THE POLITICAL ECONOMY OF PUBLIC DEBT: A LABORATORY STUDY

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Abstract
This paper reports the results from a laboratory experiment designed to study political distortions in the accumulation of public debt. A legislature bargains over the levels of a public good and of district specific transfers in two periods. The legislature can issue or purchase risk-free bonds in the first period and the level of public debt creates a dynamic linkage across policymaking periods. In line with the theoretical predictions, we find that public policies are inefficient and efficiency is increasing in the size of the majority requirement, with higher investment in public goods and lower debt associated with larger majority requirements. Debt is lower when the probability of a negative shock to the economy in the second period is higher indicating that even in a political equilibrium debt is used to smooth consumption and to insure against economic uncertainty. Also in line with the theoretical predictions, we find that dynamic distortions are eliminated when the first period proposer can commit to a policy for both periods. The experiment, however, highlights two phenomena that are surprising in terms of standard theory and have not been previously documented. First, balancing the budget in each period is a focal point, leading to lower distortions than predicted. Second, higher majority requirements induce significant delays in reaching an agreement. (JEL: D71, D72, C78, C92, H41, H54)

1. Introduction

There is a large theoretical literature, both in economics and political science, aimed at predicting the evolution of public debt and understanding how its excessive accumulation can be successfully avoided. The macroeconomic literature has focused

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on the development of normative models in sophisticated dynamic environments in which a benevolent planner optimally chooses public debt to maximize social welfare (see, among others, Barro 1979; Stokey and Lucas 1983; Ayiagari et al. 2002). This literature has highlighted the role of public debt for consumption smoothing and characterized its implications for intertemporal allocation of resources. The political economy literature, instead, has focused on the development of positive models that stressed the inefficiencies induced by the political process (Buchanan and Tullock 1962; Buchanan 2000). This literature has shed light on how political distortions can induce rational agents to over-accumulate debt and limit the scope of consumption smoothing (Persson and Svensson 1989; Alesina and Tabellini 1990; Battaglini and Coate 2008).[1]

Testing the predictions of these theories has proven challenging. Testing for consumption smoothing, for example, is difficult when it is hard to measure accurately the shocks hitting the economy, or the agents' expectations and preferences. Even more difficult is testing for the effect of institutions on public debt, since both institutions and fiscal policy are endogenous variables that depend on many other factors that are hard to control for. This leaves us with many important unanswered questions about these theories and their underlying assumptions. To what extent do these models accurately predict behavior in empirical settings? Is indebtedness driven by strategic and forward-looking decision makers, as assumed in these models, or is it more simply due to myopic political agents? How do inefficiencies depend on the institutions that govern collective decision making?

In this work, we address these questions by examining the theoretical implications of a simple political economy model of public debt by means of a controlled laboratory experiment. In our model policy choices are made by a legislature that can borrow or save in the capital market in the form of risk-free one-period bonds. Public revenues are used to finance the provision of a public good that benefits all citizens, and to provide targeted district-specific transfers, which are interpreted as pork-barrel spending, or local public goods without spillovers across districts. The value of the public good to citizens is stochastic, reflecting shocks, such as, economic crises, wars, or natural disasters. The legislature makes policy decisions by voting and legislative policy making in each period is modeled using a dynamic legislative bargaining as in Battaglini and Coate (2008). The level of public debt acts as a state variable, creating a dynamic linkage across policy making periods. This model has been explicitly designed to capture most of the key issues emerging from the public debt literature, whereas at the same time keeping it simple enough to investigate its predictions in the laboratory.

We should highlight that the purpose of our experiments is to isolate and test the empirical validity of one important general idea (the interaction of political institutions, time inconsistency, and public debt) that has been identified theoretically as a potentially important source of inefficiency and excessive debt. We make no claim that the factor we are isolating is the only factor in any particular historical

1. See Battaglini (2011) and Alesina and Passalacqua (2016) for recent surveys of the literature.

or contemporary examples where inefficiently high debt has been observed (e.g., Greece during the last decade), and we are not making claims about its relative weight compared with other forces (such as re-election concerns). To do so would be far beyond the scope of our study and it is not the objective of the research. What we are learning from the experiment is that individual behavior and outcomes respond to changes in institutional parameters as predicted by the model. Although the experiment can only test behavior within the model, the findings advance our knowledge on public debt formation to the extent that the model captures important features of the strategic interaction between policymakers in the choice of public debt.

The model generates predictions about how the legislature uses the debt instrument to smooth consumption over time and how the political process affects this activity. Fixing the distribution of the shocks, the model predicts that the legislature issues too much debt and uses the proceedings to fund transfers targeted to a minimal winning coalition of committee members. The amount of debt is decreasing in the size of the required majority and converges to the efficient level (a negative level, corresponding to positive savings) as the decision becomes unanimous. Fixing the voting rule, the level of debt is a decreasing function of the probability of the future state in which the public good has high value. The model highlights multiple sources of political distortions. First, since only $q \leq n$ votes are required for passage of a proposal, the proposer fails to internalize the value of the public good to the whole group. Second, the political uncertainty over the future coalition and the economic uncertainty over the shock to the marginal value of the public good generate dynamic distortions. A current coalition member bears the cost of an additional unit of debt only if he receives private transfers tomorrow, which does not happen if he is excluded from the future coalition and if tomorrow's public good provision is very valuable. For these reasons, the current coalition undervalues the marginal benefit of future resources, preferring to front-load rather than smooth consumption resulting in an overaccumulation of debt.

The experimental treatments are explicitly designed to explore the effect of these three sources of inefficiencies. Our first treatment is the majority requirement for passage of a proposal and it manipulates the extent to which the agenda setter is forced to internalize the value of the public good to other members of the group. Our second treatment is the probability distribution of the value of the public good in the second period and it manipulates economic uncertainty. Our third treatment is whether decisions in the first period are made with or without commitment on the allocation of second period's resources and it manipulates political uncertainty. Theoretically, this last treatment eliminates the dynamic source of distortions for any $q < n$ but it does not affect the static source of inefficiency, which is decreasing in q.

The experiment confirms the comparative statics implications of the model, but the data also provide some surprising findings that suggest new insights about the effect of voting rules on behavior in legislative bargaining games. A clear result emerging from the analysis is that players are forward-looking and political institutions have a crucial role. Aggregate outcomes are consistent with the predicted treatment effects: we observe higher public good provision and lower borrowing with a higher majority requirement; we observe lower borrowing with a higher risk of a shock to society; and we observe lower borrowing and less dynamic inefficiencies with the ability to commit on future expenditures. Perhaps more subtly, we find that, as predicted by the theory in a political equilibrium with no commitment and voting rule $q < n$ the Euler equation is systematically violated with a higher marginal utility of public goods at t than the expected marginal utility at $t + 1$; also as predicted, no such distortion is present with commitment, *independently* of the voting rule.

Political institutions, however, have a larger effect on outcomes than economic conditions or the perceived degree or risk; indeed the main driving force behind public debt accumulation is the voting rule governing collective decision making. An encouraging finding in the experiment is that public policies are less inefficient than predicted under all voting rules, with approximate efficiency under super-majority (without the need of a unanimity requirement).

Two other results appear surprising and worth highlighting. First, we find that balancing the budget in each period appears to be a focal point for the players: this phenomenon limits the size of the distortions below the levels that we would have expected from the theory alone. Second, we find that higher majority requirements induce difficulties to reach an agreement, with such bargaining delays creating a potential transaction cost, akin to political gridlock, about which existing models of public debt are silent. The problem of bargaining delay may partly explain why we do not observe unanimous rules used more frequently in real world institutions. These deviations have important empirical implications for the optimal design of political institutions and suggest the need of a deeper empirical study of the advantages and disadvantages of introducing legislative supermajorities or veto powers in fiscal policy legislation.

Our paper is not the first to study experimentally how agents allocate resources over time. Two approaches have been attempted by the previous literature. The first was to embrace a representative agent model, abstracting from how public decisions are collectively taken (Hey and Dardanoni 1988; Noussair and Matheny 2000; Carbone and Hey 2004).[2] This literature was mainly interested in exploring the extent to which single agents can solve discrete-time optimization problems in isolation and is mute on the question of how public debt is determined in a legislature operating under agenda procedures and voting rules. The second approach was to study collective decision making by a legislature whose current decision influences the future bargaining environment, but without allowing the possibility of issuing debt (see, e.g., Battaglini and Palfrey 2012; Battaglini, Nunnari, and Palfrey 2012; Nunnari 2018; Agranov et al. 2016).[3] In this latter strand of literature, the closest contribution to the current paper is Battaglini, Nunnari, and Palfrey (2012). In that paper, there is no uncertainty about the future economic environment; the bargaining protocol prescribes an exogenous

2. Cadsby and Frank (1991) and Lei and Noussair (2002) study a community of multiple agents but consider decentralized decision making. For a survey of laboratory experiments on macroeconomic questions see Duffy (2015).

3. A somewhat intermediate approach is found in Battaglini, Nunnari, and Palfrey (2016), who study a dynamic free rider problems in which players' actions are independent but are linked by externalities.

status quo allocation if a proposal is rejected; and, most importantly, the dynamic linkage between periods is the stock of durable public good accumulated by the committee (rather than public debt and the associated level of available resources). To our knowledge, this is the first experimental study of the political determination of public debt accumulation.

Finally, this paper contributes to the literature on laboratory experiments testing models of legislative bargaining (McKelvey 1991; Frechette, Kagel, and Lehrer 2003; Diermeier and Morton 2005; Frechette, Kagel, and Morelli 2005a,b; Diermeier and Gailmard 2006). In particular, Frechette, Kagel, and Morelli (2012) provide experimental evidence on the behavior of committees allocating a budget between particularistic and collective good spending. As in our experiments, proposer power is not as strong as predicted and public good provision is substantially higher than predicted.[4] This work, however, focuses on static environments where a given amount of resources is allocated only once and cannot address questions about intertemporal allocation of resources and debt accumulation.

The rest of the paper is organized as follows. In Section 2, we outline the model and characterize the first best allocation as a benchmark. In Section 3, we characterize the political equilibrium and its testable implications. Section 4 details the experimental design. Section 5 presents the experimental results. We conclude in Section 6.

2. Model

We study a model in which a committee of n players collectively chooses how to allocate resources over two periods. There are two goods: a public good, g, and a consumption good, s. The public good can be produced from the consumption good with a technology that transforms a unit of consumption into a unit of public good. An allocation in period t is a vector $\{g_t, s_t^1, \ldots, s_t^n\}$ where g_t is the public good at t, and s_t^i is the level of private consumption of agent i at t.

Each citizen's utility function in period t is $s_t + A_t u(g_t)$, where s_t are the units consumed, g_t is the public good and $u(g_t)$ is a strictly increasing, strictly concave and continuously differentiable function, with $\lim_{g_t \to 0^+} u'(g_t) = \infty$ and $\lim_{g_t \to +\infty} u'(g_t) = 0$. The parameter A_t measures the relative importance of the public good to the citizens in period t. The value of the public good varies across periods in a random way, reflecting shocks to society, such as wars, natural disasters, or economic crisis. Specifically, in period 1 the value of the public good is $A_1 = A$; in period 2 the value is $A_2 = A_H > A$ with probability p, and $A_2 = A_L < A$ with probability $1 - p$. The value of the public good in period 2 is the state of the world, $\theta = \{L, H\}$. Citizens discount future per period utilities at rate δ.

4. This is also consistent with the findings of the experimental literature on the voluntary provision of public goods. For a survey of this literature, see Ledyard (1995) and Vesterlund (2015).

In every period, the committee receives public revenues equal to W. At $t = 1$, the committee can also borrow or lend money at a constant interest rate r. If the committee borrows an amount x in period 1, it must repay $x(1 + r)$ in period 2. Public revenues and debt are used to finance the provision of the public good and the monetary transfers. Since the legislature can either borrow or lend, x can be positive or negative. We assume that the initial level of debt is zero. In period 1, the allocation must satisfy the following budget constraint:

$$W + x - \sum s_1^i - g_1 \geq 0. \tag{1}$$

In period 2, the allocation in state $\theta = \{L, H\}$ must satisfy the following budget constraint:

$$W - (1 + r)x - \sum s_{2\theta}^i - g_{2\theta} \geq 0. \tag{2}$$

The committee makes public decisions following a standard bargaining protocol à la Baron and Ferejohn (1989). In period 1, one of the committee members is randomly selected to make the first policy proposal, with each member having an equal chance of being recognized. A proposal is described by an $n + 2$-tuple $\{g_1, x, s_1^1, \ldots, s_1^n\}$, where g_1 is the proposed amount of public good provided at $t = 1$; x is the proposed level of public debt; and s_1^i is the proposed transfer to district i's residents at $t = 1$. This proposal must satisfy the budget constraint (1) and the non-negativity constraints: $g_1 \geq 0$, $s_1^i \geq 0$, $i = 1, \ldots, n$. If the proposer's plan is accepted by q committee members, then it is implemented and the legislature adjourns until the beginning of the next period. If, on the other hand, the first proposal is not accepted, there is another round of bargaining where another committee member is chosen randomly (with replacement) to make a proposal. This process continues until a proposal is accepted by q committee members: at that point the proposal is implemented and the legislature adjourns until the beginning of the next period.[5]

In period 2, the committee inherits the level of debt x chosen at $t = 1$, and observe the realized state of nature, $A_\theta = \{A_L, A_H\}$. As in period 1, one of the committee members is randomly selected to make the first policy proposal, with each member having an equal chance of being recognized. In this case a proposal is described by an $n + 1$-tuple $\{g_{2\theta}, s_{2\theta}^1, \ldots, s_{2\theta}^n\}$, where $g_{2\theta}$ is the amount of the public good provided and $s_{2\theta}^i$ is the proposed transfer to district i's residents in state θ. This proposal must satisfy the budget constraint (2), given x, and the non-negativity constraints: $g_{2\theta} \geq 0$, $s_{2\theta}^i \geq 0$, $i = 1, \ldots, n$. If the proposer's plan is accepted by q committee members, then it is implemented and the game ends. If the proposal is not accepted, then another committee member is chosen, and the procedure continues until a proposal is accepted

5. Results would be qualitatively unchanged if we considered a model where, after $T < \infty$ proposals have been made and rejected, then the policy is determined as in the bargaining protocol of Battaglini and Coate (2008).

by q committee members: at this point the proposal is implemented and the game ends. In both periods, we assume that there is no discounting following a rejected proposal.[6]

There is a limit on the amount the government can borrow: $x \leq \bar{x}$, where $\bar{x}$ is the maximum amount that the government can borrow. The limit on borrowing is determined by the unwillingness of borrowers to hold government bonds that they know will not be repaid. If the government borrowed an amount x such that the interest payments exceeded the maximum possible tax revenues—that is, $x > W/(1+r)$—then, it would be unable to repay the debt even if it provided no public good or transfers. Thus, the maximum level of debt certainly does not exceed this level, so we assume $\bar{x} = W/(1+r)$.

In a competitive equilibrium, we must have $\delta(1+r) = 1$. Otherwise, no agent would be willing to lend (if $\delta(1+r) < 1$) or to borrow (if $\delta(1+r) > 1$) and the debt market would not be in equilibrium. This condition pins down the equilibrium interest rate as a simple function of the discount factor. In the following analysis and in the experiment, we assume the competitive equilibrium interest rate, that is, $r = 1/\delta - 1$.[7]

To limit the number of possible cases, we make two assumptions on the parameters of the model. As will be shown in the next section, the efficient levels of public good are

$$g_1^O = [u']^{-1}\left(\frac{1}{An}\right), \quad g_{2\theta}^O = [u']^{-1}\left(\frac{1}{A_\theta n}\right).$$

First, we assume that, without the debt market, in the second period the legislature does not have enough resources to cover the efficient level of g if there is a high shock:

$$W < g_{2H}^O.$$

If this assumption was not satisfied, then there would be no economic reason for precautionary savings. Second, we assume that, with a debt market to shift budgets across periods, there are enough resources available to society to make sure that an optimal solution is feasible even when there is a high shock in the second period:

$$W + \frac{W}{1+r} \geq g_1^O + \frac{g_{2H}^O}{1+r}. \tag{3}$$

Given these assumptions, a benevolent planner can achieve the efficient allocation, but it can do it only by saving in the first period. In the next section we characterize exactly the amount of savings required for the efficient solution.

6. All the theoretical comparative statics we test with the experiments are robust to allowing for discounting between rounds of bargaining within the same period.

7. Note that this is the competitive equilibrium interest rate if our society is a closed economy and committee members have access to financial markets for intertemporal trade in private consumption goods that are perfectly substitutable with private transfers.

2.1. Optimal Public Policy

As a benchmark with which to compare the equilibrium allocations by a legislature, this section characterizes the public policy that maximizes the sum of utilities of the districts. This is the *optimal public policy*. The optimization problem is as follows:

$$\begin{aligned}
\max_{s_1,g_1,s_{2\theta},g_{2\theta},x} \quad & \Big\{ns_1 + Anu(g_1) + p\left[ns_{2H} + A_H nu(g_{2H})\right] \\
& + (1-p)\big[ns_{2L} + A_L nu(g_{2L})\big]\Big\} \\
\text{subj. to:} \quad & W + x - ns_1 - g_1 \geq 0, \\
& W - (1+r)x - ns_{2L} - g_{2L} \geq 0, \\
& W - (1+r)x - ns_{2H} - g_{2H} \geq 0, \\
& s_1 \geq 0, s_{2\theta} \geq 0, g_1 \geq 0, g_{2\theta} \geq 0. \qquad (4)
\end{aligned}$$

In (4) we assume that all citizens receive the same transfer: s_1 in period 1 and $s_{2\theta}$ in period 2 in state θ. This is without loss of generality since with quasilinear utilities the policy-maker is indifferent with respect to the distribution of transfers. The optimal levels of public good, in particular, are independent from the distribution of transfers. The first three constraints are the budget constraints for, respectively, the first period, the second period in the low state, and the second period in the high state. The other constraints are the non-negativity constraints for transfers and public good levels.

The following result, proven in the Appendix, characterizes the uniquely defined optimal provision of public goods and the feasible range of public debt.[8]

PROPOSITION 1. *The optimal public policy is given by*

$$x^O \in \left[g_1^O - W, \frac{W - g_{2H}^O}{1+r}\right] \qquad (5)$$

$$g_1^O = \left[u'\right]^{-1}\left(\frac{1}{nA}\right), \quad g_{2L}^O = \left[u'\right]^{-1}\left(\frac{1}{nA_L}\right), \quad g_{2H}^O = \left[u'\right]^{-1}\left(\frac{1}{nA_H}\right).$$

Proposition 1 has the following implication.

COROLLARY 1. *The optimal level of debt is negative.*

The planner provides the efficient level of public good, that is, the level that maximizes the joint utility of *n* districts, in both periods and in both states of the world. This implies that the social planner has an incentive to self-insure against shocks to society that make the public good more valuable to its citizens—for example, a war, a

8. In the Appendix, we also specify an optimal allocation for the transfers. Note that the total amount of transfers is uniquely determined by the equilibrium public good and debt presented in Proposition 1. The distribution of these transfers however is indeterminate since a utilitarian policy-maker is indifferent with respect to redistribution.

natural disaster or an economic crisis. The planner hence saves in the first period, in order to be able to provide the efficient level of public good in the second period, in case of a positive shock to the marginal benefit from public spending.

The following result clarifies how the planner chooses public debt.

COROLLARY 2. *At the optimum, the expected marginal utility of the public good is equal in both periods,*

$$Au'\left(g_1^O\right) = E\left[A_\theta u'\left(g_{2\theta}^O\right)\right]. \tag{6}$$

Equation (6) is the so called Euler equation for problem (4). It says that, at the optimal solution, the marginal utility of the public good at $t = 1$ (the left hand side of (6)) must be equal to the expected marginal utility of the public good at $t = 2$ (the right hand side).

3. Political Equilibrium

We now consider a legislature, composed by representatives of the n districts, that allocates the resources through the bargaining process described in Section 2. Section 3.1 considers the model without commitment, where legislators bargain over the allocation of resources in each period at the beginning of that same period. We solve the model using backward induction. Section 3.2 considers the model with commitment, where legislators bargain over the allocation of resources in both periods at the beginning of the first period.

3.1. Equilibrium Behavior without Commitment

3.1.1. Equilibrium Behavior in Period 2. In the second period, committee members take the level of debt incurred in the first period, x, as given and know the realized state of the world, $\theta = \{H, L\}$. The equilibrium policy is chosen by the proposer, as described in Section 2. The proposer chooses the policy that maximizes his own utility under the feasibility constraints and under the constraint requiring that a minimal winning coalition of other players is willing to support his proposal. In a stationary symmetric equilibrium, the proposer randomly selects $q - 1$ other players out of the remaining $n - 1$, each with probability $(q - 1)/(n - 1)$, to be part of his minimal winning coalition, and treats all the members of his minimal winning coalition in the same way.

The proposer's problem can be formally written as

$$\begin{aligned} \max_{s,g} \quad & \left\{W - (1 + r)x - (q - 1)s - g + A_\theta u(g)\right\} \\ \text{subj. to:} \quad & W - (1 + r)x - (q - 1)s - g \geq 0, \\ & s \geq 0, g \geq 0, s + A_\theta u(g) \geq v_2(x, \theta), \end{aligned}$$

where g is the level of public good and s is the transfer that the proposer chooses to give to the $q - 1$ coalition members. The proposer benefits from the resources he can extract net of interest payments, the payments to the other coalition members and the cost of the public good (i.e., $W - (1 + r)x - (q - 1)s - g$), and from the public good ($A_\theta u(g)$). The first constraint is the budget constraint (given the level of debt inherited from the first period); the second and third constraints are the non-negativity constraint on public good and districts' transfers. The fourth constraint is the incentive compatibility constraint: voters support the proposal if and only if the utility they derive from it (i.e., $s + A_\theta u(g)$) is at least as large as their continuation value in a further round of bargaining, $v_2(x, \theta)$. If the proposer does not receive q votes, a new proposer is chosen at random, so the continuation value $v_2(x, \theta)$ is the expected utility at $t = 2$ when the state is (x, θ) and before the identity of the proposer is known. This means that a committee member supports a proposal if and only if the private transfer he receives is greater than or equal to $v_2(x, \theta) - A_\theta u(g)$. Offering a larger level of public good reduces the private transfer demanded by potential coalition partners and increases the resources that can be devoted to the proposer's private transfer. This leads the proposer to internalize the utility that other $(q - 1)$ committee members derive from public good provision.

In the Appendix, we characterize the unique solution to this problem and we compute the value function $v_2(x, \theta)$ associated with any level of debt incurred in the first period. We show that $v_2(x, \theta)$ is a concave and almost everywhere differentiable function of debt x characterized by a state-dependent critical value of debt, $\widehat{x}_\theta$. When $x \leq \widehat{x}_\theta$, the citizens have sufficient resources in the second period for transfers, and the proposer makes positive transfers to himself and the other members of his coalition. When $x > \widehat{x}_\theta$, instead, debt is so high that transfers are zero at $t = 2$ in state A_θ. The value function fails to be differentiable at the point $\widehat{x}_\theta$, where the non-negativity constraints for transfers becomes binding.

Taking expectations with respect to θ, we obtain the expected continuation utility $v_2(x) = Ev_2(x, \theta')$. Naturally, $v_2(x)$ is also concave and almost everywhere differentiable in x. Now we have two points of nondifferentiability: at $\widehat{x}_L$, where the non-negativity constraint for transfers is binding in state L; and at $\widehat{x}_H$, where the non-negativity constraint for transfers is binding in state H. Figure 1 illustrates it in two examples.

The threshold $\widehat{x}_H$ is strictly lower than $\widehat{x}_L$: when the state is high, it is optimal to choose a higher level of public good; so, if transfers are unfeasible in state A_L, then they are unfeasible in state A_H too. When $x \leq \widehat{x}_H$, the non-negativity constraint for transfers is not binding in either state, and we have transfers in both states; when $x \geq \widehat{x}_L$, the constraint is binding in both states, so transfers are zero in both states; when $x \in (\widehat{x}_H, \widehat{x}_L)$, then the non-negativity constraint is biding in state A_H, and not binding in state A_L, implying that we have transfers only in state A_L.

3.1.2. Equilibrium Behavior in Period 1. Given the characterization of the continuation value function $v_2(x, \theta)$, we can now solve for the political equilibrium in the first period, in which forward-looking proposers and voters take into account how their current decision to save or borrow will affect their future bargaining power and the future outcomes.

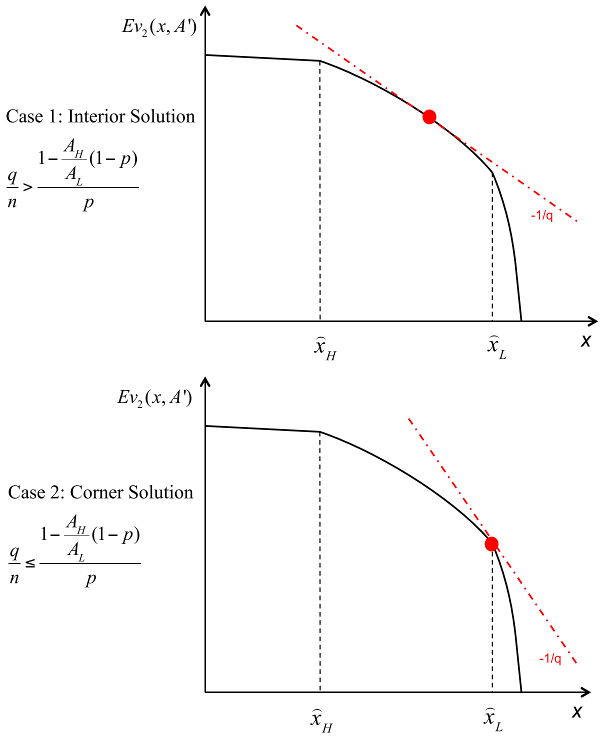

FIGURE 1. Value function in political equilibrium.

In the first period, the proposer's problem can be written as

$$\begin{aligned} \max_{s,g,x} \quad & \{W + x - (q-1)s - g + Au(g) + \delta V_2(x)\} \\ \text{subj. to:} \quad & W + x - (q-1)s - g \geq 0, \\ & s \geq 0, g \geq 0, s + Au(g) + \delta V_2(x) \geq v_1. \end{aligned} \tag{7}$$

Again the proposer maximizes his own expected utility, now comprised of the transfer he can assign to himself (i.e., $W + x - (q-1)s - g$), the value of public good in period one ($Au(g)$), and the discounted expected continuation value as a function of debt x ($\delta v_2(x)$). The first constraint is the budget constraint; the second and third constraints are the non-negativity constraint on public good and districts' transfers; and the fourth constraint is the incentive compatibility constraint for coalition members, where v_1 is the expected period 1 utility before the proposer has been selected.[9]

9. There are two additional constraints: $x \in [-W, W/(1+r)]$. These constraints are never binding because of the Inada conditions on $u(g)$, in particular because $\lim_{g\to 0^+} u'(g) = \infty$, so we drop them.

To solve this problem, we first note that

$$W + x - (q-1)s - g \geq 0 \text{ and } s \geq 0 \tag{8}$$

imply $W + x - g \geq 0$. So the following problem is a relaxed version of (7):

$$\max_{s,g,x} \quad \{W + x - (q-1)s - g + Au(g) + \delta V_2(x)\}$$
$$\text{subj. to:} \quad s + Au(g) + \delta V_2(x) \geq v_1,$$
$$W + x - g \geq 0. \tag{9}$$

If we find a solution of this problem that satisfies (8), then we have a solution of (7). In (9), moreover, we can assume without loss of generality that the first constraint is satisfied as equality; so after eliminating irrelevant constants, we have the following:

$$\max_{s,g,x} \quad \{x + Aqu(g) - g + \delta q V_2(x)\}$$
$$\text{subj. to:} \quad W + x - g \geq 0. \tag{10}$$

To solve (10), the key consideration is the determination of debt, since this determines the resources available at $t = 1$ and at $t = 2$. As in the planner case, the proposer will try to equalize the marginal utility of a dollar at time $t = 1$ to the expected marginal utility at $t = 2$. Because the expected value function is not differentiable in x, however, the analysis is less straightforward than in Section 3. In the Appendix, we show that only two cases are possible. When $q/n > (1 - (A_H/A_L)p)/(1 - p)$, the optimal value is $x^\star \in (\widehat{x}_H, \widehat{x}_L)$. In this case the marginal value of a unit of debt at time t is exactly equal to the marginal expected cost at $t = 2$. See Case 1 of Figure 1. When, instead, $q/n \leq (1 - (A_H/A_L)p)/(1 - p)$, debt is at a corner solution at $\widehat{x}_L$, where the value function is not differentiable (Case 2 of Figure 1). Interestingly, this is not just a theoretical possibility that occurs for nongeneric parameter sets: it occurs for any $q/n \leq (1 - (A_H/A_L)p)/(1 - p)$.

Notice that in both cases, $x^\star > \widehat{x}_H$. This implies that there are never transfer in equilibrium in the high value state. All the remaining budget is allocated to the public good if $\theta = H$. This discussion leads to the following characterization of the political equilibrium of the two stage game. A formal proof of the proposition is given in the Appendix.

PROPOSITION 2. *In a political equilibrium, policies are given by*

$$x^\star = \begin{cases} \dfrac{W - [u']^{-1}\left(\frac{1/q - (1-p)/n}{pA_H}\right)}{1+r} & \text{if } \frac{q}{n} > \dfrac{1 - \frac{A_H}{A_L}p}{(1-p)} \\ \dfrac{W - [u']^{-1}\left(\frac{1}{A_L q}\right)}{1+r} & \text{if } \frac{q}{n} \leq \dfrac{1 - \frac{A_H}{A_L}p}{(1-p)} \end{cases}, \tag{11}$$

$$g_1^\star = [u']^{-1}\left(\frac{1}{qA}\right), \tag{12}$$

$$g_{2L}^{\star} = [u']^{-1}\left(\frac{1}{qA_L}\right), \tag{13}$$

$$g_{2H}^{\star} = W - (1+r)x^{\star} = \left[u'\right]^{-1}\left(\frac{1/q - (1-p)/n}{pA_H}\right),$$

$$s_1^{\star} = \frac{W + x^{\star} - g_1^{\star}}{n},$$

$$s_{2\theta}^{\star} = \frac{W - (1+r)x^{\star} - g_{2\theta}^{\star}}{n}, \ \theta = \{H, L\},$$

$$\pi_1^{\star} = \left(1 - \frac{q-1}{n}\right)\left(W + x^{\star} - g_1^{\star}\right),$$

$$\pi_{2\theta}^{\star} = \left(1 - \frac{q-1}{n}\right)\left(W - (1+r)x^{\star} - g_{2\theta}^{\star}\right), \ \theta = \{H, L\},$$

where π is the transfer to the proposer.

Political decision making distorts policy choices. The proposition identifies two sources of these distortions. First, the proposer must attract support for his proposal from $q-1$ coalition partners. Accordingly, given that utility is transferable, he is effectively constructing a proposal that maximizes the utility of q committee members. The fact that q is less than n means that the decisive coalition does not fully internalize the costs of reducing public good spending. Hence, the right hand side of equations (12) and (13) have q in the denominator instead of n (as in the planner's solution). If the legislature operated by unanimity rule (i.e., $q = n$), then legislative decision making would reproduce the optimal solution. This follows immediately from Proposition 2 once it is noted that, with $q = n$, the public good levels are just the optimal levels and the debt level, $x^{\star}$, equals the upper bound of x^O. More generally, moving from majority to super-majority rule will improve welfare, since raising q reduces debt and raises public good.

Second, the uncertainty about proposal power in the legislature at $t = 2$ creates uncertainty about the identity of the minimum winning coalition. This uncertainty means that the proposer is tempted to issue more debt. Issuing an additional dollar of debt would gain $1/q$ units for each committee member in the minimum winning coalition and would lead to a one-unit reduction in pork in the next period, when the marginal utility from the public good is low. This has an expected cost of only $(1-p)/n$ because members of the current minimum winning coalition are not sure they will be included in the next period, and because there is uncertainty over the future state of the world.

Comparing (5) and (11) we have the following.

COROLLARY 3. *In any political equilibrium, if $q < n$ then debt is higher than efficient and g is lower than efficient in all periods and all states. If $q = n$, then both debt and public good provision are efficient.*

The fact that political decision making introduces dynamic distortions is highlighted by a failure of the Euler equation (6).

COROLLARY 4. *In any political equilibrium, if $q < n$, we have $Au'(g_1^\star) < E[A_\theta u'(g_{2\theta}^\star)]$.*

The failure of the Euler equation highlighted in Corollary 4 is at the core of the inefficiency problem associated with legislative choice of public debt. If the same minimal winning coalition of q committee members chose the policy in both periods, the outcome would internalize only the utilities of q agents and so would differ from the utilitarian optimum of Proposition 1. Still, that solution would coincide with the Pareto efficient solution corresponding to welfare weights that are positive only for the coalition members: and therefore it would satisfy the Euler equation. The equilibrium of Proposition 2, on the contrary, does not correspond to the Pareto optimum for *any* choice of welfare weights. The reason for this is that the minimal winning coalition at $t = 2$ is uncertain and typically different from the coalition at $t = 1$. Hence the coalition members at $t = 1$ tend to underestimate the marginal benefit of resources at $t = 2$: this leads to a failure of the Euler equation. Therefore, the equilibrium of Proposition 2 is Pareto inefficient.

Proposition 2 also highlights how majority rules affect the provision of private transfers and its distribution among members of a coalition: the amount of resources devoted to pork in the first period, $W + x^\star - g_1^\star$, is increasing in the equilibrium level of debt and decreasing in the equilibrium level of public good provided in that period. As debt decreases and public good provision increases with q, the total amount of private transfers is decreasing in q. As debt decreases with p and public good provision is unaffected by it, the total amount of private transfers is decreasing in p. In a symmetric equilibrium, the continuation value of each committee member is $(W + x^\star - g_1^\star)/n + Au(g_1^\star)$ and, thus, the amount of pork that makes a committee member indifferent between accepting and rejecting a proposal is $(W + x^\star - g_1^\star)/n$. This means that the proposer can allocate to his district $(1 - (q - 1)/n)$ of the total amount of resources devoted to private transfers, a fraction that is decreasing with q and unaffected by p.

3.2. Equilibrium Behavior with Commitment

We now consider a legislature that, in the first period, is able to commit on a contingent plan of action for the second period, that is, on an allocation of future resources as a function of the realized state of the world. In this institutional framework, the same minimum winning coalition decides on the allocation of resources in both periods. Thus, comparing equilibrium behavior in this setting with equilibrium behavior without commitment allows us to assess the effect of political uncertainty on economic outcomes.

To make its single decision, the committee uses a bargaining protocol similar to the one described previously. One of the committee members is randomly selected to make a policy proposal for period 1, period 2 in state A_H, and period 2 in state A_L, with each member having an equal chance of being recognized. A proposal is described by a $(3n + 4)$-tuple $\{x, g_1, s_1^1, \ldots, s_1^n, g_{2H}, s_{2H}^1, \ldots, s_{2H}^n, g_{2L}, s_{2L}^1, \ldots, s_{2L}^n\}$, where x is the proposed level of public debt; g_1 is the proposed amount of public good provided at $t = 1$; $g_{2\theta}$ is the proposed amount of public good provided at $t = 2$ in state A_θ; s_1^i is the proposed transfer to district i's residents at $t = 1$; and $s_{2\theta}^i$ is the proposed transfer to district i's residents at $t = 2$ in state A_θ. This proposal must satisfy the non-negativity constraints and the budget constraints:

$$W + x \geq \sum s_1^i + g_1,$$
$$W - (1 + r)x \geq \sum s_{2L}^i + g_{2L},$$
$$W - (1 + r)x \geq \sum s_{2H}^i + g_{2H}.$$

If the proposer's plan is accepted by q committee members, then it is implemented and the game ends. If, on the other hand, the first proposal is not accepted, then another committee member is chosen randomly (with replacement) to make a proposal. This process repeats itself until a proposal is accepted by q committee members: at that point the proposal is implemented and the game ends. The proposer's problem can be written as

$$\max_{s_1, g_1, s_{2\theta}, g_{2\theta}, x} \begin{cases} W + x - (q-1)s_1 - g_1 + Au(g_1) \\ \quad + \delta(1-p)[W - (1+r)x - (q-1)s_{2L} - g_{2L} + A_L u(g_{2L})] \\ \quad + \delta p[W - (1+r)x - (q-1)s_{2H} - g_{2H} + A_H u(g_{2H})] \end{cases}$$

$$\begin{aligned} \text{subj. to:} \quad & W + x - (q-1)s_1 - g_1 \geq 0, \\ & W - (1+r)x - (q-1)s_{2\theta} - g_{2\theta} \geq 0, \\ & s_1 \geq 0, s_{2\theta} \geq 0, g_1 \geq 0, g_{2\theta} \geq 0, \\ & s_1 + Au(g_1) + \delta p[s_{2H} + A_H u(g_{2H})] \\ & \quad + (1-p)[s_{2L} + A_L u(g_{2L})] \geq v^C. \end{aligned} \tag{14}$$

The last constraint is the incentive compatibility constraint for coalition members, where v^C is the expected utility from the game before the proposer has been selected. As before, we can assume without loss of generality that this constraint is satisfied with equality and solve a relaxed version of (14). Noting that r is the equilibrium interest rate and eliminating irrelevant constants, we have

$$\max_{g_1, g_{2\theta}} \{q[Au(g_1) + \delta p A_H u(g_{2H}) + \delta(1-p)u(g_{2L})] - g_1 - \delta p g_{2H} - \delta(1-p)g_{2L}\} \tag{15}$$

A solution to (15) that satisfies the budget and non-negativity constraints is a solution to (14). The FOCs with respect to public good provision are

$$u'\left(g_1^C\right) = \frac{1}{qA}, u'\left(g_{2H}^C\right) = \frac{1}{qA_H}, u'\left(g_{2L}^C\right) = \frac{1}{qA_L}. \tag{16}$$

Any level of debt $x \in [-W, W/(1+r)]$ that allows these levels of public goods to be feasible is part of an optimal proposal. Since private transfers enter legislators' utilities linearly, coalition partners are indifferent among any triplet $\{s_1, s_{2H}, s_{2L}\}$ such that $s_1 + \delta p s_{2H} + \delta(1-p)s_{2L}$ is unchanged and the proposer is indifferent among any triplet $\{\pi_1, \pi_{2H}, \pi_{2L}\}$ such that $\pi_1 + \delta\pi s_{2H} + \delta(1-p)\pi_{2L}$ is unchanged. This discussion leads to the following characterization of the political equilibrium of the game with commitment.

PROPOSITION 3. *In a political equilibrium with commitment, policies are given by*

$$x^C \in \left[g_1^C - W, \frac{W - g_{2H}^C}{1+r}\right],$$

$$g_1^C = [u']^{-1}\left(\frac{1}{qA}\right), \quad g_{2L}^C = [u']^{-1}\left(\frac{1}{qA_L}\right), \quad g_{2H}^C = [u']^{-1}\left(\frac{1}{qA_H}\right),$$

$$s_1^C + \delta p s_2^C + \delta(1-p)s_2^C = \frac{(1+\delta)W - g_1^C - \delta p g_{2H}^C - \delta(1-p)g_{2L}^C}{n},$$

$$\begin{aligned}\pi_1^C + \delta p \pi_2^C + \delta(1-p)\pi_2^C &= (1+\delta)W - g_1^C - \delta p g_{2H}^C - \delta(1-p)g_{2L}^C \\ &\quad + -(q-1)\frac{(1+\delta)W - g_1^C - \delta p g_{2H}^C - \delta(1-p)g_{2L}^C}{n}.\end{aligned}$$

The lower bound on the equilibrium level of debt corresponds to a solution to the proposer's problem where no private transfers are offered in the first period. On the other hand, the upper bound on the equilibrium level of debt corresponds to a solution to the proposer's problem where no private transfers are offered in the second period.

An immediate implication of equations (16) is the following corollary.

COROLLARY 5. *In any political equilibrium with commitment we have* $Au'(g_1^C) = E[A_\theta u'(g_{2\theta}^C)]$.

Despite the fact that policies are chosen by a committee formed by a minimal winning coalition (and q can be strictly lower than n), when the minimal winning coalition at $t = 1$ can commit, then we have no dynamic inefficiency, as measured by a systematic deviation from the Euler equation. This is because dynamic policy distortions do not depend on the use of a $q < n$ rule, but result from the dynamic inconsistency due to a potential change in proposer from $t = 1$ to $t = 2$.

3.3. Summary of Hypotheses Derived from the Theoretical Model

The model offers a number of testable hypotheses, which the laboratory experiment is specifically designed to investigate.

On Period 1: Outcomes and Behavior

HYPOTHESIS 1. *Public debt is decreasing in q/n.*

HYPOTHESIS 2. *Public good provision is increasing in q/n.*

HYPOTHESIS 3. *If $q < n$, then public debt is greater than the efficient level.*

HYPOTHESIS 4. *If $q < n$, then public good provision is inefficient.*

HYPOTHESIS 5. *Public debt is weakly decreasing in p, the probability society incurs a crisis.*

HYPOTHESIS 6. *Public good provision does not depend on p.*

HYPOTHESIS 7. *Pork is distributed to exactly q committee members.*

HYPOTHESIS 8. *Pork to the proposer is decreasing in q/n.*

HYPOTHESIS 9. *Pork to the proposer is weakly decreasing in p.*

On Period 2: Outcomes and Behavior

HYPOTHESIS 10. *For any level of debt: if $q < n$, then public good provision is inefficient.*

HYPOTHESIS 11. *For any level of debt: public good provision is weakly increasing in q/n.*

HYPOTHESIS 12. *For any level of debt: pork to the proposer is weakly decreasing in q/n.*

On Dynamic Distortions

HYPOTHESIS 13. *If $q < n$, there are dynamic inefficiencies: $Au'(g_1^\star) < E[A_\theta u'(g_{2\theta}^\star)]$.*

On Commitment

HYPOTHESIS 14. *If $q < n$, commitment reduces debt.*

HYPOTHESIS 15. *For any q, commitment eliminates dynamic inefficiencies: $Au'(g_1^C) = E[A_\theta u'(g_{2\theta}^C)]$.*

4. Experimental Design

The experiments were conducted at the Social Science Experimental Laboratory (SSEL) using students from the California Institute of Technology, at the Columbia Experimental Laboratory for the Social Sciences (CELSS) using students from Columbia University, and at Bocconi Experimental Laboratory for the Social Sciences (BELSS) using students from Bocconi University.[10] Subjects were recruited from a database of volunteer subjects. Seventeen sessions were run, using a total of 235 subjects. No subject participated in more than one session. In all sessions, the committees were composed of five members ($n = 5$), the exogenous amount of resources in each period was $W = 150$, there was no discounting between periods ($\delta = 1$, with associated interest rate $r = 0$), and the payoff from the public good was proportional to the square root of the amount invested in the public good in that period, $u(g_t) = \sqrt{g_t}$, and, therefore, $A_t u(g_t) = A_t \sqrt{g_t}$. The multiplier of this public good utility, A, was always 3 in the first period but it was either $A_L = 1$ or $A_H = 5$ in the second period.

Our experimental treatments are the majority requirement for passage of a proposal (i.e., the political institution, q), the probability distribution of the public good marginal benefit in the second period (i.e., the chance of an economic crisis, p), and whether decisions are made with or without commitment on the allocation of second period's resources. Nine sessions were run using a simple majority requirement to pass a proposal ($q = 3$, M), three sessions using a super majority requirement ($q = 4$, S), and three sessions using a minority requirement or, as we refer to it in the remainder, an oligarchic rule ($q = 2$, O). In three sessions with simple majority and in all sessions with super majority and oligarchy, there was the same chance of a high shock ($A_H = 5$) or a low shock ($A_L = 1$) to the marginal benefit from the public good in the second period ($p = 0.5$). In three sessions with simple majority, there was a low chance of a high shock to the public good marginal benefit in the second period (i.e., the probability of $A_H = 5$ was $p = 1/12$). In five sessions with simple majority and a high chance of a high shock to the public good, committees decided at the beginning of the game on a contingent plan of action for the allocation of resources in the two periods. In the other twelve sessions, committees decided at the beginning of each period on the allocation of resources available in that period.

Sessions were conducted with 10, 15, or 20 subjects, divided into committees of 5 members each. Each session consistent of 20 matches, or repetition of the game. Committees stayed the same throughout the two periods of a given match, and subjects were randomly rematched into new committees between matches. The experiment was designed so that it lasted 2 h.[11] Table 1 summarizes the design.

10. The experiment was conducted with the same software, protocol, and instructions (in English) at all three locations, with payment in dollars or euros.

11. Because of time constraints, fewer than 20 matches were run in some of the sessions. This was caused primarily by some subjects taking an unexpectedly long time to enter their proposals, perhaps because of

TABLE 1. Experimental design.

Majority rule	Risk	Commit	n	q	p	Sessions	Committees	Subjects
Oligarchy (O)	High	No	5	2	1/2	3	160	40
Simple Majority (M)	High	No	5	3	1/2	3	180	45
Super Majority (S)	High	No	5	4	1/2	3	100	50
Simple Majority (M)	Low	No	5	3	1/12	3	165	50
Simple Majority (M)	High	Yes	5	3	1/2	5	162	50

Before the first match, instructions were read aloud, followed by a practice match and a comprehension quiz to verify that subjects understood the details of the environment including how to compute payoffs. The experiments were conducted via computers.[12] The current period's payoffs from the public good investment (called *project size* in the experiment) was displayed graphically, with the size of public good on the horizontal axis and the corresponding payoff on the vertical axis. Subjects could click anywhere on the curve and the payoff for that level of public good appeared on the screen.

Each period has two separate stages, the proposal stage and the voting stage.[13] At the beginning of each match, each member of a committee is randomly assigned a committee member number that stays the same for both periods of the match. In the proposal stage, each member of the committee submits a *provisional budget* for how to divide the budget between the public good, called *public project*, and private allocations to each member. After everyone has submitted a proposal, one is randomly selected and becomes the *proposed budget*. Members are also informed of the committee member number of the proposer, but not informed about the unselected provisional budgets. Each member then casts a vote for or against the proposed budget. The proposed budget passes if and only if it receives at least q votes. If the proposed budget receives less than q votes, then another round of bargaining occurs: each member of the committee submits a new provisional budget; one provisional budget is randomly selected; and each member casts a vote for or against the proposed budget. This process continues until a proposed allocation passes.[14] Payoffs for that period are added to each subject's earnings. At the end of the last match each subject is paid privately in cash the sum of

the strategic complexity of the game. In particular, subjects played 10 matches in all sessions with $q = 4$; 15 matches in two sessions with $q = 3$ and $p = 1/12$; 8 matches in one session with commitment; and 13 matches in one session with commitment. Both periods of the game were completed in all matches that were run. A consequence of the shortened sessions is that the data is not completely balanced. Online Appendix B presents robustness checks using only the first 10 matches of each session without commitment and the results are essentially unchanged. For sessions with commitment, we present robustness checks excluding the shortened sessions and results are unchanged (see footnote 37).

12. The computer program used was an extension to the open source Multistage game software. See http://multistage.ssel.caltech.edu. A sample copy of the instructions from one of the sessions is in Online Appendix C.

13. In the sessions with commitment, proposing and voting only take place in the first period.

14. Eighty-seven percent of the periods ended either immediately or after only one failed vote.

TABLE 2. Theoretical predictions for experimental parameters, period 1 outcomes.

	No commitment				Commitment	Optimum
	High risk			Low risk	High risk	
	O	M	S	M	M	
Public debt	140.2	121.3	80.6	147.8	[−12.8, 93.8] (40.5)	[−6.3, −93.8] (43.8)
Public good	9.0	20.3	36.0	20.3	20.3	56.3
Pork to proposer	225.0	150.6	77.8	166.5	[0, 150.3] (75.2)	–
Pork to partner	56.2	50.2	38.9	55.5	[0, 50.1] (25.1)	–
Pork to MWC	281.2	251.0	194.5	277.5	[0, 250.5] (125.3)	–
Total pork	281.2	251.0	194.5	277.5	[0, 250.5] (125.3)	[0, 87.5] (43.8)

Notes: When the prediction is an interval, we report the midpoint of this interval in parentheses.

his or her earnings over all matches they played plus a show-up fee. Average earnings, including the show-up fee, were $24.

Table 2 summarizes the theoretical properties of the political equilibrium in period 1 for the five treatments, as well as the optimal policies.[15] It is useful to emphasize that, as proven in the Appendix, given these parameters the public debt and public good levels are uniquely defined for all treatments without commitment. For the treatment with commitment, this is true only for public good levels. Nonetheless, the theory predicts sharp treatment effects for the level of public debt.

5. Experimental Results

Because we are interested in the accumulation of public debt and in the role of intertemporal incentives, we begin the analysis of results by focusing on outcomes and behavior in period one of the game. The analysis of period two outcomes and behavior is briefly presented in the second part of this section. Period 2 results offer fewer insights into the dynamics of public debt accumulation and public good provision, which is the central question of this study, as the second period is a static bargaining game with no future considerations.

5.1. Period 1

5.1.1. Period 1 Outcomes. We start the analysis of the experimental results by looking at outcomes by treatment. Table 3, Table 4, Figure 2, and Figure 3 compare

15. As discussed in the following section, our analysis focuses on period 1 outcomes. Theoretical predictions for period 2 outcomes are summarized in Table B.1 in Online Appendix B.

TABLE 3. Outcomes in approved allocations, period 1, comparison of majority rules.

	High risk								
	Oligarchy Obs: 160			Simple Maj Obs: 180			Super Maj Obs: 100		
	Theory	Mean	SE	Theory	Mean	SE	Theory	Mean	SE
Public debt	140.2	98.8	5.3	121.3	12.5	3.3	80.6	−2.9	3.8
Public good	9.0	25.9	4.0	20.3	36.8	2.2	36.0	54.1	3.0
Pork to proposer	225.0	108.6	4.7	150.6	39.2	1.7	77.8	19.7	0.8
Pork to MWC	281.2	202.0	8.4	251.0	112.1	4.8	194.5	78.5	3.1
Total pork	281.2	222.8	7.1	251.0	125.7	4.1	194.5	93.0	3.3

TABLE 4. Outcomes in approved allocations, period 1, comparison of economic risk.

	High risk			Low risk		
	Simple Maj Obs: 180			Simple Maj Obs: 165		
	Theory	Mean	SE	Theory	Mean	SE
Public debt	121.3	12.5	3.3	147.8	57.9	5.7
Public good	20.3	36.8	2.2	20.3	39.8	3.7
Pork to proposer	150.6	39.2	1.7	166.5	49.6	2.8
Pork to MWC	251.0	112.1	4.8	277.5	142.2	7.8
Total pork	251.0	125.7	4.1	277.5	168.2	7.1

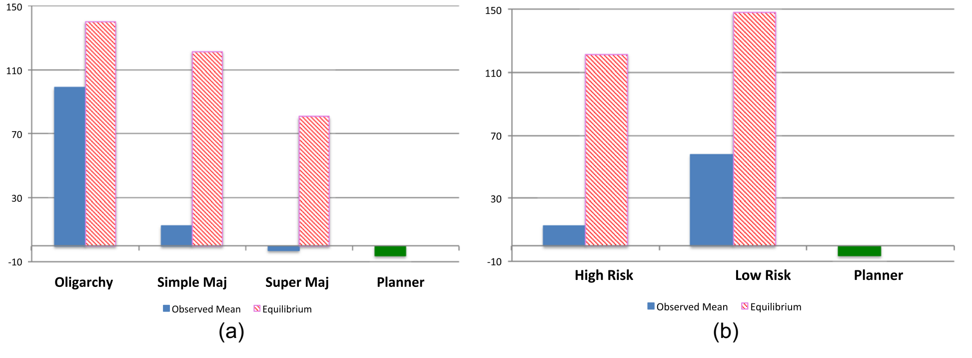

FIGURE 2. Average public debt in approved allocations. (a) Comparison of majority rules ($p = 1/2$). (b) Comparison of economic risk ($q = 3$).

the observed levels of public debt and public good by treatment. To aggregate across committees, we use the average level of public debt and public good from all first period committees. We compare these outcomes to the policies predicted by the political equilibrium and to the optimum.

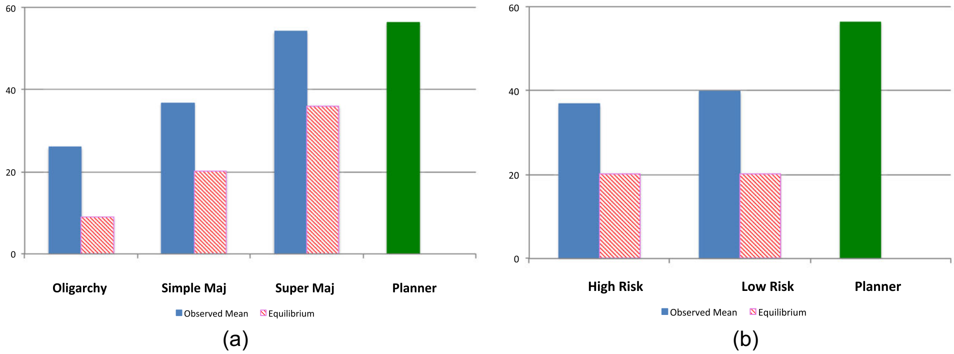

FIGURE 3. Average public good in approved allocations, period 1. (a) Comparison of majority rules ($p = 1/2$). (b) Comparison of economic risk ($q = 3$).

Finding 1: In line with Hypotheses 1 and 2, higher q leads to lower public debt and higher public good provision. The average level of public debt is positive in Oligarchy and Simple Majority, and negative in Super Majority. According to Wilcoxon–Mann–Whitney tests,[16] the level of debt in Oligarchy is higher than the level of debt in each of the other two voting rules (Simple Majority and Super Majority); and the level of debt in Simple Majority is higher than the level of debt in Super Majority.[17] In Oligarchy, 52% (83/160) of committees spend its whole intertemporal budget in the first period—that is, these committees incur a debt of 300 and have no resources to allocate in the second period. This fraction goes down to 8% in Simple Majority (14/180) and 1% (1/100) in Super Majority.

Regarding the provision of public goods, the average level is 25.9 in Oligarchy, 36.8 in Simple Majority, and 54.1 in Super Majority. These differences are statistically significant at the 1% level.[18]

16. Unless otherwise noted, our significance tests are based on Wilcoxon–Mann–Whitney tests. The null hypothesis of a Wilcoxon–Mann–Whitney test is that the underlying distributions of the two samples are the same. We are treating as unit of observation a single group. The results are unchanged if we use t-tests for differences in means. Because the same subject makes more than one decision in a session, observations are not independent across subjects. The treatment effects are so strong that most remain statistically significant using Mann–Whitney tests even with the extreme correction of using as unit of observation the average outcome in a session, although this drastically reduces the sample size in our data from between $n = 100$ and $n = 180$ to $n = 3$ for each treatment. The only exception is the difference between M and S in the pork to the proposer in the second period in the state where the public good is valuable.

17. The p-values of Wilcoxon–Mann–Whitney tests are presented on Table B.2 in Online Appendix B. The differences between Oligarchy and Simple Majority and between Oligarchy and Super Majority are significant at the 1% level. The difference between Simple Majority and Super Majority is significant at the 10% level (p-value 0.0557). The difference between each pair of voting rules is significant at the 1% level according to the results of t-tests (see Table B.3 in Online Appendix B).

18. The p-values of Wilcoxon–Mann–Whitney tests are presented on Table B.2 in Online Appendix B. According to t-tests, the difference between O and M is significant at the 5% level (p-value 0.0145), the

Finding 2: In line with Hypotheses 3 and 4, Oligarchy and Simple Majority lead to inefficient debt and inefficient public good levels; contrary to Hypotheses 3 and 4, Super Majority leads to almost optimal savings and almost optimal public good provision. In the optimal policy, there is a period one budget surplus (negative debt) in order to guarantee the efficient provision of public good in both states of the world in the second period. The minimum amount of budget surplus that guarantees efficient public good provision when the future marginal value of the public good is high is 6.25 (i.e., a negative debt of −6.25). The average debt in Oligarchy and Simple Majority is significantly greater than zero (12.5 in Simple Majority and 98.8 in Oligarchy, p-value <0.001), although in all majority rules it is significantly less than predicted (p-value <0.001). On the other hand, the average debt in Super Majority is slightly negative (−2.9) and we cannot reject the hypothesis that the amount saved in committees that decide by Super Majority is equal to the amount of savings in the optimal policy.[19]

We draw similar conclusions regarding public good provision. The average public good level is significantly less than the efficient level of 56.25 for Oligarchy and Simple Majority (p-value <0.001), although in all majority rules it is significantly greater than predicted (p-value <0.001). We cannot reject the hypothesis that the average public good level in Super Majority (54.1) is equal to the optimum.

Finding 3: In line with Hypotheses 5 and 6, higher p leads to lower public debt but does not affect public good provision. In addition to manipulating voting rules, we test the effect on public policies of another important dimension: how decreasing the risk of a shock to society affects the accumulation of debt in the first period. According to the theory, in a political equilibrium, public debt is sensitive to the probability of a shock: the current proposer has a larger incentive to provide private transfers when it is less likely that a shock will occur and public good will be valuable. In the experiments, the average level of public debt approved in committees that decide by Simple Majority when $p = 1/2$ is 12.5; the average level of public debt approved in committees that decide by Simple Majority when $p = 1/12$ is 57.9. The difference is statistically significant at the 1% level.[20] The average public good level in committees that decide by Simple Majority and face either a high or low risk of a shock to society is indistinguishable (36.8 for committees with high risk and 39.8 for committees with low risk). This lack of an equilibrium treatment effect of p on g is implied by the theory.

Since private transfers are common, it is interesting to check whether transfers are egalitarian or whether they are mainly concentrated on a minimal winning coalition of voters; and whether we observe proposer's advantage in the distribution of pork. Figure 4 shows the distribution of transfers in accepted proposals when committee members are indexed in decreasing order of their allocation.

differences between O and S and between M and S are significant at the 1% level (see Table B.3 in Online Appendix B).

19. The p-value associated with a t-test is equal to 0.3799.

20. See Table B.2 in Online Appendix B.

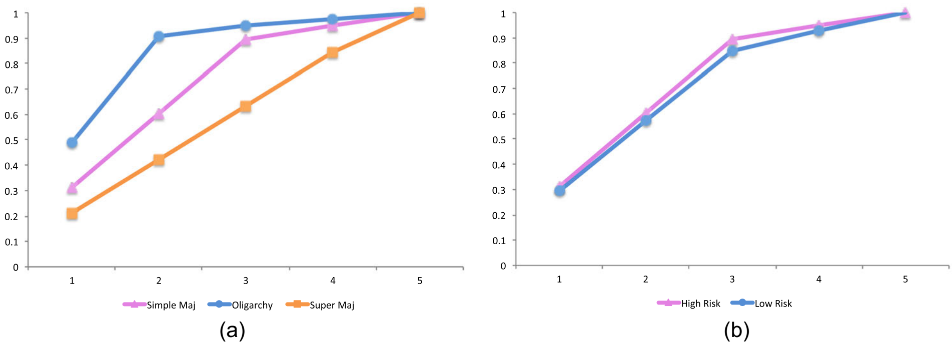

FIGURE 4. Cumulative distribution of transfers. (a) Comparison of majority rules ($p = 1/2$). (b) Comparison of economic risk ($q = 3$).

Finding 4: In line with Hypothesis 7, in Oligarchy and Simple Majority, a minimum winning coalition of agents receives a more than proportional share of transfers; in Super Majority transfers tend to be more egalitarian. In the Oligarchy treatment, 91% of the private transfers goes to the proposer and one other minimum winning coalition partner. In the Simple Majority treatments (pooling together committees with different risk), 87% goes to the proposer and two other minimum winning coalition partners. In Super Majority, proposed allocations of the private good tend to be more equitable; the proposer is allocated 21% and the member allocated the least receives 16% on average. In all treatments, the proposer receives a smaller fraction of private transfers than predicted (49% vs. 80% in Oligarchy, 30% vs. 60% in Simple Majority, and 21% vs. 40% in Super Majority). These observations are in line with findings reported in other experiments on legislative bargaining (Frechette, Kagel, and Lehrer 2003; Frechette, Kagel, and Morelli 2012).[21]

Finding 5: In line with Hypotheses 8 and 9, pork to the proposer is decreasing in q and in p. Keeping the risk of a shock constant, the average pork to the proposer is 108.6 in Oligarchy, 39.2 in Simple Majority and 19.7 in Super Majority. These differences are statistically significant at the 1% level.[22] Keeping the majority rule constant, the average pork to the proposer is 39.2 with a high risk of a shock and 49.6 with a low risk of a shock. This difference is statistically significant at the 10% level.[23]

21. Nunnari and Zapal (2016) study a multilateral bargaining game à la Baron and Ferejohn (1989)—that is, with no public good provision and a single period—and show that allowing for imperfect best response (quantal response equilibrium) reduces the share to the proposer and increases the incidence of nonminimum winning coalitions with respect to the prediction of a model where agents best respond perfectly.

22. The p-values associated with the Wilcoxon–Mann–Whitney tests are 0.0000 for the three pairwise comparisons. The results are unchanged if we use t-tests instead.

23. The p-value associated with the Wilcoxon–Mann–Whitney test is 0.0755. The same difference is significant at the 1% level according to the result of a t-test (p-value: 0.0016).

TABLE 5. Average outcomes in approved allocations, period 1, all treatments, early (1–5) versus late (6+) matches.

	High risk				Low risk			
	Oligarchy		Simple Maj		Super Maj		Simple Maj	
	Early	Late	Early	Late	Early	Late	Early	Late
Public debt	53.9	113.7**	9.4	13.5	1.1	−6.9	36.5	67.3*
Public good	29.0	24.9	38.2	36.3	57.3	50.8	58.7	31.5*
Pork to proposer	77.2	119.0**	37.3	39.9	19.8	19.5	34.1	56.2**
Pork to MWC	150.8	219.1**	107.5	113.6	79.0	78.0	100.3	160.5**
Total pork	174.9	238.8**	121.1	127.2	93.8	92.2	127.8	185.7**
Observations	40	120	45	135	50	50	50	115

Notes: Significant differences between the late and early matches are indicated by a single asterisk for significance at the 5% level and a double asterisk for significance at the 1% level.

The Effect of Experience. Although the period-one comparative static predictions of the theory are supported in the data, we observed significantly less debt on average than the theoretical equilibrium level, significantly less pork than the equilibrium amount, and there is a lot of variance across committees.[24] One possibility is that the multiperiod-period game is sufficiently complicated for subjects that it takes some time for them to learn. Recall that the theoretical solution is based on backward induction, so period one equilibrium behavior imposes rational expectations about period two behavior. Thus it would not be surprising if these expectations were adapted over time, in response to accumulated experience about period two behavior. To explore this possibility, we compare the average period one outcomes in the early matches (1–5), when subjects were relatively inexperienced, to the later matches (6–20), after subjects had been exposed to feedback and a chance to learn.[25] If there were significant learning effects, in theory this should go in the direction of the equilibrium outcomes.

Table 5 reports the period one outcome averages, broken down into the two experience levels, for each treatment. Except for the supermajority treatment, where the experience effects are negligible, all differences are in the theoretically expected direction, that is, the outcome averages in the later matches are always closer to equilibrium than the early matches. These differences are statistically significant for the oligarchy and low-risk majority treatments. This is summarized as follows.

24. As a simple illustration of the variance, as shown in Table 6, in the Oligarchy treatment 53% of proposals exhibit the maximum possible debt, leaving no budget at all for period two, whereas 21% of proposals have zero debt.

24. As a simple illustration of the variance, as shown in Table 6, in the Oligarchy treatment 53% of proposals exhibit the maximum possible debt, leaving no budget at all for period two, whereas 21% of proposals have zero debt.

25. For the supermajority sessions, there were only 10 matches of play, so the experienced rounds were 6–10. In two sessions with simple majority and low risk, there were only 15 matches of play, so the experienced rounds were 6–15.

TABLE 6. Proposal types and acceptance rates by treatment, period 1.

	High risk				Low risk			
	Oligarchy		Simple Maj		Super Maj		Simple Maj	
Proposal type	% Pr	% Ac	% Pr	% Ac	% Pr	% Ac	% Pr	% Ac
Positive debt	0.70	0.88	0.17	0.62	0.20	0.42	0.59	0.78
– Debt ∈ (0, 150)	0.17	1.00	0.09	0.56	0.16	0.50	0.28	0.75
– Spend everything	0.53	0.83	0.08	0.67	0.05	0.14	0.31	0.81
Balanced budget	0.21	0.96	0.68	0.86	0.53	0.70	0.29	0.87
Negative debt (savings)	0.10	0.94	0.15	0.39	0.26	0.36	0.13	0.41
– Debt ∈ (0, −150)	0.09	0.94	0.13	0.41	0.20	0.40	0.11	0.42
– Save everything	0.01	–	0.02	0.25	0.07	0.20	0.01	0.00
All proposals	1.00	0.89	1.00	0.75	1.00	0.56	1.00	0.74

Note: In Oligarchy, no 'Save Everything' proposal was selected to be voted on.

Finding 6: With oligarchy and with simple majority and low risk of a shock, experienced subjects accumulate more debt, provide less public good and distribute more private transfers. In the other treatments, experience has no effect on first period outcomes.

5.1.2. Period 1 Proposing Behavior. We now turn to a descriptive analysis of the proposed allocations, as a function of q and p. For this analysis we focus on the amount of debt proposed. Table 6 shows the breakdown of proposals for the four treatments. In each treatment, the first column lists the proportion of proposals of each type that were proposed at the provisional stage (i.e., before a proposal was randomly selected to be voted on). The second column gives the proportion of proposals of each type that passed when they were voted on.

In Simple Majority with High Risk and Super Majority, most first period proposals balance the budget: in Simple Majority with High Risk, 68% of all first period budget proposals use exactly W, the per-period flow of societal resources (i.e., they balance the budget); in Oligarchy, Simple Majority with Low Risk, and Super Majority, these balanced budget proposals account for, respectively, for 21%, 29%, and 53%.[26]

26. The fraction of provisional proposals and accepted proposals that balance the budget changes with experience but there is no consistent trend across different treatments. The incidence of provisional proposals that balance the budget is significantly decreasing with experience in Oligarchy (35% in early matches vs. 16% in late matches; p-value of a Wilcoxon–Mann–Whitney test is 0.000) and Simple Majority with Low Risk (33% in early matches vs. 27% in late matches; p-value = 0.025); it is significantly increasing with experience in Simple Majority with High Risk (62% in early matches vs. 70% in late matches; p-value = 0.007); and it is unaffected by experience in Supermajority (52% in early matches vs. 54% in late matches; p-value = 0.618). The incidence of accepted proposals that balance the budget is significantly decreasing with experience in Oligarchy (28% in early matches vs. 11% in late matches; p-value = 0.011) and Simple Majority with Low Risk (42% in early matches vs. 27% in late matches; p-value = 0.057) and it is unaffected by experience in Simple Majority with High Risk (78% in early matches vs. 80% in late matches; p-value 0.750) and Super Majority (76% in early matches vs. 62% in late matches; p-value = 0.132).

In Oligarchy and Simple Majority with Low Risk, most first period proposals accumulate debt: respectively, 70% and 59% of all first period proposals in these treatments use more than W. Interestingly, 53% of all first period proposals in Oligarchy and 31% of all first period proposals in Simple Majority with Low Risk use exactly $2W$, that is, they borrow W and leave no resources available for the second period. These extreme proposals are not far from the political equilibrium proposals that predict committees in these two treatments will spend, respectively, 97% and 99% of the overall intertemporal budget in the first period (see Table 2).

Proposals that spend less than W (i.e., saved for the second period) were uncommon in Oligarchy (9%) and Simple Majority (15% with High Risk, 13% with Low Risk), but much more common in Super Majority, where they account for 27% of all provisional proposals. In contrast to the data, the political equilibrium proposals should have displayed positive debt in all three voting rules.

5.1.3. Period 1 *Voting Behavior.*

Proposal Acceptance Rates. The theory predicts that all proposals should pass. Is this consistent with the data? Table 6 displays the probability that proposals of different type will pass for each treatment.

Finding 7: In Oligarchy and Simple Majority, most proposals pass. In Super Majority, only half of proposals pass. Overall acceptance rates are 89% in Oligarchy, 75% in Simple Majority, and 56% in Super Majority. Even if our legislative game is different from the standard Baron–Ferejohn setting, it is interesting to note that the numbers for O and M are nearly as high as the acceptance rates for first-period proposals in experiments testing that bargaining protocol with simple majority: In Frechette, Kagel, and Lehrer (2003) 96.4% of first period proposals are accepted. One surprise in the data is the relatively low acceptance rates for proposals with Super Majority. Acceptance rates differ by type of proposal. Some kinds of proposals are rejected somewhat frequently. This is particularly true for proposals that do not balance the budget. In Simple Majority committees and High Risk, 86% of proposals with a balanced budget pass but the same is true of only 62% of proposals with debt and only 39% of proposals with savings. In Super Majority committees, only 42% of proposals with debt and only 36% of proposals with savings pass, versus an acceptance rate of 70% for balanced-budget proposals.[27] This has a natural interpretation as a laboratory example of "political gridlock" that can result from using a supermajority rule.

Factors Affecting Voting. Table 7 displays the results from Logit regressions where the dependent variable is the probability of voting in favor of a proposal. An observation is a single committee member's vote decision on a single proposal.[28] The proposer's

27. The higher acceptance rate of balanced-budget proposals is statistically significant ($p < 0.05$) in all treatments except for O with Low Risk according to Logit regressions.

28. We cluster standard errors by subject to take into account possible correlations among decisions taken by the same individuals.

TABLE 7. Logit estimates of voting behavior, all treatments.

	High risk		Low risk	
	Oligarchy	Simple Maj	Super Maj	Simple Maj
EU(Accept)–EU(Reject)	0.05***	0.13***	0.08***	0.07***
	(0.007)	(0.036)	(0.025)	(0.013)
Proposer's relative greed	− 0.07	− 0.57***	− 0.09***	− 0.01
	(0.005)	(0.019)	(0.025)	(0.014)
Herfindahl index	− 4.02***	− 1.13	2.14	− 0.24
	(1.112)	(1.868)	(1.596)	(1.321)
Constant	1.60***	2.48***	1.82**	0.49*
	(0.389)	(0.695)	(0.755)	(0.274)
Pseudo-R^2	0.5630	0.4939	0.1390	0.2622
Observations	716	960	716	892

Notes: Dependent variable: Prob {vote "yes"}. SE clustered by subjects in parentheses. *Significant at 10%; **significant at 5%; ***significant at 1%.

vote is excluded.[29] The data are broken down according to the treatment. The first independent variable is the difference between EU(Accept), the expected value to the voter of a "yes" outcome, and EU(Reject), the expected value to the voter of a "no" outcome (including the discounted theoretical continuation value). Theoretically, a voter should vote yes if and only if the expected utility of the proposal passing is greater than or equal to the expected utility of rejecting it and going to a further round of bargaining within the same period. This would imply a positive coefficient on EU(Accept)–EU(Reject).

Voting behavior could be affected by factors other than just the continuation value and the expected utility from the current policy proposal—for instance, by other-regarding preferences. In order to account for this, we include two additional regressors: a Herfindahl index, that captures how unequal the proposed allocation of private good is across committee members; and the difference between the private allocation to the proposer and the private allocation offered to the voter (what we call "relative greed"). In the case of other-regarding preferences, the sign on the Herfindahl Index and Proposer's Relative Greed should be negative (in the sense that greedier or less egalitarian proposals are punished with more negative votes).

The coefficient on EU(Accept)–EU(Reject) has the correct sign and is highly significant in all treatments: the difference between the (theoretical) expected utility of the proposal and the (theoretical) expected utility of another round of bargaining is an important factor behind voting behavior. Some of the behavioral factors we introduced are statistically significant. For the Oligarchy treatment, proposals that share transfers more evenly across committee members are more likely to receive a positive vote; in the Simple Majority treatment with High Risk and in the Super Majority treatment, proposals that are less greedy receive greater support.

29. Proposers vote for their own proposals 97% of the time.

5.2. Period 2

This section examines outcomes and behavior in the second and last period of the game. At this point, committees do not make any decision regarding public debt and their budget is determined by their period one debt decision.

There are two special considerations for the analysis of period two data. First, since the resources available to period two committees depends on that committee's period one debt choice, different committees typically have different budgets at the beginning of the second period. This is a significant limiting factor for aggregating period two outcomes and behavior across committees. For example, a significant number of committees borrow W in period one and as a consequence have zero available budget for the period two. This happens in 52% of Oligarchy committees, 20% of Simple Majority committees, and 1% of Super Majority committees. Since these committees are not making any decision in the second period, they have to be excluded from the analysis, which reduces the number of observations. Second, since the state of the world is realized and publicly announced at the beginning of the period, we can pool together the data from the two risk treatments using a Simple Majority rule (high or low risk).

5.2.1. Period 2 Outcomes and Behavior.. Table 8 summarizes the period two outcomes. It shows the average fraction of the available budget devoted to public good provision, private transfer to the proposer, private transfers to a minimal winning coalition, and total private transfers as a function of q and θ. It also reports the average ratio between the public good provided by the committee and the efficient level, given the available resources.[30]

We highlight three results from Table 8, which are in line with the theoretical predictions:

Finding 8: In line with Hypothesis 10, public good provision is inefficient. Given the available budget, fewer resources than optimal are devoted to public good provision. When the value of the public good is low, the ratio between the budget invested in the public good and the efficient investment level is 83% with Oligarchy, 69% with Simple Majority, and 66% with Super Majority.[31] When the value of the public good is high, the ratio between the budget invested in the public good and the efficient investment level is 72% with Oligarchy, 77% with Simple Majority, and 94% with Super Majority.[32]

30. In contrast to period one, there is essentially no significant evidence of learning in period two.

31. According to one-sample t-tests, these ratios are not significantly different than 100% for Oligarchy (p-value 0.6134), significantly different than 100% at the 1% level for Simple Majority (p-value 0.0063), and significantly different than 100% at the 10% level for Super Majority (p-value 0.0537).

32. According to one-sample t-tests, these ratios are significantly different than 100% at the 1% level for Oligarchy (p-value 0.0001) and Simple Majority (p-value 0.0000), and significantly different than 100% at the 10% level for Super Majority (p-value 0.0505).

TABLE 8. Outcomes in approved allocations, period 2, all treatments, all matches.

	Oligarchy		Simple Maj		Super Maj	
	Obs: 42		Obs: 188		Obs: 58	
$\theta = L$	Mean	SE	Mean	SE	Mean	SE
Public good (% Budget)	0.04	0.01	0.03	0.01	0.03	0.01
Pork to Prop (% Budget)	0.39	0.02	0.28	0.01	0.21	0.01
Pork to MWC (% Budget)	0.73	0.04	0.81	0.01	0.85	0.01
Total pork (% Budget)	0.96	0.01	0.97	0.01	0.97	0.01
Efficiency (Given Budget)	0.83	0.33	0.69	0.11	0.66	0.17
	Obs: 35		Obs: 89		Obs: 41	
$\theta = H$	Mean	SE	Mean	SE	Mean	SE
Public good (% Budget)	0.71	0.06	0.77	0.03	0.92	0.03
Pork to Prop (% Budget)	0.11	0.03	0.08	0.01	0.02	0.01
Pork to MWC (% Budget)	0.23	0.06	0.23	0.03	0.08	0.93
Total pork (% Budget)	0.29	0.06	0.23	0.03	0.08	0.03
Efficiency (Given Budget)	0.72	0.06	0.77	0.03	0.94	0.03

Notes: "% Budget" refers to percentage of the available budget; the budget available to second-period committees is $150 - x$, where x is the public debt accrued in the first period by the same committee; statistics for outcomes as a percentage of available budget are computed excluding committees that have zero budget; second period committees with zero budget are 40/82 in Oligarchy and $\theta = L$; 43/78 in Oligarchy and $\theta = H$; 56/244 in simple majority and $\theta = L$; 12/101 in simple majority and $\theta = H$; 1/59 in super majority and $\theta = L$; 0/41 in super majority and $\theta = H$.

Finding 9: In line with Hypothesis 11, when the public good is valuable, higher q leads to higher public good provision. When the public good is not valuable ($\theta = L$), committee members devote only a negligible fraction of their budgets to public goods and play a divide-the-dollar game among themselves. On the other hand, when the public good is valuable ($\theta = H$), most resources are devoted to public good provision. This pattern is predicted by our model. In the latter case, both the relative expenditure in the public good and the level of efficiency (as a function the budget) are increasing in the majority rule adopted. Although the difference between Oligarchy and Simple Majority is not significant, the difference between Super Majority and the other two rules is significant at the 1% level.[33] Super Majority committees spend 92% of the budget on public goods, for an average level of efficiency of 94%.

Finding 10: In line with Hypothesis 12, higher q reduces pork to the proposer. As we increase q, the proposer captures a lower share of the available resources for his own consumption. In the low state, the average fraction to the proposer is 39% in

33. The p-values of the Wilcoxon–Mann–Whitney tests are presented on Table B.4 in Online Appendix B. The results are unchanged if we use t-tests for difference in means (see Table B.5 in Online Appendix B).

TABLE 9. Proposal types and acceptance rates by treatment and public good value.

	Oligarchy		Simple Maj		Super Maj	
Proposal type	% Pr	% Ac	% Pr	% Ac	% Pr	% Ac
Panel A: Period 2, low value of public good ($\theta = L$)						
Some pork	0.99	0.84	0.99	0.77	0.95	0.50
No pork	0.01	0.67	0.01	0.75	0.05	0.37
All proposals	1.00	0.84	1.00	0.77	1.00	0.50
Panel B: Period 2, high value of public good ($\theta = H$)						
Some pork	0.54	0.90	0.57	0.80	0.38	0.64
No pork	0.46	0.94	0.43	0.89	0.62	0.77
All proposals	1.00	0.92	1.00	0.84	1.00	0.72

Notes: Observations do not include second-period committees with a budget of zero.

Oligarchy, 28% in Simple Majority, and 21% in Super Majority. These differences are statistically significant. In the high state, the average fraction to the proposer is 11% in Oligarchy, 8% in Simple Majority, and only 2% in Super Majority. Although the difference between Oligarchy and Simple Majority is not statistically significant, the other differences are significant at the 1% level.[34]

Finally, we look at the proposed allocations, as a function of q. We focus on whether proposals include private transfers. Table 9 shows the breakdown of proposals for the three majority rules. For each treatment, the first column lists the proportion of proposals of each type that were proposed at the provisional stage (i.e., before a proposal was randomly selected to be voted on); the second column gives the proportion of proposals of each type that passed when they were voted on. In line with the theoretical predictions, in all voting rules, most second period proposals offer no private transfers when the value of the public good is high; most proposals offer private transfers when the value of the public good is low. As in the first period, acceptance rates are lower as we increase the majority requirements. Proposals with positive investment in the public good when the public good is not valuable and proposals with private transfers when the public good is valuable are more likely to be turned down.

5.2.2. Intertemporal Inefficiencies.. Section 3.1 showed that, in theory, political decision making will introduce static distortions in the provision of public goods. These static distortions are due to the fact that a minimal winning coalition of size $q < n$ does not fully internalize the benefit of public good provision for the whole community. In addition to this, the model suggests that inefficiencies will arise also because of dynamic distortions: the uncertainty over political power in the second period leads the first period coalition to undervalue the marginal benefit of future

34. The p-values of the Wilcoxon–Mann–Whitney tests are presented on Table B.4 in Online Appendix B. The results are unchanged if we use t-tests for difference in means (see Table B.5 in Online Appendix B).

TABLE 10. Test of intertemporal inefficiencies.

	High risk		Low risk	
	Oligarchy	Simple Maj	Super Maj	Simple Maj
$Au'(g_1)$	18.31	7.35	1.64	10.55
$E[A_\theta u'(g_{2\theta})]$	29.46	8.68	5.21	13.10
Difference	− 11.16	− 1.33	− 3.57	− 2.54
p-value	0.0000	0.0179	0.0126	0.0003

Note: p-values refer to Mann–Whitney–Wilcoxon tests.

resources. This means that the political equilibrium does not coincide with the Pareto efficient solution for any choice of welfare weights (e.g., weights that are positive only for the first period coalition members). This distortion is captured in the key theoretical result of Corollary 4: If $q < n$, then $Au'(g_1^\star) < E[A_\theta u'(g_{2\theta}^\star)]$. That is, in the political bargaining equilibrium, the expected (over the two states) period two marginal utility of the public good is greater than the period one marginal utility of the public good.

We can test this important implication of the theoretical model, separately for each experimental treatment, with data from the laboratory committees. Such a test is straightforward, since we directly observe for each committee the level of public good in period one, as well as the levels of public good for that committee's randomly assigned state in period two. For each treatment, Table 10 shows the average (across committees) marginal utility of the public good level provided in each period.[35]

Finding 11: In line with Hypothesis 13, the provision of public goods by committees displays dynamic distortions. In every treatment of the experiment, the expected marginal utility is greater in the second period than in the first period, and the difference between the two periods is statistically significant at conventional levels according to Wilcoxon–Mann–Whitney tests. This difference arises because there is too much borrowing and, therefore, too much spending in the first period.

5.3. The Effect of Commitment

We now turn to the effect of commitment on subjects' behavior. According to the theory discussed in Section 3.2, public debt is sensitive to the legislature's ability to tie its hands and commit to a contingent plan of action: when the current coalition can decide on the allocation of resources in both periods, without the fear of political turnover, the current proposer has a lower incentive to front-load expenditures and always leaves a sufficient amount of resources to provide the public good level that is optimal for a group of q legislators. Table 11 compares the observed levels of public

35. Some committees provide no public good. Since marginal utility in this case is equal to infinity, we use the marginal utility of the public good level plus a small constant. Table 10 shows results using as constant 0.001. The results of the Wilcoxon–Mann–Whitney tests shown in Table 10 are unchanged if we use a different constant between 0 and 0.1.

TABLE 11. Outcomes in approved allocations, period 1 outcomes, the effect of commitment.

	High risk, Simple Maj			High risk, Simple Maj		
	No commitment Obs: 180			Commitment Obs: 162		
	Theory	Mean	SE	Theory	Mean	SE
Public debt	121.3	12.5	3.3	[−12.8, 93.8]	− 58.5	5.3
Public good	20.3	36.8	2.2	20.3	32.8	2.5
Pork to proposer	150.6	39.2	1.7	[0, 150.3]	21.6	1.9
Pork to MWC	251.0	112.1	4.8	[0, 250.5]	54.1	4.6
Total pork	251.0	125.7	4.1	[0, 250.5]	58.7	4.8

TABLE 12. Test of intertemporal inefficiencies, committees with commitment.

	$Au'(g_1) - E[A_\theta u'(g_{2\theta})]$
Mean	6.08
Median	− 0.01
p-value of Wilcoxon signed-rank test	0.7061
p-value of two-sided sign test	0.2385

debt, public good and private transfers by treatment. To aggregate across committees, we use the average level of public debt, public good and private transfers from all first period committees.

Finding 12: In line with Hypothesis 14, commitment leads to lower public debt. The average level of public debt is 12.5 without commitment and −58.5 with commitment. This difference is statistically significant at the 1% level (p-value: 0.0000). Without commitment, 79% (143/180) of committees balances the budget and only 8% (14/180) of committees lends to the second period. With commitment, a much lower fraction balances the budget (17% or 28/162), and a much higher fraction lends to the second period (67% or 108/162).

Finding 13: In line with Hypothesis 15, commitment eliminates dynamic inefficiencies. In the commitment treatment, we observe the contingent public good level each committee agrees to provide under each possible state of the world in the second period. This means that, contrary to the treatments without commitment, we can compute $E[A_\theta u'(g_{2\theta})]$ at the level of a single committee. Since our samples for $Au'(g_1)$ and for $E[A_\theta u'(g_{2\theta})]$ are matched (i.e., we have one value for each variable from each committee), the most appropriate nonparametric tests for H15 are the Wilcoxon matched-pairs signed-rank test and the sign test. The null hypothesis of the Wilcoxon matched-pairs signed-rank test is that both distributions are the same. The null hypothesis of the sign test is that the median of the differences is zero. The results, reported in Table 12,[36] suggest that we cannot reject the null hypotheses that

36. The two Bocconi sessions in the experiment were limited to the commitment treatment. Therefore, we also conducted the comparison of debt levels and the dynamic inefficiency test excluding the Bocconi sessions, which produces the same findings. See Tables B.6 and B.7 in Online Appendix B.

the median of $Au'(g_1) - E[A_\theta u'(g_{2\theta})]$ is zero and that the distributions of $Au'(g_1)$ and $E[A_\theta u'(g_{2\theta})]$ are the same.

6. Conclusions

This article investigated, theoretically and experimentally, the accumulation of public debt by a legislature, operating with procedures that entail bargaining and voting. We ask two main questions: do legislatures accumulate inefficient levels of debt? To what extent does this inefficiency depend on the environment and the political institutions? To study these questions we have designed experiments that explore how behavior changes following three comparative static exercises: changes in the voting rule, reflecting the degree of political distortions; changes in uncertainty, reflecting different needs for consumption smoothing; and whether policy-makers can or cannot commit to a policy rule. These variations are designed to capture and test key predictions in the theoretical literature on public debt.

The experimental analysis of three alternative voting rules (oligarchy, simple majority, and super majority) supports the main qualitative implications of the theoretical model: a higher majority requirement leads unambiguously to significantly higher public good production and lower public debt accumulation. This result confirms, from an experimental point of view, the importance of institutions for public policies and the fact that incentives matter in a way predicted by complex theoretical models. Our model, with supporting evidence from a laboratory experiment, identifies an important force by which super majority voting systems may increase efficiency in the intertemporal allocation of resources. The experimental evidence of the two other dimensions of our analysis also provide support to key qualitative findings of the model regarding consumption smoothing and commitment. Our subjects react to an increase in the probability of a shock increasing the future utility from public goods by reducing public debt, thus allowing for a larger buffer to deal with the shock. The observed behavior also supports an important but nonobvious prediction regarding intertemporal distortions, or dynamic inefficiency: the fact that in a political equilibrium without commitment, the marginal utility of the public good in period 1 is systematically higher than the expected marginal utility at period 2 while $q < n$; in a political equilibrium with commitment, on the contrary, the marginal utility at period 1 is not systematically different than the expected marginal utility at period 2, *independently* of the voting rule.

Our experiments, however, identify two behavioral findings unexplained by the theory that have important practical consequences. First, we observe that balancing the budget in each period appears to be a focal point for some players. This phenomenon is not sufficient to fully offset the political distortions predicted by the theory inducing excessive debt accumulation, but it dampens the inefficiencies relative to the magnitude that one would have expected from the theory alone. Second, we observe that super majority requirements can lead to political gridlock that creates bargaining delays in the decision-making process.[37]

There are many possible directions for future research. On the theoretical side, concerning the second observation given previously, it would be interesting to explore models that could explain the lower acceptance rates observed with a larger majority requirement. A richer model might have implications for how delay depends on the voting rule, and thus provide a clearer theoretical picture of the trade-off between optimal allocations and bargaining delays in the different institutions.

Our experimental design was intentionally very simple and used a limited set of treatments. We have limited the analysis to legislatures that differ on the q-rule adopted and use a specific procedure. It would be interesting to consider the normative implications of other institutions, for example, the impact of different proposal and voting procedures, or the effect of a balanced budget rule.[38] Moreover, our political process does not have elections and parties, and there is no executive branch to oversee the general interest common to all districts. Elections, parties, and nonlegislative branches are all important components of democratic political systems, and incorporating such institutions into our framework would be a useful and challenging direction to pursue. Finally, it would be interesting to allow for a richer set of preferences and feasible allocations, such as allowing for diversity of preferences or multiple public goods, more than two periods, and to study the incentives for intergenerational shift of the financial burden in an overlapping generation model.

Appendix: Proofs

Proof of Proposition 1

Consider the optimization problem (4). First note that the budget constraints must be binding. Moreover, the public good can be assumed to be non negative without loss of generality. If we ignore the non negativity constraints for the transfers, we have the

37. The delay we observe with supermajorities might be explained by a model that allows for imperfect best response (e.g., quantal response equilibrium or QRE). Because decisions are stochastic in a QRE, this could be consistent with delays in the supermajority treatment, since the presence of multiple veto players makes it harder to obtain a qualified majority. See Nunnari and Zapal (2016).

38. Although the model and the experiment were not designed to this aim, we can comment on the desirability of a balanced budget rule. Since in our model the planner finds it optimal to run a negative deficit, imposing a budget balance rule does not impose any losses relative to the optimum, so long as the constraint is "one-sided" (i.e., surpluses are allowed), which is typically the case in practice; and it can improve efficiency whenever committees run positive deficits, which happens, both theoretically and empirically, for simple majority and oligarchic rules with the experimental parameters. However, this conclusion is specific to our parameters and future experimental investigations of this question could consider scenarios where it is optimal to run a negative deficit, such as the more general models in which this question has been recently studied from a theoretical point of view (Battaglini and Coate 2008; Halac and Yared 2014; Azzimonti, Battaglini, and Coate 2016).

following relaxed problem:

$$\max_{g_1, g_{2\theta}, x} \left\{ \begin{array}{c} W + x - g_1 + Anu(g_1) \\ + \left\{ \begin{array}{c} (1-p)[W - (1+r)x - g_{2L} + A_L nu(g_{2L})] \\ +p[W - (1+r)x - g_{2H} + A_H nu(g_{2H})] \end{array} \right\} \\ \text{subj. to}: x \in [-W, \bar{x}] \end{array} \right\}. \tag{A.1}$$

We have the following FOCs with respect to the public good:

$$\begin{aligned} Anu'(g_1) &= 1, \\ A_\theta nu'(g_{2\theta}) &= 1 \quad \forall \theta = \{L, H\}. \end{aligned} \tag{A.2}$$

It is also easy to see that any $x \in [-W, \bar{x}]$ is optimal in (A.1). Rewriting (A.2), we have

$$g_1^* = [u']^{-1}\left(\frac{1}{An}\right), \quad g_{2\theta}^* = [u']^{-1}\left(\frac{1}{A_\theta n}\right). \tag{A.3}$$

Assuming the planner treats districts symmetrically, the associated transfers are

$$\begin{aligned} s_1^* &= \frac{W + x - g_1}{n}, \\ s_{2\theta}^* &= \frac{W - (1+r)x - g_{2\theta}}{n}, \quad \forall \theta = \{L, H\}. \end{aligned} \tag{A.4}$$

To verify that this is a solution, we need to check that there is an optimal x such that the transfers are all non-negative. For (A.3)–(A.4) to be a solution we need

$$\begin{aligned} W + x - g_1 &\geq 0, \\ W - (1+r)x - g_{2L} &\geq 0, \\ W - (1+r)x - g_{2H} &\geq 0. \end{aligned}$$

These inequalities can be satisfied if

$$x^* \in \left[g_1 - W, \frac{W - g_{2H}}{1+r}\right],$$

where the interval is non empty thanks to (3). We conclude that g_1^*, $g_{2\theta}^*$, s_1^*, $s_{2\theta}^*$ for $\theta = L, H$, and x^* are optimal policies.

Proof of Proposition 2

We solve the model by backward induction.

Second Period. At $t = 2$, the proposer's problem can be written as

$$\max_{s,g} \left\{ \begin{array}{c} W - (1+r)x - (q-1)s - g + A_\theta u(g) \\ \text{subj. to}: W - (1+r)x - (q-1)s - g \geq 0, s \geq 0 \\ s + A_\theta u(g) \geq v_2(x, \theta) \end{array} \right\}, \tag{A.5}$$

where $v_2(x, \theta)$ is the utility at $t = 2$ when the state is (x, θ) and before the identity of the proposer is known. Notice that the constraints

$$W - (1 + r)x - (q - 1)s - g \geq 0 \text{ and } s \geq 0 \tag{A.6}$$

imply

$$W - (1 + r)x - g \geq 0.$$

It follows that

$$\max_{s,g} \left\{ \begin{array}{c} W - (1 + r)x - (q - 1)s - g + A_\theta u(g) \\ \text{subj. to: } s + A_\theta u(g) \geq v_2(x, \theta) \\ W - (1 + r)x - g \geq 0 \end{array} \right\} \tag{A.7}$$

is a relaxed version of (A.5). If we solve this problem and satisfy (A.6), then we have a solution. In (A.7), we must have $s = v_2(x, \theta) - A_\theta u(g)$, that is, the proposer does not waste resources and makes voters exactly indifferent between accepting and rejecting his proposal. The problem of the proposer becomes

$$\max_{g} \left\{ \begin{array}{c} A_\theta q u(g) - g + \left[W - (1 + r)x - q v_2(x, \theta)\right] \\ \text{subj. to: } W - (1 + r)x - g \geq 0 \end{array} \right\}. \tag{A.8}$$

To solve (A.8), let us first ignore the constraint $W - (1 + r)x - g \geq 0$. Eliminating irrelevant constants, we have

$$\max_{g} \left\{ A_\theta q u(g) - g \right\}$$

implying

$$g^\star_{2\theta}(x) = \left[u'\right]^{-1} \left(\frac{1}{A_\theta q}\right),$$

$$s^\star_{2\theta}(x) = v_2(x, \theta) - A_\theta u\left(g^\star_{2\theta}(x)\right).$$

In any symmetric equilibrium, we must have

$$v_2(x, \theta) = \max\left\{\frac{W - (1 + r)x - g^\star_{2\theta}(x)}{n}, 0\right\} + A_\theta u\left(g^\star_{2\theta}(x)\right). \tag{A.9}$$

So in this case, since $W - (1 + r)x - g \geq 0$ by assumption, we have

$$g^\star_{2\theta}(x) = \left[u'\right]^{-1} \left(\frac{1}{A_\theta q}\right),$$

$$s^\star_{2\theta}(x) = \frac{W - (1 + r)x - g^\star_{2\theta}(x)}{n}. \tag{A.10}$$

It is immediate to see that (A.10) satisfies $W - (1 + r)x - g^\star_{2\theta}(x) \geq 0$ if and only if

$$W - (1 + r)x - \left[u'\right]^{-1} \left(\frac{1}{A_\theta q}\right) \geq 0.$$

That is,

$$x \leq \frac{W - [u']^{-1}\left(\frac{1}{A_\theta q}\right)}{1+r} \equiv \widehat{x_\theta}. \tag{A.11}$$

If (A.11) is not satisfied, then the solution of (A.7) is

$$g^\star_{2\theta}(x) = W - (1+r)x,$$
$$s^\star_{2\theta}(x) = 0. \tag{A.12}$$

It is immediate that this solution satisfies (A.6), so it is a solution of (A.5) as well. Moreover it is also easy to see that with proposal strategies (A.10)–(A.12), the expected value function at $t = 2$ is (A.9). We conclude that the equilibrium strategy in the second period is

$$g^\star_{2\theta}(x) = \begin{cases} [u']^{-1}\left(\frac{1}{A_\theta q}\right) & x \leq \widehat{x_\theta} \\ W - (1+r)x & \text{else} \end{cases}, \quad s_2(x,\theta) = \begin{cases} \frac{W-(1+r)x-g^\star_{2\theta}(x)}{n} & x \leq \widehat{x_\theta} \\ 0 & \text{else} \end{cases}. \tag{A.13}$$

Given this equilibrium strategy, the value function in state (x, θ) is

$$v_2(x,\theta) = \begin{cases} \frac{W-(1+r)x-g^\star_{2\theta}(x)}{n} + A_\theta u\left(g^\star_{2\theta}(x)\right) & x \leq \widehat{x_\theta} \\ A_\theta u(W-(1+r)x) & \text{else} \end{cases}. \tag{A.14}$$

It is easy to verify that $vv_2(x, \theta)$ is continuous, differentiable everywhere except at $\widehat{x_\theta}$ with

$$v_2'(x,\theta) = \begin{cases} -\frac{(1+r)}{n} & x \leq \widehat{x_\theta} \\ -A_\theta(1+r)u'(W-(1+r)x) & \text{else} \end{cases} \tag{A.15}$$

and $\lim_{x\to\bar{x}} v_2'(x,\theta) = -\infty$. We also have the following lemma.

LEMMA A.1. *The value function at* $t = 2$ *is concave in* x *for all* θ *with* $v_2'(x^1,\theta) \leq v_2'(x^2,\theta)$ *for* $x^1 \geq x^2$ *and* $-v_2'(x,\theta) \geq (1+r)/q$ *for* $x > \widehat{x_\theta}$.

Proof. To see that $v_2(x, \theta)$ is concave, note that the left derivative at $\widehat{x_\theta}$ is $-(1 + r)/n$, the right derivative is

$$-A_\theta(1+r)u'(W-(1+r)\widehat{x_\theta}) = -(1+r)A_\theta u'\left(\left[u'\right]^{-1}\left(\frac{1}{A_\theta q}\right)\right)$$
$$= -\frac{(1+r)}{q} < -\frac{(1+r)}{n}.$$

The result follows from the fact that $v_2(x, \theta)$ is linear on the left of $\widehat{x_\theta}$, strictly concave on the right of $\widehat{x_\theta}$, and continuous. The first inequality in the statement immediately follows from (A.15). For the second inequality in Lemma A.1, we have

$$-v_2'(x,\theta) = A_\theta(1+r)u'(W-(1+r)x) \geq (1+r)/q \quad \text{for } x > \widehat{x_\theta}.$$

The second inequality given previously follows from the fact that if $u'(W - (1 + r)x) < 1/A_\theta q$ then it would be optimal to have $g_2(x, \theta) < W - (1 + r)x$. This implies $x \leq \widehat{x_\theta}$, a contradiction. □

First Period. At $t = 1$, the proposer's problem can be written as

$$\max_{s,g,x} \left\{ \begin{array}{c} W + x - (q-1)s - g + Au(g) + \delta E v_2(x,\theta) \\ \text{subj. to: } W + x - (q-1)s - g \geq 0, s \geq 0 \\ s + Au(g) + \delta E v_2(x,\theta) \geq v_1 \end{array} \right\}, \tag{A.16}$$

where v_1 is the expected utility at $t = 1$ before the proposer has been identified, and $\delta E v_2(x, \theta)$ is the expected utility at $t = 2$.

Proceeding as before, we note that the first two constraints in (A.16) imply $W + x - g \geq 0$. This means that the following problem is a relaxed version of (A.16):

$$\max_{s,g,x} \left\{ \begin{array}{c} W + x - (q-1)s - g + Au(g) + \delta E v_2(x,\theta) \\ \text{subj. to: } s + Au(g) + \delta E v_2(x,\theta) \geq v_1, \\ W + x - g \geq 0 \end{array} \right\}. \tag{A.17}$$

If we find a solution of this problem that satisfies $W + x - (q - 1)s - g \geq 0$ and $s \geq 0$, we have a solution of (A.16).

In (A.17) we can assume, without loss of generality, that the first constraint is satisfied as equality. After eliminating irrelevant constants, we can write the problem as

$$\max_{s,g,x} \left\{ \begin{array}{c} x + Aqu(g) - g + q\delta E v_2(x,\theta) \\ \text{subj. to: } W + x - g \geq 0 \end{array} \right\}.$$

We analyze (A.17) by assuming that the constraint $W + x - g \geq 0$ is satisfied, and then verifying that this conjecture is correct. From the first order condition with respect to g and x we have

$$1/q = Au'(g), \tag{A.18}$$

$$1/q \in -\delta E \nabla v_2(x,\theta), \tag{A.19}$$

where $-E\nabla v_2(x, \theta)$ is the subdifferential of $Ev_2(x, \theta)$. We need to have this more general approach because the value function is not differentiable at $t = 2$. However, since the value function is concave, it has a well defined differential. If we denote $E v_2^-(x,\theta)$, $E v_2^+(x,\theta)$ as the left and right derivative of $Ev_2(x, \theta)$ at x, then

$$-\nabla E v_2(x,\theta) = -\left[E v_2^-(x,\theta), E v_2^+(x,\theta)\right].$$

Note that we cannot have $x \leq \widehat{x_\theta}$ for $\theta = \{H, L\}$, otherwise we would have $-\delta v_2^+(x, L) = 1/n$ and $-\delta v_2^+(x, H) \leq 1/q$, so $1/q < \delta E v_2'(x,\theta)$ and (A.18)–(A.19) would not be true. We conclude that we must have $x > \min\left\{\widehat{x_L}, \widehat{x_H}\right\} = \widehat{x_H}$.

This implies that $v_2(x, H)$ is differentiable at x and that

$$\delta v_2'(x, H) = -\delta A_H(1+r)u'(W-(1+r)x) < -\frac{\delta(1+r)}{q} = -\frac{1}{q},$$

where, in the first line, the first inequality follows from Lemma A.1 and the second equality from the fact that r is the equilibrium interest rate.

We have two cases: $x \le \widehat{x_L}$ and $x > \widehat{x_L}$. Assume first that $x > \widehat{x_L}$. In this case $v_2'(x, L)$ is also differentiable at x and

$$-\delta v_2'(x, L) = \delta A_L(1+r)u'(W-(1+r)x) > 1/q.$$

Then (A.19) implies $1/q = -\delta E v_2'(x, \theta) > 1/q$, a contradiction.

We conclude that in equilibrium we must have $x \le \widehat{x_L}$ and

$$\delta v_2'(x, H) = -A_H u'(W-(1+r)x) > 1/q, \tag{A.20}$$

$$\delta v_2^-(x, L) = \delta v_2^+(x, L) = -1/n \text{ if } x < \widehat{x_L}, \tag{A.21}$$

$$\delta \nabla v_2(x, L) = [-1/q, -1/n] \text{ if } x = \widehat{x_L}. \tag{A.22}$$

Let's first assume $x < \widehat{x_L}$. In this case, the FOC of (A.17) with respect to x is

$$1/q = -(1-p)\delta v_2'(x, L) - p\delta v_2'(x, H).$$

Then (A.20) and (A.21) imply

$$1/q = \frac{(1-p)}{n} + pA_H u'(W-(1+r)x).$$

After some algebra, we obtain

$$x = \frac{W - [u']^{-1}\left(\frac{1/q-(1-p)/n}{pA_H}\right)}{1+r}. \tag{A.23}$$

This conjecture is correct if

$$\frac{W - [u']^{-1}\left(\frac{1/q-(1-p)/n}{pA_H}\right)}{1+r} = x < \widehat{x_L} = \frac{W - [u']^{-1}\left(\frac{1}{A_L q}\right)}{1+r}.$$

That is, if

$$[u']^{-1}\left(\frac{1/q-(1-p)/n}{pA_H}\right) > [u']^{-1}\left(\frac{1}{A_L q}\right).$$

Or if

$$\frac{q}{n} > \frac{1 - \frac{A_H}{A_L}p}{(1-p)}.$$

If $q/n \leq (1-(A_H/A_L)p)/(1-p)$, instead, we have that $x = \widehat{x_L}$. So we can conclude

$$x^\star = \begin{cases} \frac{W-[u']^{-1}\left(\frac{1/q-(1-p)/n}{pA_H}\right)}{1+r} & \text{if } \frac{q}{n} > \frac{1-\frac{A_H}{A_L}p}{(1-p)} \\ \frac{W-[u']^{-1}\left(\frac{1}{A_L q}\right)}{1+r} & \text{if } \frac{q}{n} \leq \frac{1-\frac{A_H}{A_L}p}{(1-p)} \end{cases}. \tag{A.24}$$

Since $x^\star \in \left[\widehat{x_H}, \widehat{x_L}\right]$, we have

$$g^\star_{2H}(x) = W-(1+r)x = \left[u'\right]^{-1}\left(\frac{1/q-(1-p)/n}{pA_H}\right),$$

$$g^\star_{2L}(x) = \left[u'\right]^{-1}\left(\frac{1}{qA_L}\right), \tag{A.25}$$

and

$$g^\star_1 = \left[u'\right]^{-1}\left(\frac{1}{qA}\right). \tag{A.26}$$

For this to be an equilibrium, we must now verify that the initial conjecture is correct. This means that we need $W + x^\star - g^\star_1 \geq 0$ to be verified. Note that from (A.24) we know that

$$x^\star \geq \frac{W-[u']^{-1}\left(\frac{1/q-(1-p)/n}{pA_H}\right)}{1+r}.$$

This implies that a sufficient condition is the second inequality of the following expression:

$$W + x^\star - g^\star_1 \geq W + \frac{W-\left[u'\right]^{-1}\left(\frac{1/q-(1-p)/n}{pA_H}\right)}{1+r} - [u']^{-1}\left(qA_L\right) \geq 0.$$

To prove that this sufficient condition is verified, we first prove the following lemma.

LEMMA A.2. *If $q/n > [1-(A_H/A_L)p]/(1-p)$, then the equilibrium level of debt is inefficiently large, that is, $x^\star \geq (W-g^O_{2H})/(1+r) \geq x^O$.*

Proof. Note that

$$\frac{1}{q} = \frac{(1-p)}{n} + pA_H u'\left(W-(1+r)x^\star\right),$$

while

$$\frac{1}{n} = \frac{(1-p)}{n} + pA_H u'\left(g^O_{2H}\right).$$

Subtracting the two equations, we have

$$u'\left(W-(1+r)x^\star\right) - u'\left(g^O_{2H}\right) = \frac{1}{pA_H}\left(1/q-1/n\right) > 0.$$

So $g_{2H}^O > W - (1+r)x^\star$, that is, $x^\star \geq \frac{W - g_{2H}^O}{1+r}$. □

Given Lemma A.2, we have

$$W + x^\star - \left[u'\right]^{-1}\left(qA_L\right) \geq W + \frac{W}{1+r} - g_{2H}^O - \left[u'\right]^{-1}\left(nA_L\right) > 0,$$

where the last inequality follows from (3).

A1. Proof of Corollary 3

It can be seen immediately from (5), (12), and (13) that g is inefficiently small in period 1 and state L. In state H we have

$$\begin{aligned} g_{2H}^\star(x^\star) &= W - (1+r)x^\star \\ &< W - (1+r)\frac{W - g_{2H}^O}{1+r} \leq g_1^O, \end{aligned}$$

where the first inequality follows from Lemma A.2 and the last from Proposition 1.

A2. Proof of Corollary 4

We have

$$\begin{aligned} Au'(g_1^\star) = 1/q &\leq \frac{(1-p)}{n} + pA_H u'\left(g_{2H}^\star(x^\star)\right) \\ &= E\left[A_\theta u'(g_{2\theta}^\star(x^\star))\right] + (1-p)\left(1/n - A_L u'(g_{2L}^\star(x^\star)\right) \\ &= E\left[A_\theta u'(g_{2\theta}^\star(x^\star))\right] + (1-p)\left(1/n - 1/q\right) \\ &< E\left[A_\theta u'(g_{2\theta}^\star(x^\star))\right], \end{aligned}$$

where the first equality and the first inequality follow from the first order necessary conditions; the second equality is just a rewriting; the third equality follows from (13).

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Supplementary Data

Supplementary data are available at *JEEA* online.