35.42 | 26.56 | 52.78 | 104.17 | 64.58 | 39.58 | 78.13 | 48.44 |
| 13-18 | 100 | 100 | 100 | 0.50 | 25.00 | 12.50 | 6.25 | 75.00 | 125.00 | 87.50 | 37.50 | 62.50 | 43.75 |

**Table 3. Experimental Results: Average Consumption and Savings/Bequests of Givers and Receivers**

| | | Parameters | | | | Average Consumption for Periods 1 and 2 | | | | Average Savings/Bequests for Periods 1 and 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatment** | **Round** | $\omega_{G1}$ | $\omega_{G2}$ | $\omega_{R2}$ | t | $C_{G1}$ | $C_{G2}$ | $C_{R2}$ | $C_{R3}$ | $S_{G1}$ | $S_{G1}(1\text{-}t)$ | $S_{G2}$ | $S_{G2}(1\text{-}t)$ | $S_{R2}$ | $S_{R2}(1\text{-}t)$ |
| Baseline | 6 | 100 | 50 | 100 | 0 | 49.25 | 44.81 | 50.63 | 55.94 | 50.75 | 50.75 | 55.94 | 55.94 | 49.38 | 49.38 |
| Baseline | 12 | 100 | 100 | 100 | 0 | 49.69 | 47.44 | 48.31 | 56.13 | 50.31 | 50.31 | 102.88 | 102.88 | 51.69 | 51.69 |
| Distortionary Tax | 6 | 100 | 50 | 100 | 0.25 | 37.38 | 34.69 | 48.41 | 35.58 | 62.63 | 46.97 | 62.28 | 46.71 | 51.60 | 38.70 |
| Distortionary Tax | 12 | 100 | 100 | 100 | 0.25 | 36.63 | 37.16 | 42.86 | 26.38 | 63.37 | 47.53 | 110.37 | 82.78 | 57.15 | 42.86 |
| Distortionary Tax | 18 | 100 | 100 | 100 | 0.50 | 33.22 | 25.00 | 33.16 | 7.82 | 66.78 | 33.39 | 108.30 | 54.19 | 80.12 | 40.46 |

**Table 4. Tests for Change in Savings/Bequests with Respect to a Change in Deficit Spending**

| **Treatment** | $\Delta\omega_{G2}$ | **Null** | **Statistics** | **Decision** |
|---|---|---|---|---|
| Baseline | 50 | $\Delta S_{G2} = \Delta\omega_{G2}$ | Average ΔBequests = 46.94<br>Standard Deviation = 20.44<br>Standard Error = 5.11<br>t-statistic = -0.60 | Do Not Reject Null |
| Distortionary Tax | 50 | $\Delta S_{G2}(1\text{-}t) = \Delta\omega_{G2}$ | Average ΔBequests = 36.07<br>Standard Deviation = 14.15<br>Standard Error = 3.54<br>t-statistic = -3.94 | Reject Null |

Note: Δ represents the change from Round 6 to Round 12.

**Table 5. Tests for Equality of Inter-period Consumption**

| **Treatment** | **Null: $C_{G1} = C_{G2}$** | **Decision** | **Null: $C_{R2} = C_{R3}$** | **Decision** |
|---|---|---|---|---|
| Baseline | p = 0.1044 | Do Not Reject Null | p = 0.6187 | Do Not Reject Null |
| Distortionary Tax | p = 0.0323 | Reject Null | p < 0.0001 | Reject Null |

Note: The observations are those from the last round of a regime (e.g., rounds 6 and 12 for the Baseline treatment and rounds 6, 12, and 18 for the Savings Tax treatment

**Table 6. Test for Change in Savings/Bequests with Respect to a Change in the Tax Rate**

| **Treatment** | **Δt** | **Null** | **Statistics** | **Decision** |
|---|---|---|---|---|
| Distortionary Tax | 0.25 | $\Delta S_{G2}/\Delta t = 0$ | Average $\Delta S_{G2}$ = -2.07<br>Standard Deviation =16.51<br>Standard Error = 4.13<br>t-statistic = -0.50 | Do Not Reject Null |

Note: Δ represents the change from Round 12 to Round 18.

**Figure 1. Observed and Predicted Mean Bequests in the Baseline Treatment**

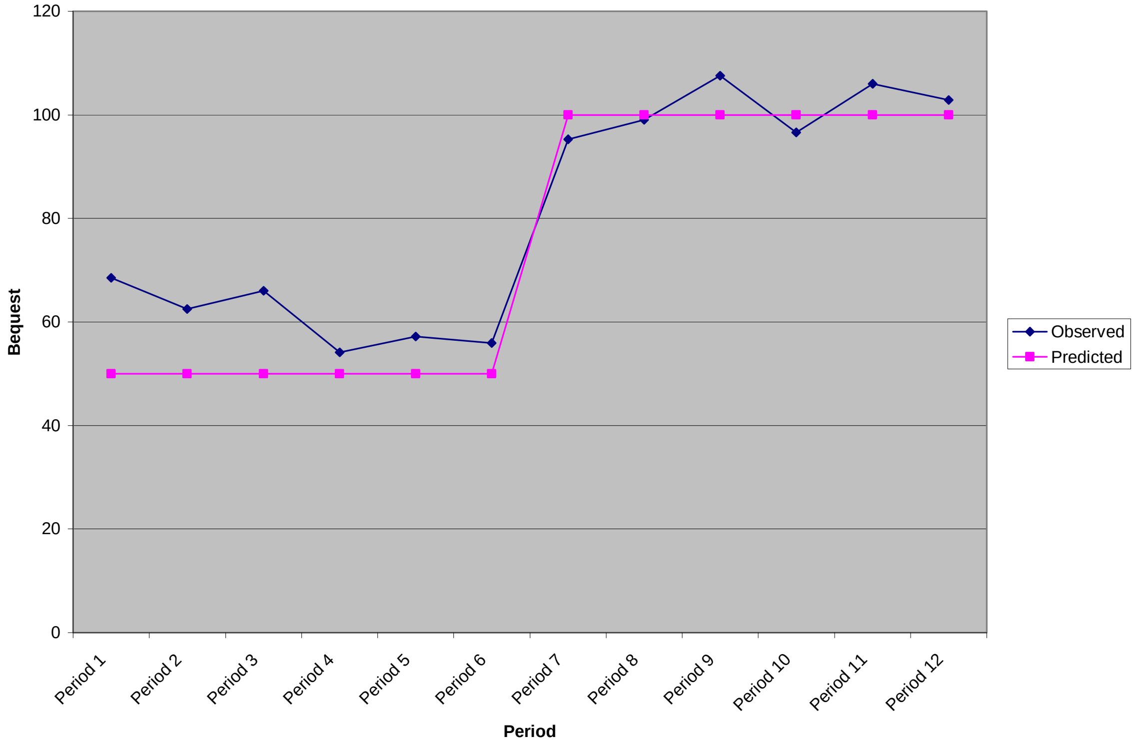
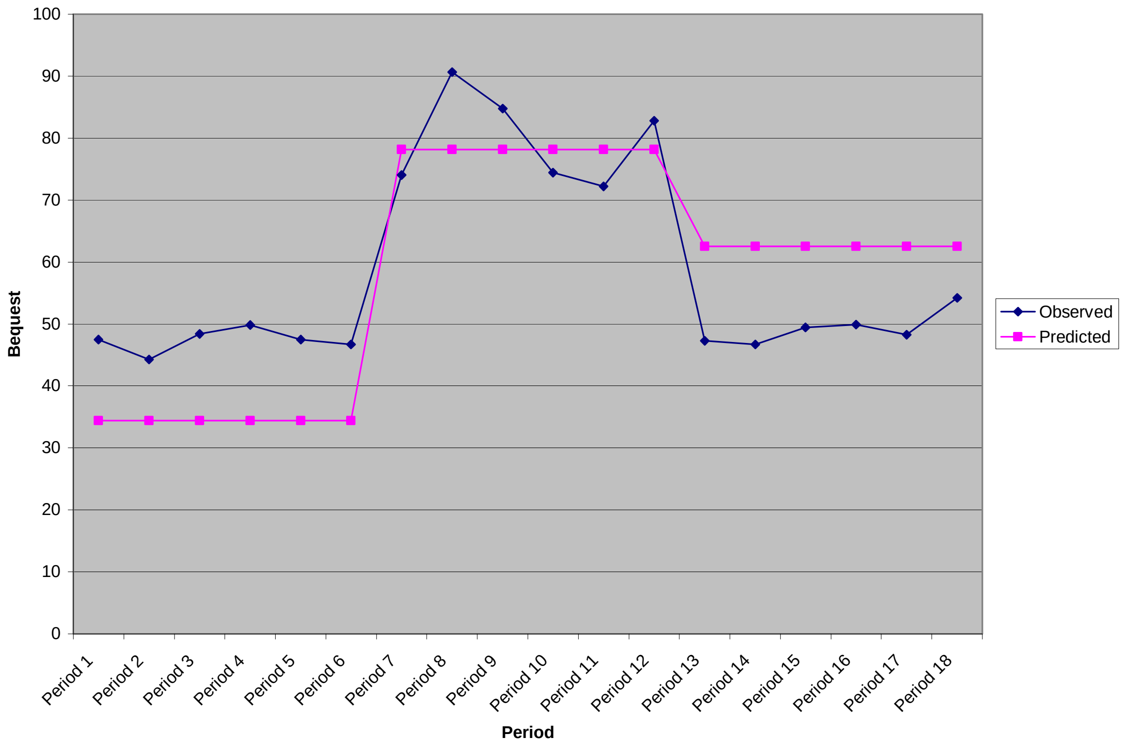



**Figure 2. Observed and Predicted Mean Bequests in the Savings Tax Treatment**



## APPENDIX: EXPERIMENTAL INSTRUCTIONS

## GENERAL INSTRUCTIONS

### Introduction

This is an experimental study of individual decision making over time. The amount of money that you will earn will depend on the scores that you obtain in the experiment. Your money will be paid to you in cash at the end of the experiment. Your earnings will depend on the decisions that you make, and, at times, will also depend on the decisions of the person with whom you are paired; your scores are not affected by anyone else in the experiment, except the person with whom you are paired. During the experiment, you are not allowed to communicate with other participants. You should feel free to make as much money as possible. You can write on the instructions.

### Sessions and Periods

The experiment will take approximately two hours. The experiment consists of two sessions: Session 1 and Session 2. Each session consists of several rounds and each round consists of three Periods: Period 1, Period 2, and Period 3. At the beginning of each session, instructions that are relevant to the session will be distributed.

### Two Groups

The participants, called "players," will be randomly divided into two groups, called Group A and Group B. We will refer to players in Group A as Players A and players in Group B as Players B. You will be in the same group throughout the experiment. You will be told at the beginning of the experiment if you are Player A or Player B.

### Group A and Group B Pairing

Each player from Group A will be randomly paired with another player from Group B. This pairing changes in every round. You will not be paired with the same person in a two consecutive rounds and you will not be paired with the same person more than twice in a session. You will never learn the identity of a person with whom you are paired, and they will never learn your identity.

### Currency

The currency used throughout the experiment is franks. At the end of the experiment, the franks you earn will be converted into U.S. dollars at the following exchange rates: 1 frank = 0.00000025 U.S. dollar when you are in Group A; 1 frank = 0.0005 U.S. dollar when you are a member of Group B. The exchange rates between players in Group A and players in Group B differ so that earnings will be similar for players who make good decisions.

### Player A's Decision Task

Player A, Period 1: At the beginning of Period 1, Player A receives an income in franks. Player A must decide how much of this income to consume. Player A has 20 seconds to make this decision. The amount of income that is not consumed is automatically saved. Savings in Period 1 will be carried over to Period 2.

Player A, Period 2: Player A receives saved franks from Period 1 (if any were saved). Player A will also receive loan for Period 2 that can be used for consumption and for savings. Player A must decide how much of the Period 1 savings and the Period 2 loan to consume. Player A has 20 seconds to make this decision. The amount of funds that is not consumed is automatically saved.

Player A, Period 3: Player A does not play in Period 3 (he or she makes no decision). Any savings by Player A in Period 2 will be given to Player B at the beginning of Period 3. However, the loan received by Player A in Period 2 will be subtracted from Player B's Period 3 available funds.

## Player B's Decision Task

Player B, Period 1: Player B does not play in Period 1.

Player B, Period 2: At the beginning of Period 2, Player B receives an income in franks. Player B must decide how much of this income to consume. Player B has 20 seconds to make this decision. The amount of income that is not consumed is automatically saved. Savings in Period 2 will be carried over to Period 3.

Player B, Period 3: Any Period 2 savings by Player B will be carried over to Period 3. At the beginning of Period 3, Player B will also receive any savings made by Player A in Period 2. However, Player B will have to pay back the loan received by Player A in Period 2 (the amount will be announced to Player B). If Player B does not have sufficient franks to pay back this amount, his/her score is set to zero. Player B makes no decision in Period 3: all of the franks available to Player B are spent on consumption. Player B has 10 seconds to review the summary of consumption and savings decisions.

## Summary

The following timeline summarizes the events in a round:

| **Period 1:** | **Period 2:** | **Period 3:** |
|---|---|---|
| **Player A:** | **Player A:** | **Player A:** |
| • Receive Period 1 Income<br>• Choose Consumption<br>• Franks not Consumed are Saved for Period 2 | • Receive Period 2 Loan<br>• Receive Period 1 Savings<br>• Choose Consumption<br>• Franks not Consumed are Saved for Player B in Period 3 | • Does not play |
| **Player B:** | **Player B:** | **Player B:** |
| • Does not play | • Receive Period 2 Income<br>• Choose Consumption<br>• Franks not Consumed are Saved for Period 3 | • Receive Period 2 Savings<br>• Receive Player A's Period 2 Savings<br>• Pay Player A's Period 2 Loan<br>• Consume remaining franks |

You will be anonymously paired with different people in subsequent rounds.

**Scores and Payoffs**

Player A’s Score

Player A’s score depends on his/her consumption in Period 1 and Period 2 and also depends on the score of the Player B with whom he or she was paired in the round. Player A’s income consumed in Period 1 is multiplied by Player A’s income consumed in Period 2, which is then multiplied by Player B’s score (thus if any of these values are zero, you earn a score of zero). The higher your score, the more money you earn.

***Player A’s Score = (Player A’s consumption in Period 1)***
***x (Player A’s consumption in Period 2) x (Player B’s Score)***

So, Player A’s score depends on Player B’s score, but Player B’s score does not depend on Player A’s score. However, Player A’s decisions do affect Player B’s score.

Player A’s Payoffs

***Player A’s Payoffs = Player A’s Score x 0.00000025***

Player B’s Score

The score of Player B depends on his/her consumption decisions. The higher your score the more money you earn.

***Player B’s Score = (Player B’s consumption in Period 2)***
***x (Player B’s consumption in Period 3)***

Player B’s Payoffs

***Player B’s Payoffs = Player B’s Score x 0.0005***

## SESSION 1 INSTRUCTIONS

This session consists of 12 rounds, and each round consists of three periods: Period 1, Period 2, and Period 3. Player A plays in Period 1 and 2, while Player B plays in Period 2 and 3. At the end of Period 3, your payoffs will be computed and a new round will begin. There will be 30 seconds of display of summary of the round and you are asked to record your score in U.S. dollar (the last line of the summary) on the Record Sheet. At the beginning of each round, the computer screen will present your "Private Information," which will tell you your player type and any other relevant rules for the round. You are not allowed to reveal this Private Information to other players. We will have 6 practice rounds at the beginning of this session.

In this session, to get 1 unit of consumption, each player has to commit 1 frank. Player A's Period 2 loan will change (double) after Round 6. Do you have any questions?

## SESSION 2 INSTRUCTIONS

This session consists of 18 rounds. Session 2 is identical to Session 1, except that a tax will be levied on savings. For Rounds 1 to 12, the tax rate will be 0.25 or twenty five percent. Therefore, when you save S franks, the amount of money transferred to the next Period will actually be S – 0.25S (example: if you save 100 franks, only 100 franks– 0.25x100 franks = 75 franks will transfer to the next Period). In other words, to save 0.75 unit of saving, a player has to commit 1 frank. All other rules are like those in Session 1. For Rounds 13 to 18, the tax rate will be 0.50 or fifty percent. Therefore, to save S units, one must commit S + 0.50S franks (example: to save 100 units, one must commit 100 franks + 0.50x100 franks = 150 franks). In other words, to save 1 unit of saving, a player has to commit 1.50 franks. Therefore, when you save S franks, the amount of money transferred to the next Period will actually be S – 0.50S (example: if you save 100 franks, only 100 franks – 0.50x100 franks = 50 franks will transfer to the next Period). In other words, to save 0.50 unit of saving, a player has to commit 1 frank. We will have 6 practice rounds at the beginning of this session.

***Player A's Score = (Player A's consumption in Period 1)***
***x (Player A's consumption in Period 2)x (Player B's Score)***

***Player B's Score = (Player B's consumption in Period 2)***
***x (Player B's consumption in Period 3)***

**Tax Rates and the Double of Player A's Period 2 Loan for Session 2**

In this session, to get 1 unit of savings, each player has to commit 1.25 franks for Rounds 1 to 12 and 1.50 franks for Rounds 13 to 18. Player A's Period 2 loan will change (double) after Round 6. Do you have any questions?