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Leijdam, L.; van de Ven, M.; Verbon, Harrie

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by Lex Meijdam,
Martijn van de Ven and
Harrie Verbon

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Lex Meijdam Martijn van de Ven Harrie Verbon

Abstract

This paper presents an overlapping-generations model in which government debt is used as an instrument to increase welfare of present generations at the cost of future generations. This instrument is used strategically in the sense that generations are assumed to be able to calculate all possible paths of future taxes as a function of the present tax rate. Every period fiscal policy is chosen according to some social welfare function. We compare a model where successive governments use a myopic social welfare function which is the weighted average of the utilities of the generations present in that period, with a normative model where the government takes account of the utility of all current and future generations. It appears that under both models a condition can be derived determining whether government debt will increase or decrease in the course of time.

1 Introduction

The recent growth in government budget deficits in most countries has stressed the importance of the limits on debt accumulation. There is no simple way to determine these limits. Evidently, government debt is bounded by a solvency constraint: like any debtor, a government cannot borrow more than it is able to repay including interest obligations. This constraint is blurred, however, by the fact that a government, unlike an ordinary debtor, has an infinite horizon. Moreover, a creditor has not many legal instruments to force a government that repudiates its debt to pay. But even in the absence of debt repudiation two questions determine how much a government can borrow: 'what is it able to repay', and 'when is it willing to repay'. This paper addresses both these questions. The answer to these questions is complicated by the fact that the future is involved, i.e. expectations have to be formed. An important feature of the present paper is

*This research was sponsored by the Economics Research Foundation, which is part of the Netherlands Organization for Scientific Research (NWO). Mailing address: M. van de Ven, Dept. of Economics, Tilburg University, PO Box 90153, 5000 LE Tilburg, Netherlands.
that expectations are assumed to be formed rationally. Moreover, it is assumed that
government policy has to be time consistent. Although the government as such is an
abstract entity that in principle exists forever, it is governed by subsequent generations
of finitely lived politicians. There is no way a present politician is able to bind his
successors to a planned policy. This does not imply that future policy is exogenously
given to the present politician: government debt is the instrument through which he is
able to influence future decisions.

In order to answer the first question posed (‘what is the government able to repay’),
Section 2 defines the set of possible policy choices by discussing conditions that guarantee
the viability of a fiscal policy. Viability is defined as the minimum requirement for
credibility of fiscal policy and comprises two conditions. The first is the well known No-
Ponzi Game (NPG) condition which excludes a policy of continually rolling over debt
by financing debt redemption and interest obligations by issuing new debt. The second
condition for viability is feasibility, by which it is meant that the economy is able to raise
the planned tax receipts every period. As we abstract from monetary finance and other
forms of debt repudiation, the NPG condition implies that government debt is nothing
but a temporary postponement of tax obligations.

As to the second question posed (‘when is the government willing to repay’), several
reasons can be mentioned why politicians want to postpone repaying debt. Firstly, there
is the standard Keynesian explanation that a temporary rise in government expenditures
financed by debt leads to a Pareto improvement. Other, positive, explanations do not
rely explicitly on the assumption of excess capacity. Government debt may, for example,
also occur as a result of political instability, as a cost of democracy (e.g. Cukierman
and Meltzer (1986)) or due to a political business cycle (e.g. Alesina and Sachs (1988),
Roubini and Sachs (1989)). Assuming Ricardian debt neutrality (Barro (1974)) not to
hold, debt finance matters for two reasons. It redistributes revenue across generations
and it has a general equilibrium effect operating through the change in the interest
rate. Cukierman and Meltzer (1989) abstract from debt repudiation. In their model
government debt is used as an instrument to get around the non-negativity constraint
on bequests taking both effects into account. The resulting allocation of welfare across
generations depends upon the degree of altruism of parents. In Tabellini (1991) there is
two-sided altruism as well as an intragenerational welfare distribution. Moreover, he takes
account of the possibility of debt repudiation. Assuming that the general-equilibrium
effect of debt is dominated by the direct effect on the distribution of resources, he shows
that an equilibrium level of debt results that is completely honoured. Persson and
Svensson (1989) and Alesina and Tabellini (1990) take yet another route. Assuming
successive generations to have different preferences, they use a two-period model to show that government debt may be used strategically between alternating governments in order to influence future policy choices.

In this paper, an overlapping generations model is developed in Section 3, in which government debt is an instrument to increase welfare of present generations possibly at the cost of future generations. As in the work of Persson and Svensson, Tabellini and Alesina and Tabellini, this instrument is used strategically in the sense that its influence on future policy choices is explicitly taken into account. In particular, generations are assumed to be able to calculate all possible paths of future taxes as a function of the present tax rate and to pick the path that maximizes their welfare. Like Persson and Svensson and Alesina and Tabellini, we abstract from repudiation. Contrary to their work, successive generations are assumed to have identical preferences. We also abstract from the assumption of altruism used by Cukierman and Meltzer and Tabellini. One might think that this implies that the generations alive prefer the stock of debt to be increased by as much as possible. This is not the case however, due to the difference in planning horizons. Old agents, having a very short horizon, will not have to bear the burden of future taxation and will indeed prefer zero taxes and a maximum increase in debt. The same holds for the young if they foresee that they will be able to shift the tax liabilities indefinitely. However, as the young face a longer horizon than the old they may expect that the government will reach the limits of feasibility within their lifetime thus implying that they have to bear part of the future burden of debt in the form of high tax rates. Therefore, they might prefer a positive tax rate in order to smooth taxes over their entire planning horizon. This takes us to the question which fiscal policy will be adopted. The government is viewed as a melting pot of different groups having different, possibly conflicting, interests. These groups are competing among each other for influence on decisions to be made. The policy adopted reflects the interests of the different groups to the extent they succeed in this. Applied to the present model this implies that every period fiscal policy is chosen according to some myopic social welfare function which is the weighted average of the utilities of the generations present in that period. An explicit solution for the model is derived. It turns out that conditions can be derived which determine whether government debt will increase or decrease in the course of time.

In Section 4 we consider the case where a government maximizes a (conventional) social welfare function taking the utility of all current and future generations into account. Surprisingly, the optimal evolution of tax rates and government debt that follows from this normative model does not differ essentially from the positive model of Section 3.
Only the timing and speed of the adjustments differ. Again conditions can be derived under which the government debt will decrease or increase in the course of time. Some comments on these results will be made in the final section.

2 On the viability of fiscal policy

This section describes conditions that guarantee the viability of fiscal policy and thus defines the framework for the following sections.

The government budget deficit $D$ in period $t$ is defined as:

$$D_t = r_{t-1}B_{t-1} + G_t - T_t$$  \hfill (2-1)

where $B$ is the amount of debt at the end of the period, $G$ is government expenditure, $T$ are the tax revenues and $r$ is the interest rate. In principle, there are two ways to finance this deficit, borrowing and monetary finance. Monetary finance can be seen as a special form of debt repudiation. However, rational lenders will take account of the possibility of repudiation. When it is advantageous for a government to repudiate, rational lenders will anticipate this and increase the required interest rate by the anticipated repudiation (inflation) rate. Hence, there is no optimal rate of repudiation. Only surprise repudiation may be advantageous. The benefit may be outweighed by negative reputational effects however. In the sequel we abstract from the possibility of monetary finance and repudiation. In that case eq. (2.1) can be rewritten as:

$$B_t = (1 + r_{t-1})B_{t-1} + G_t - T_t$$  \hfill (2-2)

Aggregating this forward from period $t$ on to a final period $n$ we get the government’s intertemporal budget constraint:

$$B_t = R_{t,n}B_n + \sum_{j=t+1}^{n} R_{t,j}(T_j - G_j)$$  \hfill (2-3)

where $R_{t,j} = \prod_{k=t+1}^{j} \frac{1}{1 + r_{k-1}}$ is the discount factor.

The first condition for the viability of fiscal policy is the NPG condition that limits the growth of government debt:

$$\lim_{n \to \infty} R_{t,n}B_n = 0$$  \hfill (2-4)

\footnote{Calvo(1988) develops a framework with perfect foresight where debt is partly repudiated. Lenders anticipate on this by requiring the appropriate interest rate. However an exogenous cost of repudiation has to be assumed otherwise no government debt would exist since it would totally be repudiated.}
for every $t$. If this condition is satisfied, the intertemporal budget constraint can be written as

$$B_t = \sum_{j=t+1}^{\infty} R_{t,j}(T_j - G_j)$$  \hspace{1cm} (2.5)$$

It tells that the present debt has to be met by future primary surpluses.

The second requirement for viability is feasibility. As Kremers (1989) pointed out, the time pattern of taxes associated with the intertemporal budget constraint may cause taxes to grow faster than taxing capacity and may thus violate the government’s collateral which is for period $t$ given by

$$C_t = \tau_{\text{max}} Y_t \sum_{j=t+1}^{\infty} Q_{t,j}$$  \hspace{1cm} (2.6)$$

where $\tau_{\text{max}}$ is the maximum feasible tax rate, $Y$ is GNP and the discount factor is given by $Q_{t,j} = \prod_{k=t+1}^{j} \frac{1+r_{k-1}}{1+r_{k-1}}$ where $r$ is the growth rate of GNP. Therefore as an additional requirement, which we henceforth refer to as the collateral condition, we might adopt

$$\sum_{j=t+1}^{\infty} R_{t,j} T_j \leq \tau_{\text{max}} Y_t \sum_{j=t+1}^{\infty} Q_{t,j}$$  \hspace{1cm} (2.7)$$

for every $t$, i.e., in every period $t$ the total amount of taxes needed from then on to satisfy the NPG condition does not exceed the maximum total amount of taxes that can be collected from then on. Violation of the collateral can only occur if it is finite. This is the case if the average growth rate of GNP is smaller than the average interest rate, i.e., when the economy is dynamically efficient. Note that since $\sum R_{t,j} T_j = B_t + \sum R_{t,j} G_j$ we must have that the average growth rate of government expenditure $G$ does not exceed the average growth rate of GNP. When the rate of growth of GNP and the interest rate are constant, the collateral together with the NPG condition is sufficient for the ratio of debt to GNP to be bounded$^2$. So one can calculate an upperbound for the debt-GNP ratio based on average growth and interest rates. It cannot be excluded, however, that the debt-GNP ratio is temporarily above this ‘average upperbound’ because actual rates may differ from average rates.

There has been done some empirical work on whether present budget deficits are in line with the government’s intertemporal budget constraint and the collateral condition. Based on the model developed by Barro (1979), frameworks which allow for testing this

$^2$Contrary to the suggestion made by Kremers, the reverse is not true. A counterexample can easily be constructed.
were built by Hamilton and Flavin (1986), Kremers (1989) and Hakkio and Rush (1991) among others. In their empirical work, attention is focused on the United States. The common conclusion reached is that until recent years the development of the deficit stayed in line with the growth of GNP. But extensive growth of the budget deficit lately might be inconsistent with the government’s intertemporal budget constraint. However the real lesson to be learned from this literature is that it is hard to test whether the present budget deficit violates the intertemporal budget constraint. Not only technical matters like finite sample properties of cointegration or misspecification lead to problems but especially the fact that unavoidably future policy is involved in these tests. The fact that the debt-GNP ratio is temporarily above its average upperbound does not suffice to conclude that the intertemporal budget constraint is violated.

Taking the collateral as an extra condition next to the NPG condition is therefore not sufficient to ensure the viability of fiscal policy. Time patterns of taxes that satisfy the collateral condition may include tax rates that exceed the maximum feasible tax rate. So, in order to exclude time paths where the tax rate is temporarily above its maximum, an additional constraint is necessary. Moreover, we assume that the tax rate is non-negative\(^3\). Hence, we have the following condition for feasibility:

\[
0 \leq \tau_t \leq \tau_{\text{max}}
\] (2-8)

for every \(t\). Since this is a sufficient condition for the collateral condition to be satisfied the latter can be discarded. So, the set of viable fiscal policies is defined by the NPG condition (2-4) together with the feasibility condition (2-8). Which policy will be chosen from this set depends on the decision making process. This is the subject of the following section.

3 Decision making when governments are myopic

This section focuses on the decision making process on fiscal policies in which explicit account is taken of the viability conditions derived in the previous section\(^4\). Moreover, the government is assumed not to take account of the utility of future generations. As

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\(^3\)Note that the existence of a lower bound for the tax rate necessitates a (negative) minimal value for the amount of government debt, i.e., a maximum for government wealth. Since the government is not allowed to make net transfers (a negative tax rate) to the private sector and has to obey the NPG condition government wealth cannot exceed the present value of future government expenditures.

\(^4\)Relaxation of the viability conditions by dispensing of the NPG condition is possible. However, in this case, to prevent the government running Ponzi schemes would require explicit modelling of the capital market. By adopting the NPG condition it is implicitly assumed that there is a capital market that ensures the government to obey the NPG condition.
we have seen in the introduction, the fiscal policy preferred may depend on an agent’s planning horizon. Conflicts of interest between agents may arise even if their preferences can be characterized by the same utility function if they have different planning horizons. Within an overlapping-generations model these conflicts can easily be illustrated. We will assume two generations of equal size\(^5\), old and young, to be present at the same time. While the old would prefer complete tax shifting, the young may be interested in policies that smooth taxes over their lifetime. The role of the government is confined to optimizing a function that consists of the utility of the two generations, old and young, presently alive. Thus, if we denote consumption of the old and the young at time \(t\) by respectively \(c^o_t\) and \(c^y_t\) and utility by a function \(U^i, i = o, y\), we get for the objective function of the government at time \(t\):

\[
W_t = W[U^o(c^o_t), U^y(c^y_t, c^o_{t+1})] \tag{3-9}
\]

Notice that as stated above the government at time \(t\) is assumed to be myopic in the sense that it does not take account of the utility of future generations. In that respect the objective function of the government differs from a social welfare function which explicitly takes account of the utility of all future generations. The next section will take a closer look at a social welfare function. In our view the government is a reflection of the different groups present in the society\(^6\). Since these groups are not altruistic in the sense that they care about future generations, the government will not care either. To avoid unnecessary confusion we will henceforth refer to this short sighted social welfare function as a decision function. In optimizing the decision function (3-9) the government takes account of the dependency of the savings by the individuals in the private sector on the tax rate. This makes it act as a Stackelberg leader towards the private sector. Furthermore, the decision function also reflects the fact that governments in different periods may differ from each other. Therefore, the scope for fiscal policy for an incumbent government is confined to the present period. It has, however, implications for the actions to be taken by future governments. We assume that the current government takes account of these actions in the decision making. This means that it also acts as a Stackelberg leader towards all future governments\(^7\).

\(^5\)The rate of population growth is implicitly assumed to be zero. It would not change the following results if population growth was allowed for.

\(^6\)For a behavioural underpinning of this view, see Coughlin et al. (1990).

\(^7\)Veall (1986) presents a model which explains the emerging of a social security system financed on a pay-as-you-go basis. He assumes Stackelberg behavior only towards the next generation and Nash towards subsequent generations. This is due to the necessity of having an infinite horizon which otherwise would give an insoluble problem. Tabellini uses a two period model to derive a political viable set of debt. The first generation acts as a Stackelberg leader towards the second generation. Furthermore he
Since the government takes account of the savings behavior of the private sector we first need to take a closer look at the private sector. As already mentioned we take an overlapping generations model where two generations, old and young, are present at the same time. Each individual lives for two periods. In the first period he is endowed with one unit of income of which he saves an amount $s$. He has to pay taxes over the remaining part. The rest is used for consumption, which therefore equals:

$$c^y_t = (1 - \tau_t)(1 - s_t)$$  \hspace{1cm} (3-10)$$

where $\tau$ is the tax rate. When he is old the savings including the interest revenues net of taxes are consumed:

$$c^o_{t+1} = (1 - \tau_{t+1}) R s_t$$  \hspace{1cm} (3-11)$$

where $R = 1 + r$ is the interest rate which is assumed to be constant. The young optimize a lifetime utility function $U^y(c^y_t, c^o_{t+1})$ subject to eqs. (3-10) and (3-11). The instrument in the optimization is the savings rate. Hence the first-order condition reads:

$$\frac{\partial U^y}{\partial s_t} = - \frac{\partial U^y}{\partial c^y_t}(1 - \tau_t) + \frac{\partial U^y}{\partial c^o_{t+1}} R (1 - \tau_{t+1}) = 0$$  \hspace{1cm} (3-12)$$

From this follows $s^*_t = s^*_t(\tau_t, \tau_{t+1})$ as the optimal amount of savings. In the optimization of eq. (3-9) the government explicitly takes account of $s^*_t$. From eqs. (3-10) and (3-11) it follows that total tax revenue equals

$$T_t = \tau_t (1 - s_t + R s_{t-1})$$  \hspace{1cm} (3-13)$$

Inserting this in the government's budget constraint (2-2) and rewriting it gives:

$$RB_{t-1} + G_t = B_t + \tau_t (1 - s_t + R s_{t-1})$$  \hspace{1cm} (3-14)$$

The tax rate set by the government follows from the maximization of eq. (3-9) subject to eq. (3-14). Assuming an interior solution the first order condition reads:

$$\frac{\partial W_t}{\partial \tau_t} = \frac{\partial W_t}{\partial \tau_t} \frac{\partial U^y}{\partial s_t} (- R s^*_{t-1}) + \frac{\partial W_t}{\partial \tau_t} \left\{ - \frac{\partial U^y}{\partial c^y_t} (1 - s^*_t) + (1 - \tau_t) \frac{\partial s^*_t}{\partial \tau_t} \right\} +$$

\hspace{4cm} explicitly needs altruism between generations and heterogeneity within generations.
\[
\frac{\partial U^y}{\partial c^y_{t+1}} \left[ (1 - \tau^*_{t+1}) R \frac{\partial s^*_t}{\partial \tau_t} - R s^*_t \frac{\partial \tau^*_{t+1}}{\partial \tau_t} \right] = 0 \tag{3-15}
\]

\( \tau^*_{t+1} \) is the tax rate set by the next period government\(^8\). Note that \( \tau^*_{t+1} \) is a function of \( \tau_t \), reflecting the fact that an incumbent government acts as a Stackelberg leader towards future governments. In eq. (3-15) the terms \( \frac{\partial W^c}{\partial U^v} \) and \( \frac{\partial W^c}{\partial U^v} \) can be interpreted as the marginal political power of the old and the young respectively. If \( \frac{\partial W^c}{\partial U^v} \) equals zero, the old are solely decisive for the tax rate. As a result the tax rate will be set at its lowest possible level given the viability of the implied fiscal policy. \( \frac{\partial W^c}{\partial U^v} \) equal to zero means that the young have full control over the tax rate. In this case inserting eq. (3-12) into eq. (3-15) and rewriting gives

\[
\frac{\partial \tau^*_{t+1}}{\partial \tau_t} = \frac{(1 - \tau^*_{t+1})(1 - s^*_t)}{(1 - \tau_t)s^*_t} \tag{3-16}
\]

For any \( t \) it will hold that \( \frac{\partial \tau^*_{t+1}}{\partial \tau_t} \leq 0 \). This is a consequence of the fact that if the political power of the young is non-negligible, the government is urged to trade-off current and future tax rates, given the Stackelberg assumption that it takes account of the relation between the current and all future tax rates. A lower current tax rate will lead to a higher debt inherited by the next generation which as a result might have to opt for a higher tax rate\(^9\). According to eq. (3-16) the gain in current consumption and the loss in future consumption for the young which results from tax shifting will preferably be set by them so that on the margin the desired intertemporal allocation of consumption remains unimpaired.

To derive an explicit solution we assume that the marginal political power of the two generations is constant and normalized so that \( \lambda = \frac{\partial W^c}{\partial U^v} = 1 - \frac{\partial W^c}{\partial U^v} \) and \( 0 \leq \lambda \leq 1 \). Furthermore, we take the utility function to be of a logarithmic type, i.e., \( U^y_t = ln(c^y_t) + \theta ln(c^y_{t+1}) \), where \( \theta \) is the private discount factor. Finally we assume \( G \) to be constant and set \( \tau^{max} \) equal to 1. Given these assumptions, it immediately follows from eq. (3-12) that the young choose \( s^*_t = \frac{\theta}{1+\theta} \) for all \( t \). Since we assumed the government to be a Stackelberg leader towards the private sector it takes account of \( s^* \). Inserting \( s^* \) in eq. (3-15) gives for the first order condition for the government:

\[
(1 - \tau^*_{t+1}) + \theta(1 - \lambda)(1 - \tau_t) \frac{\partial \tau^*_{t+1}}{\partial \tau_t} = 0 \tag{3-17}
\]

\(^8\)Since they are assumed to be Stackelberg leader to their successors, implicitly account is taken in \( \tau^*_{t+1} \) of \( \tau^*_{t+2}, \ldots, \tau^*_{\infty} \).

\(^9\)This is, however, not necessary. The tax rise may be postponed until period \( t + 2 \) or later, leaving \( \tau^*_{t+1} \) unaffected. In that case the interests of the young and old coincide.
for $t = 1, \ldots, \infty$. Notice in eq. (3-17) that as expected the relation between the current and future tax rate is of importance only if the young have some political power, i.e., $\lambda < 1$. At any time $t$, the government as a Stackelberg leader towards future governments knows that future governments use eq. (3-17) to solve for the tax rate. To derive a solution for the infinite horizon problem we first solve the finite horizon problem and then arrive at a solution for the infinite horizon problem as the limit of the finite horizon problem. Assume the time horizon to be finite, $n$, and take the finite horizon equivalent of the NPV condition:

$$B_n = 0$$

(3-18)

The calculation is executed backward starting in the final period $n$. In that period there are no savings and the government has no choice but to obey the NPV condition. The tax rate in the final period then follows immediately from the budget constraint:

$$\tau_n^* = \frac{1 + \theta}{1 + (1 + R)\theta}(RB_{n-1} + G)$$

(3-19)

At period $n - 1$, the incumbent government explicitly takes account of eq. (3-19). Inserting it in its own budget constraint and taking the derivative with respect to $\tau_{n-1}$ gives

$$\frac{\partial \tau_n^*}{\partial \tau_{n-1}} = -R \frac{1 + R\theta}{1 + (1 + R)\theta}$$

(3-20)

Inserting eqs. (3-19) and (3-20) into eq. (3-17) and solving for $\tau_{n-1}$ gives for the interior solution

$$\tau_{n-1}^{int} = \frac{(1 + \theta)R}{R(1 + R\theta)\theta}(1 - \lambda) + 1 \right) \left\{ B_{n-2} + \frac{1 + R}{R^2} G + \frac{(1 + R\theta)(\theta(1 - \lambda)R - 1) - \theta}{(1 + \theta)R^2} \right\}$$

(3-21)

Taking account of the constraints given by eqs. (2-8) and (3-18) the whole solution for period $n - 1$ is given by

$$\tau_{n-1}^* = \begin{cases} 
\tau_{n-1}^{min} & \text{if } B_{n-1}^{min} \leq B_{n-2} \leq B_n \\
\tau_{n-1}^{int} & \text{if } B_n \leq B_{n-2} \leq B_{n-1}^{max} \\
\tau_{n-1}^{max} & \text{if } B_{n-2} = B_{n-1}^{max} 
\end{cases}$$

(3-22)
where $B_n^{min} = -\frac{1+R}{R^2}G$ is equal to minus the discounted value of the total future government expenditures. If the inherited government debt equals this value a zero tax rate can be maintained forever. At the other extreme, $B_n^{max} = -\frac{1+R}{R^2}G + \frac{(1+R\theta)(R+l)+\theta}{(1+\theta)R^2}$ gives the maximum amount of debt possible without violating the NPG condition eq. (3-18). $	au^{min}$ is defined by the constraints on $	au$, eq. (2.8) and the NPG condition eq. (3-18).

An illustration is provided in Figure 1. The dashed lines in Figure 1 are given by the constraints on $	au$, eq. (2.8), and the NPG condition, eq. (3-18). Given some inherited value of the debt $B_{n-2}$ the thick line indicates the tax rate chosen at time $n-1$. Notice from the figure that two sets of solutions are possible. In particular, in Figure 1a the tax rate will be set equal to 0 for a range of values of $B_{n-2}$, while in Figure 1b $\tau = 0$ will only be chosen if the inherited debt is at its minimum level, i.e., a surplus which is exactly sufficient for financing all current and future government outlays. The difference between these two solutions holds true for the general solution as we will see below. Given eq. (3-22) the solution for the tax rate $\tau_{n-2}$, $\tau_{n-3}$ and so on can be obtained in the same way. The solution for $\tau_t$ ($t = 1, \ldots, n-1$) is provided in the Appendix.

As the horizon of this government is assumed infinitely long, we have to find a solution for the infinite horizon analogue of the model. This solution can be obtained as the limit of the $n$ period model\(^{10}\). The general solution then reads:

\(^{10}\)That the limit of the solution of the finite horizon problem is indeed a solution for the infinite horizon problem is easily seen by writing down the first order conditions of the infinite horizon model and checking the candidate solution.
\[
\tau_{\infty, t}^* = \begin{cases} 
\tau_{\text{min}} & \text{if } B_{t-1}^\text{min} \leq B_{t-1} \leq B_{\infty}, \\
\tau_{\text{int}} & \text{if } B_{\infty} \leq B_{t-1} \leq B_{\text{max}}, \\
\tau_{\text{max}} & \text{if } B_{t-1} = B_{\text{max}}, 
\end{cases}
\]

where

\[
\tau_{\text{min}} = \begin{cases} 
0 & \text{if } \theta(1 - \lambda)(R - 1) - 1 \leq 0 \\
\frac{(1 + \theta) R}{1 + \theta R} \left( B_{t-1} + \frac{G}{R(1 - \lambda)} \right) & \text{if } \theta(1 - \lambda)(R - 1) - 1 > 0
\end{cases}
\]

\[
B_{\text{min}} = -\frac{G}{R - 1}
\]

\[
B_{\infty} = \begin{cases} 
-\frac{G}{R - 1} + \frac{1 + \theta R}{1 + \theta} R(1 - \lambda)(R - 1) & \text{if } \theta(1 - \lambda)(R - 1) - 1 \leq 0 \\
-\frac{G}{R - 1} + \frac{1 + \theta R}{1 + \theta} \frac{R(1 - \lambda)(R - 1)}{R' \theta R' \theta - 1} & \text{if } \theta(1 - \lambda)(R - 1) - 1 > 0
\end{cases}
\]

\[
B_{\text{max}} = -\frac{G}{R - 1} + \frac{1 + \theta R}{1 + \theta} \frac{R(1 - \lambda)(R - 1)}{R(1 - \lambda)R(1 - \lambda) - 1}
\]

\[
\tau_{\text{int}} = \begin{cases} 
\frac{(1 + \theta) R}{\theta(1 - \lambda) + 1}[B_{t-1} + \frac{G}{R - 1} + \frac{1 + \theta R}{1 + \theta} \frac{R(1 - \lambda)(R - 1) - 1}{R(1 - \lambda)R(1 - \lambda) - 1}]
\end{cases}
\]

where

\[
\tau_{\text{int}, k} \tau_{\infty, t}^* = \begin{cases} 
\frac{(1 + \theta) R}{\theta(1 - \lambda) + 1}[B_{t-1} + \frac{G}{R - 1} + \frac{1 + \theta R}{(1 + \theta) R} \left( \frac{[\theta(1 - \lambda)(R - 1) - 1]R^k + 1}{R^k(R - 1)} \right)]
\end{cases}
\]

for \( B^k \leq B_{t-1} \leq B^{k+1} \) \( k = 1, \ldots, \infty \)

where

\[
B^k = -\frac{G}{R - 1} + \frac{1 + \theta R}{(1 + \theta) R} \left( \frac{R^{k+1} - 1)(1 - \lambda) \theta^k - [(1 - \lambda) \theta + 1]^k(R - 1)}{(1 - \lambda) \theta^k(R - 1)R^k} \right)
\]

Again, \( B_{\text{min}} \) and \( B_{\text{max}} \) correspond to the minimum and the maximum amount of debt where \( B_{\text{min}} \) equals the minus of all discounted future government expenditures so that if
the inherited debt equals $B^\text{min}$ a zero tax rate can be maintained forever. $B^\text{max}$ corresponds to the maximum amount of debt possible without violating the NPG condition.  Figure 2 provides a graphical illustration.

From eq. (3-23) it appears that two regimes, (a) and (b), are relevant. These regimes are the generalization of the regimes that already became apparent from Figure 1. As will become clear from Proposition 3.1 below, these regimes correspond to the case where government debt is non-decreasing, respectively, non-increasing in time. Which of the regimes prevails depends on $\Gamma \equiv \theta(1 - \lambda)(R - 1) - 1$. Intuitively spoken, if the future is of relatively low importance so that $\Gamma \leq 0$, then a zero tax rate will be chosen for a range of realizations of $B_{t-1}$. Note that the future can be relatively 'unimportant' if the young have a low private discount rate $\theta$, if they have low political power $1 - \lambda$ compared to the old, or if the return, $R - 1$, on their savings is low. The behaviour of the two generations present is, in essence, the same in both cases, $\Gamma \leq 0$, respectively, $\Gamma > 0$. The old prefer the tax rate to be set as low as possible and shift the burden of taxation over to future generations. The young prefer smoothing of the tax burden over their lifetime. The exact pattern of the tax rate can be described as follows. If $\Gamma \leq 0$ (a) prevails and the tax rate will be set equal to zero if the inherited debt $B_{t-1}$ is below a threshold value, $B_\infty$. Obviously, $B_\infty$ depends on the political power parameter $\lambda$, the private discount rate $\theta$ and the interest rate $R$. For higher values of $\lambda$ the threshold value will be higher. The intuition behind this is as follows: a higher value of $\lambda$ corresponds to more power for

$1^1$The conditions defining the viable set of fiscal policies in section 2 were sufficient for the debt-GNP ratio to be bounded provided there were constant growth and interest rates. Since this is the case and, moreover, GNP is assumed to be constant, an upperbound to the amount of debt can be given, $B^\text{max}$. 

\[\frac{\text{th1}}{\text{th2}}\]

Figure 2: Myopic solution for the infinite horizon case

(\text{th1})  \theta(1 - \lambda)(R - 1) - 1 \leq 0 

(\text{th2})  \theta(1 - \lambda)(R - 1) - 1 > 0
the old. They want to keep the tax rate as low as possible. The higher the threshold value
the longer it takes before the inherited debt \( B_{t-1} \) exceeds the threshold value and, thus,
the longer the tax rate can be zero. In particular, if the old have all political power, i.e., \( \lambda = 1 \), the tax rate is completely determined by the viability conditions. Hence, the tax
rate will be set at zero as long as the viability conditions are obeyed. Then it will in one
or two periods jump to its maximum value. If the young have some political influence,
i.e., \( \lambda < 1 \), the time pattern of the tax rate will be smoothed over time. The higher \( \gamma \) the
higher first period taxes as preferred by the young. In other words, the lower the young
want the government debt to be. The reason for this is twofold. Firstly, for higher values
of \( H \) the government debt will rise faster, so that higher taxes are necessary. Secondly,
higher values of \( \gamma \) make it more attractive for the young to save through the government.
Because of the compensating forces of the income and substitution effects changes in \( \gamma \)
do not affect private savings. Saving through the government by levying relatively higher
taxes now in return for lower taxes in the future, however, generates a 'collective' return
because older generations contribute in decreasing the government debt without sharing
in the fruits of these efforts. This becomes particularly clear if \( \Gamma > 0 \), case (b). In that
case the tax rate will decrease in time, implying that the young, through the forced tax
contributions of the old, receive a high 'return' on their 'governmental' saving because
they have a lower future tax rate.

The difference between the two regimes \( \Gamma \leq 0 \) and \( \Gamma > 0 \) becomes clear from Figure 2. If
in case a. the inherited government debt is below the threshold value \( B_{\infty} \) the tax rate is
set equal to the lowerbound zero. Otherwise a negative tax rate would result in a positive
government debt at the end of the planning horizon and the NPG condition would be
violated. On the other hand if in case b. the inherited government debt is below the
threshold value \( B_{\infty} \), the tax rate is set equal to an upperbound, since keeping the tax
rate equal to \( \tau_{\infty}^{\text{int}} \) would create a surplus which exceeds the total discounted value of all
future government expenditures, \( B_{\min} \). This would leave a negative government debt,
or a surplus, at the end of the planning horizon and thus violate the NPG condition.

Furthermore notice that \( B_{\min} \) and \( B_{\max} \) are completely determined by the variables \( G^{12} \),
\( H \) and \( \theta \), while the threshold value \( B_{\infty} \) also depends on the political power parameter

\[ \frac{\partial B_{\max}}{\partial \gamma} = \frac{G - 1}{(R - 1)^2} \left\{ \begin{array}{ll}
< 0 & \text{if } 0 < G < 1 \\
> 0 & \text{if } 1 < G < \frac{1 + \gamma}{1 + \gamma}
\end{array} \right. \]

Note that \( G \) has to be below the total tax base of a period, \( 1 + \frac{R_{t}}{1 + \gamma} \) since this is the maximum possible
amount of taxes to be raised. Immediately it follows that an increase (decrease) in \( G \) causes \( B_{\max} \) to
decrease (increase). The effect of a change in \( H \) on \( B_{\max} \) is, however, ambiguous since it depends on the
magnitude of the government's expenditures \( G \) as can be seen from the first order derivative of \( B_{\max} \)
with respect to \( R \):
\( \lambda \). Within a regime the specific values of the parameters determine the speed by which the tax rate and the debt develop. In particular, in case (a) the threshold value \( B_\infty \) will be lower and the tax rate will be higher for an increase in the political power of the young. In case (b) an increase of the political power of the young implies a rotation of the interior solution around \( (B^{\max}, \tau^{\max}) \) so that the range for the interior solution gets narrower, and the interior solution itself gets larger. The direction of the evolution of the tax rate and the government debt is completely determined by the occurrence of one of both regimes. This becomes clear in the following proposition which states the resulting patterns of \( \tau_t \) and \( B_t \):

Proposition 3.1 If \( B^{\min} < B_0 < B^{\max}, \lambda < 1 \text{ and } \theta > 0 \) we have for every finite \( t \):

(a) If \( \theta(1 - \lambda)(R - 1) - 1 \leq 0 \) then
\[
\begin{align*}
B_{t-1} &< B_t & \text{if } \theta(1 - \lambda)(R - 1) - 1 < 0 \\
B_{t-1} &= B_t & \text{if } \theta(1 - \lambda)(R - 1) - 1 = 0 \\
\tau^{\star}_{\infty,t-1} &\leq \tau^{\star}_{\infty,t}
\end{align*}
\]

(b) If \( \theta(1 - \lambda)(R - 1) - 1 > 0 \) then
\[
\begin{align*}
B_{t-1} &\geq B_t \\
\tau^{\star}_{\infty,t-1} &\geq \tau^{\star}_{\infty,t}
\end{align*}
\]

Note that if \( B_0 \) would equal \( B^{\max} \) (respectively \( B^{\min} \)) we would be left with a trivial case where \( B_t \) equals \( B^{\max} \) (\( B^{\min} \)) and \( \tau_t \) would equal \( \tau^{\max} \) (\( \tau^{\min} \)) for every \( t \). We also abstained from the case where the old are solely decisive, i.e., \( \lambda \) equal to one. If \( \lambda = 1 \) the tax rate will be set at its lower bounds every period which implies that debt will reach its maximum in finite time. As soon as the young have some influence in the political process, i.e., \( \lambda \) smaller than one, we see from Proposition 3.1 that in case (a), if \( \theta(1 - \lambda)(R - 1) - 1 < 0 \), \( B_t \) is strict monotonic. This implies that \( B^{\max} \) never will be reached in finite time. Strict monotonicity of \( B_t \) implies non stationarity though the viability conditions are satisfied. This raises some additional doubt beside the point made in section 2 on the value of the empirical research into the solvency of the government. Contrary to the assumption made in empirical research a continuously increasing debt-GNP ratio need not contradict solvency of the government.

Which of the cases of Proposition 3.1 will prevail depends on the relation between \( R, \lambda \) and \( \theta \). In particular, for a given value of \( \lambda \) and \( \theta \), the tax rate will be non-increasing.

Thus, if \( G \) is lower than total income in the private sector net of interest payments, then an increase (decrease) in \( R \) causes \( B^{\max} \) to decrease (increase). If \( G \) is above total income net of interest payments, the effect of a change in \( R \) becomes reverse. Usually, \( G < 1 \) can be assumed.
if $R$ is high enough. This corresponds with the result derived from solution (3-23) that the lower the value of $R$ the more the interests of the young and the old coincide. Some more comments will be made in the final section.

4 Decision making when governments maximise social welfare

In the previous section some fiscal policy was chosen according to a decision function in which the conflicting interests of the generations present was reflected. There the government was seen as a melting pot of these different generations and did only care about the utility of future generations as far as the generations present did. Instead of assuming the government to be myopic in this sense the government can be taken as a social optimizer, maximising a social welfare function which gives a Pareto optimal allocation of taxes over time. The government can be seen as an everlasting social dictator. Compared to the previous section this approach is of a more normative nature and must first of all be seen as a benchmark case to which the decision making outcome of the previous section can be compared. The government is now assumed to optimize a social welfare function of the following form

$$ W_{t}^{soc} = \sum_{i=0}^{\infty} \rho^i U(c_t^y, c_{t+1}^{o}) $$

(4-24)

where $\rho < 1$ is a discount factor.

Using the same assumptions as in the previous section to derive an explicit solution, we get

$$ \tau_{soc}^{\infty, t} = \begin{cases} \tau_{min} & \text{if } B_{min} \leq B_{t-1} \leq B_{soc} \\ \tau_{int_{soc}} & \text{if } B_{soc} \leq B_{t-1} \leq B_{max} \\ \tau_{max} & \text{if } B_{t-1} = B_{max} \end{cases} $$

(4-25)

where

$$ B_{soc}^{\infty} = \begin{cases} \frac{C}{R - 1} - \frac{(1 + R)(R_{p} - 1)}{(R - 1)(1 - R)(1 + R)} & \text{if } R \rho \leq 1 \\ B_{min} & \text{if } R \rho > 1 \end{cases} $$

and
\[
\tau_{\infty,t}^{\text{inf soc}} = \begin{cases} 
\frac{R(1-\rho)(1+\theta)}{1+\theta R} \left[ B_{t-1} + \frac{G}{R-1} + \frac{1+R\theta}{(R-1)(1-\rho)(1+\theta)} (R\rho - 1) \right] & \text{if } R\rho \leq 1 \\
\tau(B_{t-1}) & \text{if } R\rho > 1
\end{cases}
\]

Figure 3 provides a graphical representation. The solution for \( \tau_{\infty,t}^{\text{inf soc}} \) if \( R\rho > 1 \) is given in the appendix. Equivalent to Proposition 3.1 we derive

**Proposition 4.1** If \( B_{\text{min}} < B_0 < B_{\text{max}} \) we have for every finite \( t \):

(a) If \( R\rho - 1 \leq 0 \) then

\[
\begin{align*}
B_{t-1} &< B_t & \text{if } R\rho - 1 < 0 \\
B_{t-1} & = B_t & \text{if } R\rho - 1 = 0 \\
\tau_{\infty,t-1}^{\text{soc}} & \leq \tau_{\infty,t}^{\text{soc}}
\end{align*}
\]

(b) If \( R\rho - 1 > 0 \) then

\[
\begin{align*}
B_{t-1} &> B_t \\
\tau_{\infty,t-1}^{\text{soc}} & \geq \tau_{\infty,t}^{\text{soc}}
\end{align*}
\]

Notice that just as in the positive analysis of Section 3 there are two different regimes (\( R\rho \leq 1 \) and \( R\rho > 1 \) respectively), where tax rates and government debt move in different directions in the course of time\(^{13}\). In case (a) where \( R\rho \leq 1 \) the tax rate will be

\(^{13}\)Which case prevails depends on whether \( R\rho - 1 \) is positive, negative or zero. This condition can be rewritten to get \( \tau \leq \frac{1}{\rho} - 1 \), since \( R \equiv 1 + \tau \). The right-hand-side of this condition is the rate of time preference. Hence, if the interest rate is below the rate of time preference, debt increases monotonically over time and, vice versa, an interest rate above the rate of time preference induces debt to decrease monotonically.
set equal to \( \tau_{\text{min}} \) if the inherited debt is below a threshold value, \( B_{\infty}^{\text{soc}} \). This threshold value is decreasing in \( \rho \). Higher values of \( \rho \) means more weight attached to the utility of future generations. The tax rate will be set above the zero level sooner to decrease the burden of taxation for future generations since the weight attached to their utility is higher. The resemblance between this case and case (a) (Figure 2a) of the previous section is obvious. The interpretation is analogous: in both cases the future plays a relatively unimportant role. This is reflected in the relative low values of \( \theta, 1 - \lambda \) and \( R \) in the former case and of \( R \) and \( \rho \) in the latter case. However in the normative analysis the welfare of all future generations is taken into account in determining the optimal allocation of taxes and government debt over time, while in the positive analysis of the previous section only the future utility of the current young is of direct importance. Only indirectly through the Stackelberg assumption the current government takes the reactions of future generations on the present policy into account. Nevertheless the evolution of the tax rates and the debt are essentially the same. It can easily be checked that \( B_{\infty}^{\text{soc}} \) can be smaller as well as larger than \( B_{\infty} \). So, a government maximizing a social welfare function may opt for a larger tax rate than the myopic government of Section 3, thus implying a faster increase of government debt in time.

For the regime \( R\rho > 1 \) and its counterpart of the previous section, the tax rate under social welfare maximization can be larger as well as smaller than the tax rate chosen by a myopic government. Figure 4 provides an example where for a range of values of the

![Figure 4](image-url)

Figure 4:

inherited government debt, the interval \((B^0, B^1)\), the social optimizer chooses larger a tax rate than the myopic government of the previous section. Outside this interval the reverse holds. This implies that the downward adjustments of the government debt
between the two types of government differ depending on the amount of debt inherited. For values of the debt passed over from the previous period outside this interval, the government debt will temporarily decrease at a larger rate with the myopic type of government, whereas in some future period the inherited debt may be in the interval \((B^0, B^1)\) and the reverse holds. In other words, the speed at which the government adjusts its debt does not give an indication as to what type the incumbent government actually is.

5 Concluding remarks

This paper focused on two questions. First, how much is a government able to borrow without running into solvency problems. The second question was when will it redeem its debt. In answering the first question conditions were derived in Section 2 defining a viable set of fiscal policies. The well known NPG condition together with a feasibility condition were shown to be sufficient for a credible fiscal policy. Though these conditions seem to be self-evident, they have not been formulated simultaneously before as far as we are aware. Most authors confine themselves by using the No-Ponzi-Game. As an exception Kremers (1989) has formulated a collateral taken to be the present value of the taxing capacity as an extra condition next to the NPG-condition. As we have argued in Section 2, this condition is not sufficient for ensuring viability either. Every period the tax rate should be below a maximum feasible tax rate. If that is the case, obviously taxes will never grow faster than the collateral as just defined. The collateral is thus redundant as a condition restricting debt policy by the government.

In the third section of this paper we introduced a model with different non-altruistic overlapping generations living at the same time having constant and equal labor incomes. Without loss of generality a zero rate of population growth was assumed. The government was seen as a melting pot of the different groups present. Its objective function was a weighted average of the utilities of these groups. The government was assumed to be a Stackelberg leader both towards the private sector and towards future governments. Thus, in its decision making the behavior of the private sector as reflected by its savings, as well as the implications of the fiscal policy adopted on future government decisions was taken into account. We studied which path of tax rates and government debt will be chosen given that the feasibility conditions are obeyed and given the fact that different generations can have different preferences on debt policy due to different horizons. As we assumed perfect foresight by the current decision makers and no intragenerational income inequality the possibility of debt repudiation was excluded. But it can be argued
that tax shifting between different generations which occurs in our model can be interpreted as a special form of debt repudiation. Debt policy is the outcome of a compromise between different generations. Unless the debt can be rolled over to future generations the young would prefer higher tax rates than the old. It appears that the evolution of the tax rate and the debt is determined by an interplay of the political power of the young and old generations, the interest rate and rate of time preference. This reflects the fact that the young do not want to postpone tax as they in their political role take account of the negative relation between current and future tax rates and the more so if the interest rate or the subjective discount rate is high. The central result that can be derived is that, given a debt policy within the bounds imposed by the viability conditions, the tax rate and the government debt will be non-increasing in the course of time if the rate of interest or the subjective rate of time preference is high or the political power of the old is low, while the reverse holds if the rate of interest or the subjective rate of time preference is low or the political power of the old is high. In the latter case, the government debt will be increasing monotonically, asymptotically reaching the maximum feasible upperbound on the government debt. This raises doubts on the validity of empirical studies trying to investigate the solvency of the government: the development of the government debt can follow a non-stationary series for a considerable lapse of time without the government ever running into solvency problems.

In Section 4 the government was assumed to maximize a social welfare function so that the utility of future generations was taken into account. Surprisingly, the resulting evolution of the tax rates and the government debt are essentially the same as under the myopic government which acts as a Stackelberg leader towards future generations. The point is that a myopic government although it is able to steer the future to a certain extent, it is not able to exploit the future completely. In particular, since one day the system will reach its physical limits in terms of taxing capacity, the effective political power of the young will sooner or later get large enough to lead to positive tax rates. This fact restricts the possibility of earlier governments to postpone tax payments. In particular, the future political power of the young plays the same role in the positive model as altruism towards future generations in the normative model.

Of course, the model developed in this paper is not rich enough in economic and political content to be able to give an interpretation of current-day policies. However, the forces that are inherent in our model can shed some light on two observations on actual developments. The first point is that, starting in the 1980s when debt-GNP ratios were approaching unprecedented levels, a start was made in many European countries to restrict the growth of the government debt. In the framework of our model this in-
dicates, first, that the relevant variant of our model is regime (a) where debt per capita is increasing. Second, it indicates that politicians (or the capital market) perceive the maximum sustainable debt to be within close range which makes a decreasing growth of debt necessary. The decreasing growth of debt was reinforced by the increase in the interest rates occurring in the 1980s. On the other hand, the increase of the interest rate may also lead to a regime switch. The same holds for a decrease in the growth rate of the population and an increase of the private discount factor $\theta$. As to the latter two effects we can refer to the ageing of the population and a gradual improvement of the pension systems after World War II, which might indicate a higher value of $\theta$. Simultaneously with the development of pension systems in several countries, a demand for lower levels of government debt has arisen.

Appendix

Solution to finite horizon problem

A solution to the infinite horizon problem can be obtained by solving the finite horizon case and then solving for the infinite horizon problem by taking the limit. The endpoint condition is the finite horizon equivalent of the NPG condition, $B_n = 0$. By repeated backward induction we find for the solution for the $n$ period problem:

(a) $\theta(1 - \lambda)(R - 1) - 1 \leq -\frac{1 + \theta}{(1 + R\theta)R^{n-1}}$

\[
\tau^*_n = \begin{cases} 
\tau^{\text{min}}_n & \text{if } B^{\text{min}}_n \leq B_{t-1} \leq B_n \\
\tau^{\text{int}}_n & \text{if } B_n \leq B_{t-1} \leq B^{\text{max}}_n \\
\tau^{\text{max}}_n & \text{if } B_{t-1} = B^{\text{max}}_n 
\end{cases}
\]

for $t = 1, \ldots, n - 1$, where

\[
B^{\text{min}}_n = -\frac{G}{R^{n-t+1}} \sum_{i=0}^{n-t} R^i
\]

\[
B_n = \frac{G}{R^{n-t+1}} \sum_{i=0}^{n-t} R^i - \frac{(1 + R\theta)[\theta(1 - \lambda)(R - 1) - 1]}{(1 + \theta)R(R - 1)} - \frac{1}{(R - 1)R^{n-t+1}}
\]

\[
B^{\text{max}}_n = \frac{G}{R^{n-t+1}} \sum_{i=0}^{n-t} R^i + \frac{1 + R\theta}{(1 + \theta)R(R - 1)} - \frac{1}{(R - 1)R^{n-t+1}}
\]
and
\[
\tau_{n,t}^{\text{int}} = \frac{(1 + \theta)R}{[\theta(1 - \lambda) + 1](1 + R\theta)} \left\{ B_{t-1} + \frac{G}{R^{n-t+1}} \sum_{i=0}^{n-t-1} R^i + \frac{[\theta(1 - \lambda)(R - 1) - 1](1 + R\theta)}{(1 + \theta)R(R - 1)} + \frac{1}{(R - 1)R^{n-t-1}} \right\}
\]

(b) \( \theta(1 - \lambda)(R - 1) - 1 \geq -\frac{1 + \theta}{(1 + R\theta)R^{n-t}} \)

\[
\tau_t^* = \begin{cases} 
\tau_{\text{min}}^{\text{int}} & \text{if } B_n^{\min} \leq B_{t-1} \leq B_n^i \\
\tau_{\text{int},k}^{\text{int}} & \text{if } B_n^k \leq B_{t-1} \leq B_n^{k+1}
\end{cases}
\]

for \( t = 1, \ldots, n - 1 \) and \( k = 1, \ldots, n - t - 1 \), where
\[
B_n^k = -\frac{G}{R^{n-t}} \sum_{i=0}^{n-t-1} R^i + \frac{1 + R\theta}{(1 + \theta)R} \left\{ \frac{(R^{k+1} - 1)(1 - \lambda)^k \theta^k - [(1 - \lambda)\theta + 1]^k(R - 1)}{(1 - \lambda)^k \theta^k (R - 1) R^k} \right\}
\]

\[
\tau_{\text{min}}^{\text{int}} = \frac{(1 + \theta)R}{1 + R\theta} \left[ B_{t-1} + \frac{G}{R^{n-t+1}} \sum_{i=0}^{n-t-1} R^i \right]
\]

and
\[
\tau_{\text{int},k}^{\text{int}} = \frac{(1 + \theta)R}{\theta(1 - \lambda) + 1}(1 + R\theta) \left\{ B_{t-1} + \frac{G}{R^{n-t+1}} \sum_{i=0}^{n-t-1} R^i + \frac{1 + \theta R}{(1 + \theta)R} \left[ \frac{[\theta(1 - \lambda)(R - 1) - 1]R^k + 1}{R^k (R - 1)} \right] - \frac{\theta}{1 + \theta} \frac{1}{R^{n-t+1}} \right\}
\]

and for period \( n \)
\[
\tau_n^* = \frac{2}{2 + R} [RB_{n-1} + G]
\]

The solution to the infinite horizon problem (3.23) is derived by taking the limit. Figure 5 provides a graphical illustration.

**Proof of Proposition 3.1**

**Proof:**
The following Lemma is trivially satisfied:

**Lemma** \( \tau_{n,t}^* \) is non-decreasing in \( B_{t-1} \)
Figure 5: Myopic solution for the finite horizon case

Case (a) $\theta(1 - \lambda)(R - 1) - 1 \leq 0$

i. $B_{t-1} < B_t$ if $\theta(1 - \lambda)(R - 1) - 1 < 0$.

Suppose $B_{t-1} \geq B_t$ for some $t$.

Inserting the budget constraint for period $t$ and rewriting, gives:

$$B_{t-1} \leq \frac{G}{R-1} + \frac{1 + R\theta}{(1+\theta)(R-1)} \tau^*_{\infty,t}$$

(A) If $\tau^*_{\infty,t} = \tau^*_{\infty} = 0$, we have $B_{t-1} \leq -\frac{G}{R-1} = B^{\min}$

But since $B_0 > B^{\min}$ there must be some $j < t - 1$ such that $B_j = B^{\min}$ and $B_{j-1} > B^{\min}$.

- Suppose $B_{j-1} \leq B_\infty$. Then $\tau^*_{\infty,j} = \tau^*_{\infty} = 0$ and $B_j = RB_{j-1} + G$. But since $B_j = B^{\min}$ we must have $B_{j-1} = -\frac{G}{R-1} = B^{\min}$. Contradiction.

- Suppose $B_\infty \leq B_{j-1} \leq B_\infty$.

Then $\tau^*_{\infty,j} = \tau^*_{\infty} = \frac{(1+\theta)R}{\theta(1-\lambda) + 1 + R\theta} \left[ B_{j-1} + \frac{G}{R-1} + \frac{1 + R\theta}{1+\theta} \frac{\theta(1-\lambda)(R-1) - 1}{R(R-1)} \right]$ and $B_j = \frac{\theta(1-\lambda)R}{\theta(1-\lambda) + 1} B_{j-1} + \frac{\theta(1-\lambda)(R-1) - 1}{\theta(1-\lambda) + 1 + R\theta} G - \frac{1 + R\theta}{1+\theta} \frac{\theta(1-\lambda)(R-1) - 1}{R(R-1)}$. Since $B_j = B^{\min}$ we have $\frac{G}{R-1} + \frac{1 + R\theta}{1+\theta} \frac{\theta(1-\lambda)(R-1) - 1}{R(R-1)}$. But then $B_{j-1} < B_\infty$. Contradiction.

- Suppose $B_{j-1} \geq B_\infty = B^{\max}$. Then $\tau^*_{\infty,j} = \tau^*_{\infty} = 1$ and $B_j = RB_{j-1} + G - \frac{1 + R\theta}{1+\theta}$. But since $B_j = B^{\min}$ we have $B_{j-1} = -\frac{G}{R-1} + \frac{1 + R\theta}{1+\theta} \frac{1}{R} < B^{\max}$. Contradiction.

(B) If $\tau^*_{\infty,j} = \tau^*_{\infty} = \frac{(1+\theta)R}{\theta(1-\lambda) + 1 + R\theta} \left[ B_{j-1} + \frac{G}{R-1} + \frac{1 + R\theta}{1+\theta} \frac{\theta(1-\lambda)(R-1) - 1}{R(R-1)} \right]$ we have $B_{t-1} \geq -\frac{G}{R-1} + \frac{1 + R\theta}{1+\theta} B^{\max}$. But since $B_0 < B^{\max}$ there must be some $j < t - 1$ such that $B_j = B^{\max}$ and $B_{j-1} < B^{\max}$. 


- Suppose \( B_{j-1} \leq B_{\infty} \). Then \( \tau_{\infty,j}^* = \tau_{\infty,j}^{\min} = 0 \) and \( B_j = RB_{j-1} + G \). Since \( B_j = B_{\max} \) we get \( B_{j-1} = -\frac{G}{R-1} + \frac{1+r_0}{(1+\theta)(R-1)} \). But then \( 1 \leq 1 - \theta(1-\lambda)(R-1) \). Contradiction since \( \lambda < 1 \).

- Suppose \( B_{\infty} < B_{j-1} < B_{\infty} = B_{\max} \). Then \( \tau_{\infty,j}^* = \tau_{\infty,j}^{\min} = \frac{1+\theta}{(1+\theta)(R-1)} \tau_{\infty,j} \). Hence \( B_{j-1} = -\frac{G}{R-1} + \frac{1+r_0}{(1+\theta)(R-1)} \tau_{\infty,j} \). Since \( B_j = B_{\max} \) we have \( B_{j-1} = -\frac{G}{R-1} + \frac{1+r_0}{(1+\theta)(R-1)} = B_{\max} \). Contradiction.

(C) If \( \tau_{\infty,t}^* = \tau_{\max} = 1 \) we have \( B_{t-1} = -\frac{G}{R-1} + \frac{1+r_0}{(1+\theta)(R-1)} = B_{\max} \). Since \( \tau_{\infty,t}^* = \tau_{\max} \) we must have \( B_{t-1} = B_{\max} \). But since \( B_0 < B_{\max} \) there must be some \( j < t-1 \) such that \( B_j = B_{\max} \text{ and } B_{j-1} < B_{\max} \).

- Suppose \( B_{j-1} \leq B_{\infty} \). Then \( \tau_{\infty,j}^* = \tau_{\infty,j}^{\min} = 0 \) and \( B_j = RB_{j-1} + G \). Since \( B_j = B_{\max} \) we get \( B_{j-1} = -\frac{G}{R-1} + \frac{1+r_0}{(1+\theta)(R-1)} \). But then \( 1 \leq 1 - \theta(1-\lambda)(R-1) \). Contradiction since \( \lambda < 1 \).

- Suppose \( B_{\infty} \leq B_{j-1} \leq B_{\infty} = B_{\max} \). Then \( \tau_{\infty,j}^* = \tau_{\infty,j}^{\min} = \frac{1+\theta}{(1+\theta)(R-1)} \tau_{\infty,j} \). Hence \( B_{j-1} = -\frac{G}{R-1} + \frac{1+r_0}{(1+\theta)(R-1)} \tau_{\infty,j} \). Since \( B_j = B_{\max} \) we have \( B_{j-1} = -\frac{G}{R-1} + \frac{1+r_0}{(1+\theta)(R-1)} = B_{\max} \). Contradiction.

\( \tau_{\infty,t}^* \leq \tau_{\infty,t-1}^* \).

This follows immediately from part i. and the Lemma.

**Case \( b \) \( \theta(1-\lambda)(R-1) - 1 > 0 \).**

\( B_t \geq B_{t-1} \).

Suppose \( B_t < B_{t-1} \) for some \( t \). Inserting the budget constraint and rewriting gives:

\[
B_{t-1} > -\frac{G}{R-1} + \frac{1+r_0}{(1+\theta)(R-1)} \tau_{\infty,t}^*
\]

(A) If \( \tau_{\infty,t}^* = \tau_{\min} = \frac{(1+\theta)R}{1+r_0} \left( B_{t-1} - \frac{G}{R-1} \right) \) we have \( B_{t-1} < -\frac{G}{R-1} \). Contradiction.
(B) If \( \tau_{\infty,t}^* = \tau_{\infty,t}^{\text{init}} = \frac{(1+\theta)R}{\theta(1-\lambda)+1}(1+R\theta) \left[ B_{t-1} + \frac{G}{R-1} + \frac{1+R\theta}{R^2} \frac{\theta(1-\lambda)R-1}{1+\theta} \right] \) we have \( B_t - 1 \succ B_{t-1} \succ B_{t-2} \). But then \( B_{t-1} > B_\infty \). Contradiction.

(C) If \( \tau_{\infty,t}^* = \tau^{\text{max}} \) = 1 we have \( B_{t-1} > -\frac{G}{R-1} + \frac{1+R\theta}{(1-\lambda)(R-1)} = B^{\text{max}} \). Contradiction.

\( \tau_{\infty,t}^* \geq \tau_{\infty,t-1}^* \).

This follows immediately from part i. and the Lemma.

Q.E.D.

Solution social optimizer's problem

By applying repeated backward induction and taking account of the restrictions a solution can be derived to the social optimizers' problem of Section 4. For \( R \rho - 1 \geq 0 \) an explicit solution for \( \tau_t^* \) was given in this Section 4. No explicit expression for \( \tau_t^* \) was given in case of \( R \rho = 1 \). It proved impossible to derive an explicit solution, only implicitly the solution \( \tau_t^* \) as a function of \( B_{t-1} \) can be described. This solution is given by the lower envelope of an infinite number of tangent lines of the following form

\[
\tau^k = \frac{R(1+\theta)(1-\rho)}{(1+R\theta)(1-\rho^{k+1})} \left\{ B_{t-1} + \frac{G}{R-1} - \frac{1+R\theta}{1+\theta} \left[ \frac{1}{R-1} - \frac{1-\rho^{k+1}}{R(1-\rho)} \right] \right\}
\]

for \( k = 1, \ldots, \infty \).

Figure 6 provides a graphical illustration. The loci of the points of the solution are given by

\[
\begin{align*}
B_{t-1} &= -\frac{G}{R-1} - \frac{1}{\rho^{k}(1-\rho)} \frac{1+R\theta}{1+\theta} \left[ \frac{R^{-k-1}(R-1)(1-R\rho)-\rho^{k}(1-\rho)}{R^{-1}} \right] \\
\tau_t &= 1 + \rho R^{-k} \frac{1-\rho^{k-1}}{1+\rho^{k+1}}
\end{align*}
\]

Proof of Proposition 4.1

Proof:

The following lemma is trivially satisfied:

Lemma \( \tau_{\infty,t}^* \) is non-decreasing in \( B_{t-1} \).
Case (a) $R\rho - 1 \leq 0$.

i. $B_{t-1} < B_t$ if $R\rho < 0$.

Suppose $B_{t-1} \geq B_t$ for some $t$.

Inserting the budget constraint and rewriting gives:

$$B_{t-1} \leq -\frac{G}{R-1} + \frac{1 + R\theta}{(1 + \theta)(R-1)} \tau_{\infty,t}^{soc}$$

(A) If $\tau_{\infty,t}^{soc} = \tau_{\infty,t}^{min} = 0$ we have $B_{t-1} \leq -\frac{G}{R-1} = B_{min}$ But since $B_0 > B_{min}$ there must be some $j < t-1$ such that $B_j = B_{min}$ and $B_{j-1} > B_{min}$.

- Suppose $B_{j-1} \leq B_{\infty,t}^{soc}$. Then $\tau_{\infty,t}^{soc} = \tau_{\infty,t}^{min} = 0$ and $B_j = RB_{j-1} + G$. But since $B_j = B_{min}$ we must have $B_{j-1} = -\frac{G}{R-1} = B_{min}$. Contradiction.

- Suppose $B_{\infty,t}^{soc} \leq B_{j-1} \leq B_{max}$.

Then $\tau_{\infty,t}^{soc} = \tau_{\infty,t}^{int,soc} = \frac{R(1-\rho)(1+\theta)}{1+R\theta} \left[ B_{t-1} + \frac{G}{R-1} + \frac{1 + R\theta}{(1-\rho)(1+\theta)\theta}(R\rho - 1) \right]$ and $B_j = R\rho B_{j-1} + \frac{G - \frac{1 + R\theta}{1+\theta} \left( R(R\rho - 1) \right)}{(R-1)\theta}$. Since $B_j = B_{min}$ we have $B_{j-1} = -\frac{G}{R-1} + \frac{1 + R\theta}{1+\theta} \left( \frac{G}{R-1} \right)$. But then $B_{j-1} < B_{\infty,t}$. Contradiction.

- Suppose $B_{j-1} = B_{max}$. Then $\tau_{\infty,t}^{soc} = \tau_{\infty,t}^{max} = 1$ and $B_j = RB_{j-1} + G - \frac{1 + R\theta}{1+\theta}$.

But since $B_j = B_{min}$ we have $B_{j-1} = -\frac{G}{R-1} + \frac{1 + R\theta}{1+\theta} \left( \frac{G}{R-1} \right) < B_{max}$. Contradiction.

(B) If $\tau_{\infty,t}^{soc} = \tau_{\infty,t}^{int,soc} = \frac{R(1-\rho)(1+\theta)}{1+R\theta} \left[ B_{t-1} + \frac{G}{R-1} + \frac{1 + R\theta}{(1-\rho)(1+\theta)\theta}(R\rho - 1) \right]$ we have $B_{t-1} \geq \frac{G}{R-1} + \frac{1 + R\theta}{(1-\rho)(1+\theta)} = B_{max}$. But since $B_0 < B_{max}$ there must be some $j$ such that $B_j = B_{max}$ and $B_{j-1} < B_{max}$. From the budget constraint we have $B_j = RB_{j-1} + G - \frac{1 + R\theta}{1+\theta} \tau_{\infty,t}^{soc}$. Inserting $B_j = B_{max}$ and $\tau_{\infty,t}^{soc} = \tau_{\infty,t}^{int,soc}$ and rewriting
gives: $B_{j-1} = -\frac{G}{R-1} + \frac{1+R\theta}{(R-1)(1+\theta)} = B_{\text{max}}$. Contradiction.

(C) If $\tau_{\infty,j} = \tau_{\text{max}} = 1$ we have $B_{t-1} \leq -\frac{G}{R-1} + \frac{1+R\theta}{(1+\theta)(R-1)} = B_{\text{max}}$. Since $\tau_{\infty,j} = \tau_{\text{max}}$ we must have $B_{t-1} = B_{\text{max}}$. But since $B_0 < B_{\text{max}}$ there must be some $j$ such that $B_j = B_{\text{max}}$ and $B_{j-1} < B_{\text{max}}$. From the budget constraint we have $B_j = RB_{j-1} + G - \frac{1+R\theta}{1+\theta} \tau_{\infty,j}$. Inserting $B_j = B_{\text{max}}$ and $\tau_{\infty,j} = \tau_{\infty,j}^{\text{inf, soc}}$ and rewriting gives: $B_{j-1} = -\frac{G}{R-1} + \frac{1+R\theta}{(R-1)(1+\theta)} = B_{\text{max}}$. Contradiction.

ii. $B_{t-1} = B_t$ if $R\rho - 1 = 0$.

Note that in this case we always have $\tau_{\infty,j} = \tau_{\infty,j}^{\text{inf, soc}}$.

Taking the budget constraint, inserting $\tau_{\infty,j}^{\text{inf, soc}}$ and rewriting gives:

$$B_t = R\rho B_{t-1} + \left[\frac{R\rho}{R-1}\right]$$

Since $R\rho = 1$ we have $B_t = B_{t-1}$.

$\tau_{\infty,j}^{\text{soc}} \leq \tau_{\infty,j}^{\text{soc}}$.

This follows immediately from part i. and the Lemma.

Case b. $R\rho - 1 > 0$.

$B_{t-1} > B_t$.

In this case $B_{t-1}$ and the adjoining tax rate $\tau_t$ are given by

$$\begin{cases} B_{t-1} = -\frac{G}{R-1} - \frac{1}{\rho^k(1-\rho)} \frac{1+R\theta}{1+\theta} \left[\frac{R^{-k-1}(R-1)+R^{-k-1}\rho^k(1-R\rho)-\rho^k(1-\rho)}{R-1}\right] \\ \tau_t = 1 + \rho R^{-k} \frac{1-\rho^k}{1+\rho^k+1} \end{cases}$$

Consider some $k = \hat{k}$. Inserting the adjoining $B_{t-1}$ and $\tau_t$ into the budget constraint gives an expression for $B_t$:

$$B_t = \frac{G}{R-1} - \frac{1}{\rho^k(1-\rho)} \frac{1+R\theta}{1+\theta} \left[\frac{R^{-\hat{k}-1}(R-1)+R^{-\hat{k}-1}\rho^k(1-R\rho)-\rho^k(1-\rho)}{R-1}\right]$$

Compared to $B_{t-1}$ the postulate immediately follows.

$\tau_{\infty,t-1}^{\text{soc}} > \tau_{\infty,t}^{\text{soc}}$.

Since $B_{t-1} > B_t$ there is by construction a $\hat{k} < \hat{k}$ which corresponds to $B_{t-1}$. Since $\frac{\partial \tau}{\partial k} < 0$ the tax rate is decreasing in $k$. It immediately follows that $\tau_{\infty,t-1}^{\text{soc}} > \tau_{\infty,t}^{\text{soc}}$

Q.E.D.
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