Seminar Paper No. 331

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1. Introduction

The problem of the optimal combination of income taxation and borrowing for financing government expenditure can be treated as an intertemporal optimal taxation problem as in Lucas and Stokey (1983) . A path of distortionary income taxes is chosen so as to finance a given path of government expenditure at minimal welfare losses. Any excess of the optimally chosen taxes over expenditures in a given period is covered by borrowing. With fiat money goverment expenditures can also be financed by an inflation tax. Such a tax is distortionary by driving real balances below Friedman's optimum quantity of money. Phelps (1973) was the first to seriously discuss the "general macroeconomic public finance problem", namely how to find the optimal combination of the two taxes. It is well known that in general the solution implies the use of both the inflation tax and the income tax for financing government expenditures.

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These aspects of the optimal combination of income taxes, inflation tax and borrowing applies to a situation where a goverment can commit itself to a particular policy. It is well known after Kydland and Prescott (1977) that a government under discretion usually has incentive to deviate from previously announced policy, and hence that the optimal policy under commitment is not time-consistent under discretion. Further, the time-inconsistent policy under discretion usually implies welfare losses relative to the optimal policy under commitment.

These results have led to several suggestions to how the time-consistency problem can be avoided and welfare improved. Some researchers, like Kydland and Prescott, have advocated fixed rules for policy rather than discretion (the credibility of these rules has typically been assumed rather than analysed, however). Others, like Barro and Gordon (1983), have suggested that when expectations of future policy depend on current policy, reputational considerations may impose restrictions on governments which improve welfare. In their study of the intertemporal optimal tax problem mentioned above, Lucas and Stokey (1983) suggest a third alternative. They show that a carefully managed maturity structure for the national debt may induce later governments to follow a previously announced policy, and that the optimal policy under commitment can actually be made time-consistent under discretion. Their suggestion involves a partial commitment, namely to honour previous debt, but no commitment about taxes. These results are further extended and interpreted by Persson and Svensson (1984, 1985).

Lucas and Stokey's result applies to a situation without money. For an economy with money, they argue, in line with previous literature such as Calvo (1978), that the time-consistency problem is inherent whenever there is fiat money. This is so since when taxes are distortionary there is always an incentive for a government to create a surprise inflation and thus to effectively impose a lump-sum tax by reducing the real value of the private sector's nominal assets. The only way out of this dilemma, it has been argued, is a commitment to a continous path for nominal prices, hence a commitment not to cause surprise inflations. It has indeed been claimed (Chamley (1985)) that a commitment to a continuous price path is both a necessary and sufficient condition for a time-consistent inflation tax.

In this paper we shall again look at the problem of an optimal combination of income taxes, inflation tax and borrowing to finance government expenditure. We shall focus on the time-consistency issues rather than on characterizing the optimal policy. Counter to previous literature, we shall indeed show that, even in a monetary economy, the optimal policy under commitment can be made time-consistent under discretion, without a commitment to a contiuous price path. We shall show that this can be done by careful management of the structure of national debt, both with regard to its maturity and its composition into nominal and indexed debt.

The sources of the time-consistency problem and of our solution are as follows. There are basically two different reasons for time inconsistency. The first is the incentive we have already mentioned to engage in a surprise inflation, thereby eroding the real value of money and other nominal assets in a lump-sum fashion. We remove this incentive to time inconsistency by specifying that the goverment leaves to its successor net nominal claims on the private sector equal to the money stock. This way the sucessive governments' gains and losses from a surprise inflation balance.

The second source of time inconsistency is the following. When choosing the optimal path for income taxes and money growth (and hence indirectly the inflation tax) each government trades off each of the two distortions against the effects on government wealth. In particular, changing taxes in the future affects real interest rates and hence the present value of government wealth. Similarly, changing future money growth affects future price levels and therefore changes the real value of future nominal obligations. The incentive to affect government wealth in these ways by changing the time path for taxes and money growth varies over time; hence the time-consistency problem.

If, however, each government inherits from its predecessor just the right maturity structure of the total national debt, the incentive to change the time path for income taxes is removed. (This is essentially the same solution as that discussed by Lucas and Stokey (1983), and by Persson and Svensson (1984)). Furthermore, if each government inherits just the right maturity structure of its nominal debt, the incentive to change the path for the money growth is also removed.

The outline is as follows. Section 2 presents the model, and Section 3 deals with the optimal policy under commitment. Section 4 shows how that policy can be made time-consistent under discretion, and Section 5 includes some conlusions.

2. The Model

We consider a closed one-good monetary economy without investment, and without uncertainty.[2] The model is a variant of that of Lucas and Stokey (1983) and Persson and Svensson (1984, 1985).

There is discrete time, $t = \ldots, -1, 0, 1, \ldots$ The technology is linear, and one unit of labor produces one unit of the good for private or public consumption. Labor endowment, y_t, is exogenous and can be used for leisure, x_t, private consumption, c_t, and public consumption, g_t, according to the resource constraint

(2.1) $$y_t \geqslant x_t + c_t + g_t .$$

There is a representative consumer with preferences over private consumption, leisure and real balances, $m_t \equiv \pi_t M_t$ (π_t is the reciprocal of the price level P_t, and M_t is the nominal money stock) given by the utility function

(2.2) $$\Sigma_0^\infty \beta^t U(c_t, x_t, \pi_t M_t), \qquad 0 < \beta < 1 .$$

The usual disclaimer for money in the utility function applies. We have assumed $\pi_t M_t$ to be an argument in (2.2) in order to introduce a monetary distortion into the model in the simplest possible way. Any other distortion will also do; in fact, the arguments in this paper will go through equally well within the framework of a cash-in-advance model. As for government consumption, we might as well let g_t enter as an argument in the utility function. Since this is immaterial to the main argument of this paper, we have however chosen to assume that g_t does not

[2] Uncertainty can be incorporated as in Lucas and Stokey (1983), but our points can be made in a simpler way in a perfect-foresight set-up.

affect the consumer's utility[3] (or affects it only additively) and that the sequence $\{g_t\}$ is an exogenously given stream of expenditures. The utility function has the standard properties. In addition we restrict it to be additively separable in real balances and the other arguments, or, equivalently, that the corresponding cross partials are zero:

$$U_{cm} = U_{xm} = 0. \tag{2.3}$$

The consumer enters each period t with money balances and with claims on the government, consisting of indexed and nominal bonds. The consumer also receives wage income net of taxes to the government. The consumer purchases consumption goods, adjusts his money and bond holdings and leaves the period with new holdings of money and bonds according to the budget constraint

$$\begin{aligned} p_t c_t + p_t \pi_t M_t + \Sigma_{t+1}^{\infty} p_s ({}_{t+1}b_s + \pi_s \, {}_{t+1}B_s) \leq \\ p_t \pi_t M_{t-1} + \Sigma_t^{\infty} p_s ({}_t b_s + \pi_s \, {}_t B_s) + p_t (1 - \tau_t)(y_t - x_t). \end{aligned} \tag{2.4}$$

Here p_t is the present value in period 0 of goods in period t, and $\pi_t \equiv 1/P_t$ is the current goods value of money in period t. We let $\{{}_t b_s\}_{s=t}^{\infty}$ denote claims, held when entering period t, to goods to be delivered in period s. We may identify ${}_t b_s$ with the total debt service, the sum of interest payment and amortization, in period s on indexed bonds. Similarly, $\{{}_t B_s\}_{s=t}^{\infty}$ denotes claims to money to be delivered in period s, i.e. the total debt service on nominal debt. The term $y_t - x_t$ is labor supply and wages (the wage rate is unity), the tax rate is τ_t, and after-tax income is hence $(1 - \tau_t)(y_t - x_t)$. With this notation, the terms on the right-hand side of (2.4) are initial real balances, the value of the

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[3] Assuming a general utility function $U(c_t, x_t, g_t, \pi_t M_t)$ and regarding g_t as a choice variable for the government, as is done by e.g. Turnovsky and Brock (1980), would not change any of the conclusions in this paper. The only difference would be that we will have one more optimality condition in Section 3 below.

initial claims on the government, and the after-tax income. The terms on the left-hand side of (2.4) are consumption expenditures, new money holdings, and new bond holdings.

The budget constraints for each t can be added and simplified to give the present-value budget constraint in period 0,

$$(2.5)\qquad \Sigma_0^\infty p_t c_t + \Sigma_0^\infty (p_t\pi_t - p_{t+1}\pi_{t+1})M_t \leqslant$$
$$p_0\pi_0 M_{-1} + \Sigma_0^\infty p_t({}_0b_t + \pi_t\ {}_0B_t) + \Sigma_0^\infty p_t(1 - \tau_t)(y_t - x_t).$$

The first-order conditions for maximizing (2.2) over $\{c_t, x_t, M_t\}_0^\infty$ subject to (2.5), can be written

$$(2.6a)\qquad p_t = \beta^t U_{ct},$$

$$(2.6b)\qquad \tau_t = 1 - U_{xt}/U_{ct}, \text{ and}$$

$$(2.6c)\qquad \pi_{t+1} = \gamma_{t+1}\pi_t, \text{ where}$$

$$(2.6d)\qquad \gamma_{t+1} \equiv (U_{ct} - U_{mt})/\beta U_{ct+1}.$$

The condition (2.6a) says that present value prices equal the discounted marginal utility of consumption (the Lagrange multiplier is unity by a suitable normalization of prices). Condition (2.6b) expresses the distortion, caused by proportional income taxes, between the marginal rate of substitution between leisure and consumption in consumption (U_{xt}/U_{ct}) and in production (unity). The condition (2.6c) follows from maximizing with respect to the money stock. It is expressed as a difference equation in the value of money, and hence in the price level.

Condition (2.6c) can be written in a more familiar form in the following way. We note that the nominal interest rate i_{t+1} can be defined in the standard way by

$$(2.7)\qquad 1/(1 + i_{t+1}) = p_{t+1}\pi_{t+1}/p_t\pi_t.$$

Combining (2.7) with (2.6a, c, d) gives, after some rewriting,

$$(2.8)\qquad i_{t+1} = U_{mt}/(U_{ct} - U_{mt}).$$

This is a familiar relation between the nominal interest rate and the marginal utility of real balances, which implicitly defines the demand for real balances (conditional on c_t and x_t) as a decreasing function of the nominal interest rate. Note that as long as i_{t+1} is positive, the usual Friedmanian distortion is present, namely that the marginal benefit of real balances (U_{mt}) is above their marginal production cost (zero).

The behavior of the consumer is summarized by (2.5) (with equality) and (2.6). The solutions to these equations give $\{c_t, x_t, M_t\}_0^\infty$ for given $\{p_t, \tau_t, \pi_t, g_t, {}_0b_t, {}_0B_t\}_0^\infty$ and given M_{-1}. In the following discussion of the optimization problem of the government it will be practical to look at consumer behavior in a different way. We will therefore consider (2.6) as defining functions

(2.9a) $\quad p_t = p_t(c_t, x_t)$,

(2.9b) $\quad \tau_t = \tau(c_t, x_t)$ and

(2.9c) $\quad \gamma_{t+1} = \gamma(c_t, x_t, m_t, c_{t+1}, x_{t+1})$

of consumption, leisure and real balances.[4] We can interpret (2.9) as expressing the present value prices, tax rates and reciprocal inflation rates (recall that $P_{t+1}/P_t \equiv \pi_t/\pi_{t+1} \equiv 1/\gamma_{t+1}$, hence γ_{t+1} is the reciprocal of the inflation rate between date t and t+1) that, given an initial price level π_0, support a given allocation $\{c_t, x_t, m_t\}_0^\infty$ of consumption, leisure and real balances. As mentioned, this alternative interpretation of (2.6) will be useful in the discussion of the government's optimization in Section 3.

We shall end this section by formulating the constraints facing the government in period 0. The government has an initial debt $\{{}_0b_t, {}_0B_t\}_0^\infty$

[4] Note that real balances m_t do not enter (2.9a) and (2.9b), and that only m_t but not m_{t+1} enters (2.9c), by the additive separability between real balances and the other arguments of the utility function.

to the consumer. It finances given expenditures $\{g_t\}_0^\infty$ by taxing wage income, by borrowing, and by money creation. Taxation of debt and interest payment is excluded. It is practical to express the government's intertemporal budget constraints in the following way, by defining real and nominal "cash-flows", as in Persson and Svensson (1984).

For t = 0, 1,... we hence define, for the government in period 0, the real cash-flow ${}_0z_t$ and the nominal cash-flow ${}_0Z_t$ according to

(2.10a) $\quad {}_0z_t \equiv \tau_t(y_t - x_t) - g_t - {}_0b_t$ and

(2.10b) $\quad {}_0Z_t \equiv M_t - M_{t-1} - {}_0B_t.$

The real cash-flow in period t is the excess of taxes over expenditures and real debt service. The nominal cash-flow in period t is the excess of the increase in money supply over nominal debt service. The government's intertemporal budget constraint can then be written

(2.10c) $\quad \Sigma_0^\infty p_t({}_0z_t + \pi_t\ {}_0Z_t) \geqslant 0.$

That is, that the present value of government expenditure must not exceed the present value of the sum of income taxes and nominal money growth less the value of the initial debt.

The government in period 0 leaves a new debt structure $\{{}_1b_t,\ {}_1B_t\}_1^\infty$ to its successor. This debt structure obeys

(2.10d) $\quad \Sigma_1^\infty p_t[{}_1b_t - {}_0b_t + \pi_t({}_1B_t - {}_0B_t)] \geqslant -p_0({}_0z_0 + \pi_t\ {}_0Z_0),$

which says that deficits in the cash-flow in period 0 is covered by issue of new debt.

Next we discuss the optimization problem of the government in period zero.

3. Optimum Policy Under Commitment

The government of date 0 thus faces a given sequence of labor endowments $\{y_t\}_0^\infty$ and an inherited national debt with a maturity structure described by $\{{}_0b_t\}_0^\infty$ and $\{{}_0B_t\}_0^\infty$. Its problem is to choose paths for its policy instruments $\{\tau_t\}_0^\infty$ and $\{M_t\}_0^\infty$ to finance the exogenously given consumption stream $\{g_t\}_0^\infty$ in such a way that the consumer's welfare is maximized. This is an intertemporal optimal taxation problem, which amounts to finding at each date an optimal mix of borrowing and two distortionary taxes - the tax on labor income and the inflation tax (the inflation tax is distortionary by driving the nominal interest rate above zero; cf Section 2).

The government maximizes welfare subject to its budget constraint (2.10) and the general equilibrium requirements (2.1) and (2.9): namely that the resource constraint is fulfilled of each date and that the consumer is maximizing. We can then formulate the Lagrangean as

$$(3.1) \qquad L = \Sigma_0^\infty \beta^t U(c_t, x_t, \pi_t M_t) + \lambda_0 \Sigma_0^\infty p_t({}_0z_t + \pi_t\, {}_0Z_t) + \Sigma_0^\infty \mu_{0t}(y_t - x_t - c_t - g_t),$$

where it is understood that p_t, ${}_0z_t$ and ${}_0Z_t$ are consistent with (2.9).

In the optimum (we assume that there is a unique second-best optimal allocation), no reallocation of the policy instruments should increase welfare, or equivalently:

$$(3.2) \qquad dL = \Sigma_0^\infty \beta^t du_t + \lambda_0 \Sigma_0^\infty p_t(d_0z_t + \pi_t\, d_0Z_t) + \lambda_0 \Sigma_0^\infty({}_0z_t + \pi_t\, {}_0Z_t)dp_t + \lambda_0 \Sigma_0^\infty p_t\, {}_0Z_t d\pi_t - \Sigma_0^\infty \mu_{0t}(dx_t + dc_t) = 0.$$

Let us try to understand the different welfare effects as measured by the right-hand side of (3.2). First, there is, of course, a direct effect on instantaneous utility in period t: $du_t = U_{ct}dc_t + U_{xt}dx_t + U_{mt}dm_t$. Next, the government's wealth is increased to the extent that its income from labor taxes or money creation goes up at date t. Since higher income at t means that the distortionary taxes can be lowered at some other date, the effect on welfare is given by the multiplier on the government wealth constraint, λ_0, which we refer to as the level of "tax distortion". Third, if the government's total cash-flow at date t is positive, its wealth is revalued if the present value of goods at that date goes up. The increase in wealth allows for lower taxes so multiplying it with λ_0 again gives the welfare effect.[5] A similar wealth revaluation of the government's nominal cash-flow at date t results if the value of money increases (the price level at date t goes down); this is the fourth term. And, finally, we have the resource cost of any reallocation at each date t; μ_{0t} being the multiplier on the resource constraint at t.

Having described the government's trade-offs in general terms, we shall now look closer at the conditions for an optimum. Exploiting the discussion in Section 2, we know that a given path of M_t and τ_t, the direct policy instruments, is equivalent to a given path of c_t, x_t and m_t and a particular value of π_0. Indeed, we shall find it convenient to look primarily at the latter set of variables.

Let us first note that (2.6c) and the definition of real balances give the following equilibrium requirements:

$$(3.3a) \qquad d\pi_s = \begin{cases} \pi_s(d\pi_0/\pi_0) & s \leq t-1 \\ \pi_s(d\pi_0/\pi_0 + d\gamma_t/\gamma_t) & s = t \\ \pi_s(d\pi_0/\pi_0 + d\gamma_t/\gamma_t + d\gamma_{t+1}/\gamma_{t+1}) & s \geq t+1, \end{cases}$$

$$(3.3b) \qquad dM_s = M_s(dm_s/m_s - d\pi_s/\pi_s).$$

As a further preliminary, (2.6) and some manipulations yield

$$(3.3c) \qquad d\gamma_t = -\gamma_t dp_t/p_t,$$

[5] Another way to interpret the third term is to think of the government's cash-flows as its net exports to the private sector; $({}_0z_t + \pi_t\,{}_0Z_t)dp_t$ then becomes a standard (intertemporal) terms-of-trade effect, wellknown from trade theory.

(3.3d) $$d\gamma_{t+1} = \gamma_{t+1}(\pi_t/\pi_{t+1}p_{t+1})dp_t - \gamma_{t+1}(\beta^t U_{mmt}\pi_t/\pi_{t+1}p_{t+1})dm_t,$$

where $dp_t = U_{cct}dc_t + U_{cxt}dx_t$.

Suppose now that the government considers a small reallocation of consumption and leisure at date t which obeys the resource constraint, that is the changes in private consumption and leisure fulfill $dc_t = -dx_t$. Then, relying on (3.3), we can express the resulting welfare effect as

(3.4) $$\begin{aligned} dL = \{&\beta^t(U_{ct} - U_{xt}) + \lambda_0 p_t[d(\tau_t(y_t - x_t))]/dc_t + \\ &+ \lambda_0({}_0z_t + \pi_t\ {}_0Z_t)(dp_t/dc_t) + \\ &+ \lambda_0(p_t\pi_t M_{t-1} + \Sigma_t^\infty p_s\pi_s\ {}_0B_s)(1/p_t)(dp_t/dc_t) - \\ &- \lambda_0(p_{t+1}\pi_{t+1}M_t + \Sigma_{t+1}^\infty p_s\pi_s\ {}_0B_s)(\pi_t/\pi_{t+1}p_{t+1})(dp_t/dc_t)\}\ dc_t. \end{aligned}$$

Here, the first term captures the direct welfare effect, amounting to the distortion from the tax. Second there is an effect on tax income. Next comes the effect on government wealth of a change in the present value factor - that is in today's real bond prices - caused by $dc_t = -dx_t$. Further, the change in c_t changes the real interest rate between periods t-1 and t, as well as between t and t+1. Since we hold m_{t-1} and m_t constant, the inflation rates $1/\gamma_t$ and $1/\gamma_{t+1}$ have to change so as to make the nominal interest rates consistent with those real balances being held. The effects on government wealth of the resulting changes in future price levels - and hence in the real value of future nominal obligations - and the necessary accommodating changes in nominal balances are given by the two final terms in (3.4). In an optimum the distortion from the income tax is appropriately traded-off and there are no further gains from reallocating consumption and leisure at any date. Therefore, (3.4) is equal to zero[6] for all $t = 0 \ldots \infty$.

[6]Note that for t=0, the third term in (3.4) is identically equal to zero.

Consider next a change in real balances of date t, dm_t. The welfare effect of this is

(3.5) $$dL = \{\beta^t U_{mt} + \lambda_0 p_t(i_{t+1}/(1+i_{t+1})) +$$

$$+ \lambda_0(p_{t+1}\pi_{t+1}M_t + \Sigma_{t+1}^{\infty}p_s\pi_s\ {}_0B_s)\beta^t U_{mmt}\pi_t/\pi_{t+1}p_{t+1}\}\ dm_t.$$

First, we have a direct welfare effect, and next there is the increase in the government budget from the standard inflation tax. Third, we have the wealth effects of the change in the price level from date t+1 and onwards. We note that this amounts to a change in the real value of the money stock outstanding in the beginning of date t as well as in the government's nominal debt obligations from date t+1 and forward. In an optimum there is no welfare gain from changing m_t at any date and so (3.5) is equal to zero for all t.

Last, think of a change in π_0. From (3.3) this is achieved by an equiproportionate change in the path for the nominal money stock and changes the price level of all dates in proportion. We can thus think of $d\pi_0$ as a once-and-for-all change in the value of money, or a "surprise inflation" carried out at date 0. As can be verified from the welfare effect,

(3.6) $$dL = -\lambda_0(p_0\pi_0M_{-1} + \Sigma_0^{\infty}p_s\pi_s\ {}_0B_s)(d\pi_0/\pi_0),$$

this does not change the real allocation and thus works as a pure capital levy on the initial money stock and outstanding nominal debt obligations. Since there are no trade-offs in (3.6), there is not necessarily an interior solution for π_0 where dL = 0. In the typical case we treat below the government is initially (that is, at date 0) a net nominal debtor, meaning that the expression within brackets is positive. It would then be optimal to drive π_0 towards zero, that is to drive the price level $P_0 (\equiv 1/\pi_0)$ towards infinity, so as to reduce the real value of the government's nominal obligations. This would reduce λ_0, but not to zero, since the resulting increase in government wealth (except in uninteresting special cases) would not be sufficient to finance the entire path of future government expenditure.[7] In practise it might however be difficult to drive P_0 to infinity. Let us therefore assume that optimal behavior implies $P_0 = \bar{P}_0$ where $\bar{P}_0$ is a high but finite number, maybe given by the Mint's printing capacity.[8]

To summarize, the considerations we have described in this section lead to an optimal allocation $\{c_t, x_t, m_t\}_0^\infty$ and an initial price level π_0. If, in fact, the government at date 0 could commit all the future policy instruments to those values that support the optimal allocation, that would be the end of the story. Here we rule such commitments out, however, and consider instead discretionary policy-making. That is, for each date t = 1,..., the government in power at that date is given complete freedom to reoptimize. In the next section we describe the time-consistency problems that arise in such a set-up and show how they can be

[7] Thus dL in (3.6) need not be equal to zero reflecting the fact that no bounded solution for P_0 exists.

[8] If the government at date 0 instead were a net nominal creditor, the bracketed expression in (3.6) is negative and the optimal policy is to increase π_0 (reduce P_0) until the real value of the claims on the private sector become large enough to cover all future expenditures. The resulting equilibrium is then first best and the optimal tax problem as well as the time consistency problem we are interested in disappear. We therefore rule this case out by assumption. Turnovsky and Brock (1980) implicitly treat this case in their solutions of the optimal tax problem when they assume that the real value of the government's initial assets can be freely chosen.

resolved by an appropriate maturity structure of the government debt which turns out to make the optimum policy incentive-compatible.

4. Time Consistency Under Discretion

The governments at $\theta = 1, \ldots, \infty$ (from now on Government 1, 2, etc.) solve the same optimal tax problem as did Government 0. There are two different reasons why each of these governments might want to choose a different allocation than did its predecessor. In the sequel we discuss these two time-consistency problems in turn.

First, the new government at each date has, like Government 0, an incentive to engage in an immediate surprise inflation. This incentive can however be eliminated if each government inherits a set of nominal net claims on the private sector with a total market value equal to the outstanding money stock. For example, if Government 1 inherits a nominal debt $\{{}_1B_s\}_1^\infty$ such that

$$\Sigma_1^\infty p_s \pi_s \; {}_1B_s = -p_1 \pi_1 M_0,$$

the welfare effect of a change in the initial price level given by the equivalent of (3.6),

$$dL = -\lambda_1 (p_1 \pi_1 M_0 + \Sigma_1^\infty p_s \pi_s \; {}_1B_s)(d\pi_1/\pi_1),$$

is identically equal to zero. In general therefore Government θ-1, $\theta = 1, \ldots \infty$, should leave its successor with net nominal claims on the private sector equal to the money stock[9], i.e. with a nominal debt $\{{}_\theta B_s\}_\theta^\infty$ such that

$$\Sigma_\theta^\infty p_s \pi_s \; {}_\theta B_s = -p_\theta \pi_\theta M_{\theta-1}. \quad (4.1)$$

This is the first aspect of our scheme for time consistency. One should note that if (4.1) is satisfied, i.e. the government has a zero net

[9]This was first suggested to us by Robert King at a seminar at the University of Rochester.

position in nominal terms vis-a-vis the private sector, this does not mean that there will be no scope for exploiting the inflation tax. The (anticipated) inflation tax is derived from the private sector's willingness to hold a non-interest-bearing nominal asset, i.e. money. Even if this asset is exactly balanced by an interest-bearing nominal liability to the government (${}_{\theta}B_s$) there will still be a base for the inflation tax since the nominal interest rate will change in relation to the anticipated inflation rate. Thus (4.1) only rules out the government's incentive for surprise inflation, and not for anticipated inflation.

While the above scheme solves the time consistency problem associated with Government θ's choice of π_θ, there is another time consistency problem associated with its choice of the other (indirect) instruments, namely $\{c_t, x_t, m_t\}$. To understand this, notice from (3.4) and (3.5) that the optimal choice of c_t (and x_t) and m_t both involve trading off a distortion against the effect on the government budget. The distortion is expressed by the first term on the right-hand side, measuring the "direct" welfare effect which would be equal to zero if lump-sum taxation were available. The effect on the government budget is expressed by the other terms in (3.4) and (3.5), i.e. by the tax distortion λ_0 times the change in government wealth. Since the tax distortion changes over time, that is λ_θ, $\theta = 1 \ldots \infty$ does not stay constant and equal to λ_0 (see further below), successive governments would seem to have incentives to choose different allocations.

The optimality condition for Government θ's choice of m_t can, in analogy with (3.5), be written

$$(4.2) \qquad dL = \{\beta^t U_{mt} + \lambda_\theta [p_t(i_{t+1}/(1+i_{t+1}) - $$
$$- (p_{t+1}\pi_{t+1}M_t + \Sigma_{t+1}^{\infty} p_s \pi_s \, {}_{\theta}B_s)(\pi_t \beta^t U_{mmt}/\pi_{t+1}p_{t+1})]\} dm_t = 0.$$

Suppose now that Government $\theta-1$, $\theta = 1\ldots\infty$, leaves its successor with a debt structure such that

$$\Sigma_{t+1}^{\infty} p_s \pi_s \, {}_{\theta}B_s = -p_{t+1}\pi_{t+1}M_t - (1+1/\lambda_{\theta})(\pi_{t+1}p_{t+1}U_{mt}/\pi_t U_{mmt}), \tag{4.3}$$

where we have used that $p_t i_{t+1}/(1 + i_{t+1}) = \beta^t U_{mt}$ from (2.6) - (2.8). Then (4.2) is satisfied identically and there is no incentive for Government θ to deviate from the m_t that was chosen by Government $\theta-1$. Obviously, there will be an equation like (4.3) for each $t \geqslant 0$. These equations together with (4.1) thus yield a unique nominal debt structure $\{{}_{\theta}B_t\}_{\theta}^{\infty}$ that Government $\theta-1$ should leave to its successor to make the optimal plan for $\{m_t\}_{\theta}^{\infty}$ incentive-compatible. We note also that (4.3) is precisely defined for a given value of λ_{θ}. To obtain the appropriate λ_{θ} value we turn to the other (indirect) policy instruments, namely the choice of $\{c_t\}_{\theta}^{\infty}$.

By the analog to (3.4), Government θ maximizes welfare with respect to c_t by solving

$$\begin{aligned} dL = \{&\beta^t(U_{ct} - U_{xt}) + \lambda_{\theta}[p_t \frac{d(\tau_t(y_t - x_t))}{dc_t} + \\ &+ ({}_0z_t + \pi_t \, {}_0Z_t)(dp_t/dc_t) + \\ &+ ((p_t\pi_t M_{t-1} + \Sigma_t^{\infty} p_s \pi_s \, {}_{\theta}B_s)/p_t)(dp_t/dc_t) - \\ &- ((p_{t+1}\pi_{t+1}M_t + \Sigma_{t+1}^{\infty} p_s \pi_s \, {}_{\theta}B_s)\pi_t/\pi_{t+1}p_{t+1})(dp_t/dc_t)]\} = 0. \end{aligned} \tag{4.4}$$

However, using equation (4.3) and rearranging a little, we may rewrite (4.4) as

$$\begin{aligned} dL = (dp_t/dc_t)\{&[\beta^t(U_{ct}-U_{xt})(dc_t/dp_t) - \frac{\pi_t U_{mt-1}}{\pi_{t-1}U_{mmt-1}} + \frac{U_{mt}}{U_{mmt}}] \\ &+ \lambda_{\theta}[\frac{d(\tau_t(y_t-x_t))}{dp_t} - \frac{\pi_t U_{mt-1}}{\pi_{t-1}U_{mmt-1}} + \frac{U_{mt}}{U_{mmt}}] + \lambda_{\theta}({}_{\theta}z_t+\pi_t \, {}_{\theta}Z_t)\} \, dc_t \\ &= 0. \end{aligned} \tag{4.5}$$

To save on notation, rewrite (4.5) as

(4.6) $$dL = (J_t + \lambda_\theta K_t + \lambda_\theta \, {}_\theta\tilde{z}_t)dp_t = 0,$$

where we note that J_t and K_t only depend on the real allocation. Multiplying the bracketed expression in (4.6) by p_t and summing over t, we get

(4.7) $$\lambda_\theta = -\Sigma_\theta^\infty p_t J_t / \Sigma_\theta^\infty p_t K_t.$$

Now we have a value for λ_θ and thus also values for $\{_\theta B_t\}_\theta^\infty$ from (4.3). If we substitute these into (4.5) we get unique indexed debt obligations $\{_\theta b_t\}_\theta^\infty$ which will make (4.5) identically satisfied for each $t \geqslant \theta$. In other words, we have found a unique indexed debt structure that government θ-1, θ = 1...∞, should leave to its sucessor to sustain the optimum choice of $\{c_t\}_\theta^\infty$.

In summary, we have shown that for every government there is a unique maturity structure of the nominal as well as the indexed part of the public debt that remove the incentives to deviate from the optimal policy $\{\tau_t, M_t\}_0^\infty$ chosen and announced by Government 0.

Let us finally say something about how the debt structures of successive governments differ, that is characterize the restructuring scheme of the debt that each government has to perform to impose time-consistency on its successor. To that end we write the θ-1 analogs to (4.6) and (4.7),

(4.8) $$dL = (J_t + \lambda_{\theta-1} K_t + \lambda_{\theta-1} \, {}_{\theta-1}\tilde{z}_t)dp_t = 0$$ and

(4.9) $$\lambda_{\theta-1} = -\Sigma_{\theta-1}^\infty p_t J_t / \Sigma_{\theta-1}^\infty p_t K_t.$$

To get more definite results, we also make the unrestrictive assumption that J_t is negative for all t. Sufficient conditions for this is that the utility function displays constant reltive risk aversion in m_t, and that the optimal solution is such that τ_t is positive and M grows with time.[10]

From (4.6) - (4.9) it then follows that

$$(4.10) \qquad \lambda_\theta \gtrless \lambda_{\theta-1} \quad \text{if and only if} \quad {}_{\theta-1}\tilde{z}_{\theta-1} \gtrless 0.$$

Government θ thus will have a higher tax distortion than Government θ-1 if and only if the total cash-flow at date θ-1 is negative, something which squares well with intuition. By (4.6) and (4.8) we then have

$${}_\theta\tilde{z}_t = - J_t/\lambda_\theta - K_t \text{ and}$$

$${}_{\theta-1}\tilde{z}_t = - J_t/\lambda_{\theta-1} - K_t.$$

Thus

$$(4.11) \qquad ({}_\theta b_t + \pi_t \; {}_\theta B_t) - ({}_{\theta-1}b_t + \pi_t \; {}_{\theta-1}B_t) = {}_{\theta-1}\tilde{z}_t - {}_\theta\tilde{z}_t = $$
$$= J_t(1 - \lambda_{\theta-1}/\lambda_\theta)/\lambda_{\theta-1},$$

which gives us the scheme for the restructuring of aggregate debt that has to take place at date θ-1. Combining (4.10) and (4.11) and assuming $J_t <$ 0, we see that

$$({}_\theta b_t + \pi_t \; {}_\theta B_t) - ({}_{\theta-1}b_t + \pi_t \; {}_{\theta-1}B_t) \lessgtr 0$$

$$\text{if and only if} \quad {}_{\theta-1}\tilde{z}_{\theta-1} \gtrless 0$$

for all t. This means that a negative cash-flow at θ-1 (that is government income from taxes and money creation falls short of government consumption and debt service) should be financed by issuing some debt of <u>all</u> maturities.[11]

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[10] The first term in J_t, $\beta^t(U_{ct}-U_{xt})/(U_{cct}-U_{cxt})$, is negative if goods and leisure are normal. Also, the sum of the second and third term can be rewritten $-\pi_t(M_t-M_{t-1})/r$, where $r \equiv -m_t U_{mmt}/U_{mt}$

[11] These results are analoguous to those in Persson and Svensson (1984) regarding indexed debt in a model without money.

What about the indexed versus nominal components in this restructuring scheme? From (4.3) and its θ-1 analog, we may derive for $t \geqslant \theta+1$,

$$(4.12) \qquad {}_{\theta}B_t - {}_{\theta-1}B_t = N_t(1 - \lambda_{\theta-1}/\lambda_{\theta})/\lambda_{\theta-1},$$

where $N_t \equiv (U_{mt-1}/U_{mmt-1})(\pi_t p_t/\pi_{t-1}) - (U_{mt}/U_{mmt})(\pi_{t+1}p_{t+1}/\pi_t)$. The sign of N_t is not unambiguous, in general, but our presumption is that on average it is negative.[12] Comparing to (4.11) we see that nominal and indexed debt might well have to be restructured in opposite directions for some t. Note, however, that (4.12) applies only for $t \geqslant \theta+1$, that is for maturities of two periods and longer. From (4.1) and its θ-1 analog, we know that the growth in the market value of the government's total nominal claims on the private sector satisfies

$$(4.13) \qquad -(\Sigma_{\theta}^{\infty} p_s \pi_s \, {}_{\theta}B_s - \Sigma_{\theta}^{\infty} p_s \pi_s \, {}_{\theta-1}B_s) =$$
$$= p_{\theta-1}\pi_{\theta-1}[{}_{\theta-1}Z_{\theta-1} - i_{\theta}M_{\theta-1}/(1 + i_{\theta})]$$

where we have used (2.7) and the definition of ${}_{\theta}Z_t$. In other words the government at date θ-1 should use its nominal cash-flow minus the proceeds from the inflation tax to buy nominal bonds from the private sector. Whatever the operations in long-term nominal bonds described above result in, Government θ-1 thus has to adjust its purchases of short-term (one-period) securities so that its total open market operations in nominal bonds fulfill (4.13).

5. Conclusions

We have shown that optimal fiscal and monetary policy under commitment can be made time-consistent under discretion, in the following

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12 Take the case with constant relative risk aversion in m_t discussed above. Then N_t can be written as $N_t = (m_t p_{t+1}\pi_{t+1}/\pi_t - m_{t-1}p_t\pi_t/\pi_{t-1})/r$. Suppose real balances and inflation are both relatively stable over time. Then we have $m_t\pi_{t+1}/\pi_t \approx m_{t-1}\pi_t/\pi_{t-1}$ and thus N_t is negative (provided $p_t > p_{t+1}$).

way. First, the incentive for each government to engage in a surprise inflation is removed by each government leaving nominal claims with a total market value equal to the money stock to its successor. Second, the incentive to manipulate future real money balances, inflation rates and nominal interest rates is removed by leaving a suitable maturity structure of the nominal debt. Third, the incentive to manipulate income taxes, real interest rates and real bond prices is removed by a suitable choice of the maturity structure of the total debt, including both nominal and indexed bonds.

The determination of fiscal and monetary policy can then be described as follows. The time path of tax rates and monetary expansion is determined in the intertemporal optimal taxation problem. This also determines total borrowing and total debt in each period. The composition of this debt is determined so as to give each government total nominal claims equal to the money stock. This can be formulated as a simple rule of thumb. In each period, the government should be a net creditor, in nominal bonds, to the private sector, and the total value of the outstanding stock of nominal bonds should be equal to the money stock. This is accomplished by open market operations where the government at each date uses its entire nominal cash flow minus the proceeds from the inflation tax to buy nominal bonds from the private sector. The maturity structure of the nominal claims is determined by the requirement that there shall not exist any incentives to manipulate future inflation rates and nominal interest rates.

Total indexed debt is determined as the difference between total debt, as determined by the optimal taxation problem, and the nominal claims referred to above. It remains to determine the maturity structure of the indexed debt. The maturity structure of the total debt is determined by the requirement that incentives to manipulate taxes and real interest rates are removed. The maturity structure of the nominal debt is determined as specified above. Hence, the maturity of the indexed debt is determined as the resulting residual.

Therefore, it is crucial that both nominal and indexed debt exist together, although they are used for different purposes. Nominal debt/claims are used to balance the money stock, whereas the required net borrowing is done via indexed debt. One reason why previous literature have not found the solution to time-consistent monetary policy that we suggest may be that the anlysis has been arbitrarily restricted to considering nominal debt only.

We shall also add some qualifications and mention some possible extensions.

As in Lucas and Stokey (1983), our solution involves a commitment to honor previous debt, and taxes on debt are not allowed. If there were capital, a commitment not to tax capital would be required. Our solution does hence not contribute to explaining time-consistency in debt and capital taxation. It may be argued that reputational considerations might be able to explain the absence of both surprise taxation on capital and debt and surprise inflation, and hence be preferable to our solution.

Uncertainty is easy to introduce, along the lines of Lucas and Stokey (1983), as long as perfect markets for contingent debt is assumed. Then the debt structure is determined not only with regard to maturity and nominal/indexed composition but also with regard to its contingency structure.

The analysis could be extended to deal with a gold standard and other monetary arrangements. It seems clear though that a strict gold standard would remove the possibility of an inflation tax and the monetary aspects of the time-consistency problem.

We should also make the obvious remark that monetary and fiscal policy here concerns "public-finance" issues only. There are no nominal rigidities in our model and no unemployment/excess capacity. In that sense, "business-cycle" aspects of monetary and fiscal policy are not being discussed here.

What we do in this paper is mainly to demonstrate the existence of a particular solution to the problem of time-consistent fiscal and monetary policy. It remains to characterize the solution in greater detail, for instance to examine whether fiscal and monetary policy is pro- or counter-cyclical. We hope to address that issue in future work.

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TIME CONSISTENCY OF FISCAL AND MONETARY POLICY[1]

by

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1. Introduction

The problem of the optimal combination of income taxation and borrowing for financing government expenditure can be treated as an intertemporal optimal taxation problem as in Lucas and Stokey (1983) . A path of distortionary income taxes is chosen so as to finance a given path of government expenditure at minimal welfare losses. Any excess of the optimally chosen taxes over expenditures in a given period is covered by borrowing. With fiat money goverment expenditures can also be financed by an inflation tax. Such a tax is distortionary by driving real balances below Friedman's optimum quantity of money. Phelps (1973) was the first to seriously discuss the "general macroeconomic public finance problem", namely how to find the optimal combination of the two taxes. It is well known that in general the solution implies the use of both the inflation tax and the income tax for financing government expenditures.

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These aspects of the optimal combination of income taxes, inflation tax and borrowing applies to a situation where a goverment can commit itself to a particular policy. It is well known after Kydland and Prescott (1977) that a government under discretion usually has incentive to deviate from previously announced policy, and hence that the optimal policy under commitment is not time-consistent under discretion. Further, the time-inconsistent policy under discretion usually implies welfare losses relative to the optimal policy under commitment.

These results have led to several suggestions to how the time-consistency problem can be avoided and welfare improved. Some researchers, like Kydland and Prescott, have advocated fixed rules for policy rather than discretion (the credibility of these rules has typically been assumed rather than analysed, however). Others, like Barro and Gordon (1983), have suggested that when expectations of future policy depend on current policy, reputational considerations may impose restrictions on governments which improve welfare. In their study of the intertemporal optimal tax problem mentioned above, Lucas and Stokey (1983) suggest a third alternative. They show that a carefully managed maturity structure for the national debt may induce later governments to follow a previously announced policy, and that the optimal policy under commitment can actually be made time-consistent under discretion. Their suggestion involves a partial commitment, namely to honour previous debt, but no commitment about taxes. These results are further extended and interpreted by Persson and Svensson (1984, 1985).

Lucas and Stokey's result applies to a situation without money. For an economy with money, they argue, in line with previous literature such as Calvo (1978), that the time-consistency problem is inherent whenever there is fiat money. This is so since when taxes are distortionary there is always an incentive for a government to create a surprise inflation and thus to effectively impose a lump-sum tax by reducing the real value of the private sector's nominal assets. The only way out of this dilemma, it has been argued, is a commitment to a continous path for nominal prices, hence a commitment not to cause surprise inflations. It has indeed been claimed (Chamley (1985)) that a commitment to a continuous price path is both a necessary and sufficient condition for a time-consistent inflation tax.

In this paper we shall again look at the problem of an optimal combination of income taxes, inflation tax and borrowing to finance government expenditure. We shall focus on the time-consistency issues rather than on characterizing the optimal policy. Counter to previous literature, we shall indeed show that, even in a monetary economy, the optimal policy under commitment can be made time-consistent under discretion, without a commitment to a contiuous price path. We shall show that this can be done by careful management of the structure of national debt, both with regard to its maturity and its composition into nominal and indexed debt.

The sources of the time-consistency problem and of our solution are as follows. There are basically two different reasons for time inconsistency. The first is the incentive we have already mentioned to engage in a surprise inflation, thereby eroding the real value of money and other nominal assets in a lump-sum fashion. We remove this incentive to time inconsistency by specifying that the goverment leaves to its successor net nominal claims on the private sector equal to the money stock. This way the sucessive governments' gains and losses from a surprise inflation balance.

The second source of time inconsistency is the following. When choosing the optimal path for income taxes and money growth (and hence indirectly the inflation tax) each government trades off each of the two distortions against the effects on government wealth. In particular, changing taxes in the future affects real interest rates and hence the present value of government wealth. Similarly, changing future money growth affects future price levels and therefore changes the real value of future nominal obligations. The incentive to affect government wealth in these ways by changing the time path for taxes and money growth varies over time; hence the time-consistency problem.

If, however, each government inherits from its predecessor just the right maturity structure of the total national debt, the incentive to change the time path for income taxes is removed. (This is essentially the same solution as that discussed by Lucas and Stokey (1983), and by Persson and Svensson (1984)). Furthermore, if each government inherits just the right maturity structure of its nominal debt, the incentive to change the path for the money growth is also removed.

The outline is as follows. Section 2 presents the model, and Section 3 deals with the optimal policy under commitment. Section 4 shows how that policy can be made time-consistent under discretion, and Section 5 includes some conlusions.

2. The Model

We consider a closed one-good monetary economy without investment, and without uncertainty.[2] The model is a variant of that of Lucas and Stokey (1983) and Persson and Svensson (1984, 1985).

There is discrete time, $t = \ldots, -1, 0, 1, \ldots$ The technology is linear, and one unit of labor produces one unit of the good for private or public consumption. Labor endowment, y_t, is exogenous and can be used for leisure, x_t, private consumption, c_t, and public consumption, g_t, according to the resource constraint

$$(2.1) \qquad y_t \geq x_t + c_t + g_t.$$

There is a representative consumer with preferences over private consumption, leisure and real balances, $m_t \equiv \pi_t M_t$ (π_t is the reciprocal of the price level P_t, and M_t is the nominal money stock) given by the utility function

$$(2.2) \qquad \Sigma_0^\infty \beta^t U(c_t, x_t, \pi_t M_t), \qquad 0 < \beta < 1 .$$

The usual disclaimer for money in the utility function applies. We have assumed $\pi_t M_t$ to be an argument in (2.2) in order to introduce a monetary distortion into the model in the simplest possible way. Any other distortion will also do; in fact, the arguments in this paper will go through equally well within the framework of a cash-in-advance model. As for government consumption, we might as well let g_t enter as an argument in the utility function. Since this is immaterial to the main argument of this paper, we have however chosen to assume that g_t does not

[2] Uncertainty can be incorporated as in Lucas and Stokey (1983), but our points can be made in a simpler way in a perfect-foresight set-up.

affect the consumer's utility[3] (or affects it only additively) and that the sequence $\{g_t\}$ is an exogenously given stream of expenditures. The utility function has the standard properties. In addition we restrict it to be additively separable in real balances and the other arguments, or, equivalently, that the corresponding cross partials are zero:

$$U_{cm} = U_{xm} = 0. \tag{2.3}$$

The consumer enters each period t with money balances and with claims on the government, consisting of indexed and nominal bonds. The consumer also receives wage income net of taxes to the government. The consumer purchases consumption goods, adjusts his money and bond holdings and leaves the period with new holdings of money and bonds according to the budget constraint

$$\begin{aligned} (2.4) \qquad & p_t c_t + p_t \pi_t M_t + \Sigma_{t+1}^{\infty} p_s ({}_{t+1}b_s + \pi_s\, {}_{t+1}B_s) \leq \\ & p_t \pi_t M_{t-1} + \Sigma_t^{\infty} p_s ({}_t b_s + \pi_s\, {}_t B_s) + p_t (1 - \tau_t)(y_t - x_t). \end{aligned}$$

Here p_t is the present value in period 0 of goods in period t, and $\pi_t \equiv 1/P_t$ is the current goods value of money in period t. We let $\{{}_t b_s\}_{s=t}^{\infty}$ denote claims, held when entering period t, to goods to be delivered in period s. We may identify ${}_t b_s$ with the total debt service, the sum of interest payment and amortization, in period s on indexed bonds. Similarly, $\{{}_t B_s\}_{s=t}^{\infty}$ denotes claims to money to be delivered in period s, i.e. the total debt service on nominal debt. The term $y_t - x_t$ is labor supply and wages (the wage rate is unity), the tax rate is τ_t, and after-tax income is hence $(1 - \tau_t)(y_t - x_t)$. With this notation, the terms on the right-hand side of (2.4) are initial real balances, the value of the

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[3] Assuming a general utility function $U(c_t, x_t, g_t, \pi_t M_t)$ and regarding g_t as a choice variable for the government, as is done by e.g. Turnovsky and Brock (1980), would not change any of the conclusions in this paper. The only difference would be that we will have one more optimality condition in Section 3 below.

initial claims on the government, and the after-tax income. The terms on the left-hand side of (2.4) are consumption expenditures, new money holdings, and new bond holdings.

The budget constraints for each t can be added and simplified to give the present-value budget constraint in period 0,

$$(2.5) \qquad \Sigma_0^\infty p_t c_t + \Sigma_0^\infty (p_t \pi_t - p_{t+1}\pi_{t+1}) M_t \leq p_0 \pi_0 M_{-1} + \Sigma_0^\infty p_t ({}_0 b_t + \pi_t \, {}_0 B_t) + \Sigma_0^\infty p_t (1 - \tau_t)(y_t - x_t).$$

The first-order conditions for maximizing (2.2) over $\{c_t, x_t, M_t\}_0^\infty$ subject to (2.5), can be written

$$(2.6a) \qquad p_t = \beta^t U_{ct},$$

$$(2.6b) \qquad \tau_t = 1 - U_{xt}/U_{ct}, \text{ and}$$

$$(2.6c) \qquad \pi_{t+1} = \gamma_{t+1}\pi_t, \text{ where}$$

$$(2.6d) \qquad \gamma_{t+1} \equiv (U_{ct} - U_{mt})/\beta U_{ct+1}.$$

The condition (2.6a) says that present value prices equal the discounted marginal utility of consumption (the Lagrange multiplier is unity by a suitable normalization of prices). Condition (2.6b) expresses the distortion, caused by proportional income taxes, between the marginal rate of substitution between leisure and consumption in consumption (U_{xt}/U_{ct}) and in production (unity). The condition (2.6c) follows from maximizing with respect to the money stock. It is expressed as a difference equation in the value of money, and hence in the price level.

Condition (2.6c) can be written in a more familiar form in the following way. We note that the nominal interest rate i_{t+1} can be defined in the standard way by

$$(2.7) \qquad 1/(1 + i_{t+1}) = p_{t+1}\pi_{t+1}/p_t\pi_t.$$

Combining (2.7) with (2.6a, c, d) gives, after some rewriting,

$$(2.8) \qquad i_{t+1} = U_{mt}/(U_{ct} - U_{mt}).$$

This is a familiar relation between the nominal interest rate and the marginal utility of real balances, which implicitly defines the demand for real balances (conditional on c_t and x_t) as a decreasing function of the nominal interest rate. Note that as long as i_{t+1} is positive, the usual Friedmanian distortion is present, namely that the marginal benefit of real balances (U_{mt}) is above their marginal production cost (zero).

The behavior of the consumer is summarized by (2.5) (with equality) and (2.6). The solutions to these equations give $\{c_t, x_t, M_t\}_0^\infty$ for given $\{p_t, \tau_t, \pi_t, g_t, {}_0b_t, {}_0B_t\}_0^\infty$ and given M_{-1}. In the following discussion of the optimization problem of the government it will be practical to look at consumer behavior in a different way. We will therefore consider (2.6) as defining functions

(2.9a) $p_t = p_t(c_t, x_t)$,

(2.9b) $\tau_t = \tau(c_t, x_t)$ and

(2.9c) $\gamma_{t+1} = \gamma(c_t, x_t, m_t, c_{t+1}, x_{t+1})$

of consumption, leisure and real balances.[4] We can interpret (2.9) as expressing the present value prices, tax rates and reciprocal inflation rates (recall that $P_{t+1}/P_t \equiv \pi_t/\pi_{t+1} \equiv 1/\gamma_{t+1}$, hence γ_{t+1} is the reciprocal of the inflation rate between date t and t+1) that, given an initial price level π_0, support a given allocation $\{c_t, x_t, m_t\}_0^\infty$ of consumption, leisure and real balances. As mentioned, this alternative interpretation of (2.6) will be useful in the discussion of the government's optimization in Section 3.

We shall end this section by formulating the constraints facing the government in period 0. The government has an initial debt $\{{}_0b_t, {}_0B_t\}_0^\infty$

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[4] Note that real balances m_t do not enter (2.9a) and (2.9b), and that only m_t but not m_{t+1} enters (2.9c), by the additive separability between real balances and the other arguments of the utility function.

to the consumer. It finances given expenditures $\{g_t\}_0^\infty$ by taxing wage income, by borrowing, and by money creation. Taxation of debt and interest payment is excluded. It is practical to express the government's intertemporal budget constraints in the following way, by defining real and nominal "cash-flows", as in Persson and Svensson (1984).

For t = 0, 1,... we hence define, for the government in period 0, the real cash-flow ${}_0z_t$ and the nominal cash-flow ${}_0Z_t$ according to

(2.10a) $\quad {}_0z_t \equiv \tau_t(y_t - x_t) - g_t - {}_0b_t$ and

(2.10b) $\quad {}_0Z_t \equiv M_t - M_{t-1} - {}_0B_t.$

The real cash-flow in period t is the excess of taxes over expenditures and real debt service. The nominal cash-flow in period t is the excess of the increase in money supply over nominal debt service. The government's intertemporal budget constraint can then be written

(2.10c) $\quad \Sigma_0^\infty p_t({}_0z_t + \pi_t\, {}_0Z_t) \geqslant 0.$

That is, that the present value of government expenditure must not exceed the present value of the sum of income taxes and nominal money growth less the value of the initial debt.

The government in period 0 leaves a new debt structure $\{{}_1b_t, {}_1B_t\}_1^\infty$ to its successor. This debt structure obeys

(2.10d) $\quad \Sigma_1^\infty p_t[{}_1b_t - {}_0b_t + \pi_t({}_1B_t - {}_0B_t)] \geqslant -p_0({}_0z_0 + \pi_t\, {}_0Z_0),$

which says that deficits in the cash-flow in period 0 is covered by issue of new debt.

Next we discuss the optimization problem of the government in period zero.

3. Optimum Policy Under Commitment

The government of date 0 thus faces a given sequence of labor endowments $\{y_t\}_0^\infty$ and an inherited national debt with a maturity structure described by $\{{}_0b_t\}_0^\infty$ and $\{{}_0B_t\}_0^\infty$. Its problem is to choose paths for its policy instruments $\{\tau_t\}_0^\infty$ and $\{M_t\}_0^\infty$ to finance the exogenously given consumption stream $\{g_t\}_0^\infty$ in such a way that the consumer's welfare is maximized. This is an intertemporal optimal taxation problem, which amounts to finding at each date an optimal mix of borrowing and two distortionary taxes - the tax on labor income and the inflation tax (the inflation tax is distortionary by driving the nominal interest rate above zero; cf Section 2).

The government maximizes welfare subject to its budget constraint (2.10) and the general equilibrium requirements (2.1) and (2.9): namely that the resource constraint is fulfilled of each date and that the consumer is maximizing. We can then formulate the Lagrangean as

$$(3.1) \qquad L = \Sigma_0^\infty \beta^t U(c_t, x_t, \pi_t M_t) + \lambda_0 \Sigma_0^\infty p_t({}_0z_t + \pi_t\, {}_0Z_t) + \Sigma_0^\infty \mu_{0t}(y_t - x_t - c_t - g_t),$$

where it is understood that p_t, ${}_0z_t$ and ${}_0Z_t$ are consistent with (2.9).

In the optimum (we assume that there is a unique second-best optimal allocation), no reallocation of the policy instruments should increase welfare, or equivalently:

$$(3.2) \qquad dL = \Sigma_0^\infty \beta^t du_t + \lambda_0 \Sigma_0^\infty p_t(d_0z_t + \pi_t\, d_0Z_t) + \lambda_0 \Sigma_0^\infty({}_0z_t + \pi_t\, {}_0Z_t)dp_t + \lambda_0 \Sigma_0^\infty p_t\, {}_0Z_t d\pi_t - \Sigma_0^\infty \mu_{0t}(dx_t + dc_t) = 0.$$

Let us try to understand the different welfare effects as measured by the right-hand side of (3.2). First, there is, of course, a direct effect on instantaneous utility in period t: $du_t = U_{ct}dc_t + U_{xt}dx_t + U_{mt}dm_t$. Next, the government's wealth is increased to the extent that its income from labor taxes or money creation goes up at date t. Since higher income at t means that the distortionary taxes can be lowered at some other date, the effect on welfare is given by the multiplier on the government wealth constraint, λ_0, which we refer to as the level of "tax distortion". Third, if the government's total cash-flow at date t is positive, its wealth is revalued if the present value of goods at that date goes up. The increase in wealth allows for lower taxes so multiplying it with λ_0 again gives the welfare effect.[5] A similar wealth revaluation of the government's nominal cash-flow at date t results if the value of money increases (the price level at date t goes down); this is the fourth term. And, finally, we have the resource cost of any reallocation at each date t; μ_{0t} being the multiplier on the resource constraint at t.

Having described the government's trade-offs in general terms, we shall now look closer at the conditions for an optimum. Exploiting the discussion in Section 2, we know that a given path of M_t and τ_t, the direct policy instruments, is equivalent to a given path of c_t, x_t and m_t and a particular value of π_0. Indeed, we shall find it convenient to look primarily at the latter set of variables.

Let us first note that (2.6c) and the definition of real balances give the following equilibrium requirements:

$$\text{(3.3a)} \qquad d\pi_s = \begin{cases} \pi_s(d\pi_0/\pi_0) & s \leqslant t-1 \\ \pi_s(d\pi_0/\pi_0 + d\gamma_t/\gamma_t) & s = t \\ \pi_s(d\pi_0/\pi_0 + d\gamma_t/\gamma_t + d\gamma_{t+1}/\gamma_{t+1}) & s \geqslant t+1, \end{cases}$$

$$\text{(3.3b)} \qquad dM_s = M_s(dm_s/m_s - d\pi_s/\pi_s).$$

As a further preliminary, (2.6) and some manipulations yield

$$\text{(3.3c)} \qquad d\gamma_t = -\gamma_t dp_t/p_t,$$

[5] Another way to interpret the third term is to think of the government's cash-flows as its net exports to the private sector; $({}_0z_t + \pi_t\, {}_0Z_t)dp_t$ then becomes a standard (intertemporal) terms-of-trade effect, wellknown from trade theory.

(3.3d) $$d\gamma_{t+1} = \gamma_{t+1}(\pi_t/\pi_{t+1}p_{t+1})dp_t - \gamma_{t+1}(\beta^t U_{mmt}\pi_t/\pi_{t+1}p_{t+1})dm_t,$$

where $dp_t = U_{cct}dc_t + U_{cxt}dx_t$.

Suppose now that the government considers a small reallocation of consumption and leisure at date t which obeys the resource constraint, that is the changes in private consumption and leisure fulfill $dc_t = -dx_t$. Then, relying on (3.3), we can express the resulting welfare effect as

(3.4)
$$\begin{aligned} dL = \{&\beta^t(U_{ct} - U_{xt}) + \lambda_0 p_t[d(\tau_t(y_t - x_t))]/dc_t + \\ &+ \lambda_0({}_0z_t + \pi_t\ {}_0Z_t)(dp_t/dc_t) + \\ &+ \lambda_0(p_t\pi_t M_{t-1} + \Sigma_t^\infty p_s\pi_s\ {}_0B_s)(1/p_t)(dp_t/dc_t) - \\ &- \lambda_0(p_{t+1}\pi_{t+1}M_t + \Sigma_{t+1}^\infty p_s\pi_s\ {}_0B_s)(\pi_t/\pi_{t+1}p_{t+1})(dp_t/dc_t)\}\ dc_t. \end{aligned}$$

Here, the first term captures the direct welfare effect, amounting to the distortion from the tax. Second there is an effect on tax income. Next comes the effect on government wealth of a change in the present value factor - that is in today's real bond prices - caused by $dc_t = -dx_t$. Further, the change in c_t changes the real interest rate between periods t-1 and t, as well as between t and t+1. Since we hold m_{t-1} and m_t constant, the inflation rates $1/\gamma_t$ and $1/\gamma_{t+1}$ have to change so as to make the nominal interest rates consistent with those real balances being held. The effects on government wealth of the resulting changes in future price levels - and hence in the real value of future nominal obligations - and the necessary accommodating changes in nominal balances are given by the two final terms in (3.4). In an optimum the distortion from the income tax is appropriately traded-off and there are no further gains from reallocating consumption and leisure at any date. Therefore, (3.4) is equal to zero[6] for all $t = 0 \ldots \infty$.

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[6] Note that for t=0, the third term in (3.4) is identically equal to zero.

Consider next a change in real balances of date t, dm_t. The welfare effect of this is

(3.5) $$dL = \{\beta^t U_{mt} + \lambda_0 p_t (i_{t+1}/(1+i_{t+1})) +$$

$$+ \lambda_0 (p_{t+1}\pi_{t+1}M_t + \Sigma_{t+1}^{\infty} p_s \pi_s \, {}_0B_s)\beta^t U_{mmt}\pi_t/\pi_{t+1}p_{t+1}\} \, dm_t.$$

First, we have a direct welfare effect, and next there is the increase in the government budget from the standard inflation tax. Third, we have the wealth effects of the change in the price level from date t+1 and onwards. We note that this amounts to a change in the real value of the money stock outstanding in the beginning of date t as well as in the government's nominal debt obligations from date t+1 and forward. In an optimum there is no welfare gain from changing m_t at any date and so (3.5) is equal to zero for all t.

Last, think of a change in π_0. From (3.3) this is achieved by an equiproportionate change in the path for the nominal money stock and changes the price level of all dates in proportion. We can thus think of $d\pi_0$ as a once-and-for-all change in the value of money, or a "surprise inflation" carried out at date 0. As can be verified from the welfare effect,

(3.6) $$dL = -\lambda_0 (p_0\pi_0 M_{-1} + \Sigma_0^{\infty} p_s \pi_s \, {}_0B_s)(d\pi_0/\pi_0),$$

this does not change the real allocation and thus works as a pure capital levy on the initial money stock and outstanding nominal debt obligations. Since there are no trade-offs in (3.6), there is not necessarily an interior solution for π_0 where dL = 0. In the typical case we treat below the government is initially (that is, at date 0) a net nominal debtor, meaning that the expression within brackets is positive. It would then be optimal to drive π_0 towards zero, that is to drive the price level $P_0 (\equiv 1/\pi_0)$ towards infinity, so as to reduce the real value of the government's nominal obligations. This would reduce λ_0, but not to zero, since the resulting increase in government wealth (except in uninteresting special cases) would not be sufficient to finance the entire path of future government expenditure.[7] In practise it might however be difficult to drive P_0 to infinity. Let us therefore assume that optimal behavior implies $P_0 = \bar{P}_0$ where $\bar{P}_0$ is a high but finite number, maybe given by the Mint's printing capacity.[8]

To summarize, the considerations we have described in this section lead to an optimal allocation $\{c_t, x_t, m_t\}_0^\infty$ and an initial price level π_0. If, in fact, the government at date 0 could commit all the future policy instruments to those values that support the optimal allocation, that would be the end of the story. Here we rule such commitments out, however, and consider instead discretionary policy-making. That is, for each date t = 1,..., the government in power at that date is given complete freedom to reoptimize. In the next section we describe the time-consistency problems that arise in such a set-up and show how they can be

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[7] Thus dL in (3.6) need not be equal to zero reflecting the fact that no bounded solution for P_0 exists.

[8] If the government at date 0 instead were a net nominal creditor, the bracketed expression in (3.6) is negative and the optimal policy is to increase π_0 (reduce P_0) until the real value of the claims on the private sector become large enough to cover all future expenditures. The resulting equilibrium is then first best and the optimal tax problem as well as the time consistency problem we are interested in disappear. We therefore rule this case out by assumption. Turnovsky and Brock (1980) implicitly treat this case in their solutions of the optimal tax problem when they assume that the real value of the government's initial assets can be freely chosen.

resolved by an appropriate maturity structure of the government debt which turns out to make the optimum policy incentive-compatible.

4. Time Consistency Under Discretion

The governments at $\theta = 1, \ldots, \infty$ (from now on Government 1, 2, etc.) solve the same optimal tax problem as did Government 0. There are two different reasons why each of these governments might want to choose a different allocation than did its predecessor. In the sequel we discuss these two time-consistency problems in turn.

First, the new government at each date has, like Government 0, an incentive to engage in an immediate surprise inflation. This incentive can however be eliminated if each government inherits a set of nominal net claims on the private sector with a total market value equal to the outstanding money stock. For example, if Government 1 inherits a nominal debt $\{{}_1B_s\}_1^{\infty}$ such that

$$\Sigma_1^{\infty} p_s \pi_s \, {}_1B_s = -p_1 \pi_1 M_0,$$

the welfare effect of a change in the initial price level given by the equivalent of (3.6),

$$dL = -\lambda_1 (p_1 \pi_1 M_0 + \Sigma_1^{\infty} p_s \pi_s \, {}_1B_s)(d\pi_1/\pi_1),$$

is identically equal to zero. In general therefore Government $\theta-1$, $\theta = 1, \ldots \infty$, should leave its successor with net nominal claims on the private sector equal to the money stock[9], i.e. with a nominal debt $\{{}_\theta B_s\}_\theta^{\infty}$ such that

$$\Sigma_\theta^{\infty} p_s \pi_s \, {}_\theta B_s = -p_\theta \pi_\theta M_{\theta-1}. \tag{4.1}$$

This is the first aspect of our scheme for time consistency. One should note that if (4.1) is satisfied, i.e. the government has a zero net

[9] This was first suggested to us by Robert King at a seminar at the University of Rochester.

position in nominal terms vis-a-vis the private sector, this does not mean that there will be no scope for exploiting the inflation tax. The (anticipated) inflation tax is derived from the private sector's willingness to hold a non-interest-bearing nominal asset, i.e. money. Even if this asset is exactly balanced by an interest-bearing nominal liability to the government (${}_{\theta}B_s$) there will still be a base for the inflation tax since the nominal interest rate will change in relation to the anticipated inflation rate. Thus (4.1) only rules out the government's incentive for surprise inflation, and not for anticipated inflation.

While the above scheme solves the time consistency problem associated with Government θ's choice of π_{θ}, there is another time consistency problem associated with its choice of the other (indirect) instruments, namely $\{c_t, x_t, m_t\}$. To understand this, notice from (3.4) and (3.5) that the optimal choice of c_t (and x_t) and m_t both involve trading off a distortion against the effect on the government budget. The distortion is expressed by the first term on the right-hand side, measuring the "direct" welfare effect which would be equal to zero if lump-sum taxation were available. The effect on the government budget is expressed by the other terms in (3.4) and (3.5), i.e. by the tax distortion λ_0 times the change in government wealth. Since the tax distortion changes over time, that is λ_{θ}, $\theta = 1 \ldots \infty$ does not stay constant and equal to λ_0 (see further below), successive governments would seem to have incentives to choose different allocations.

The optimality condition for Government θ's choice of m_t can, in analogy with (3.5), be written

(4.2)
$$dL = \{\beta^t U_{mt} + \lambda_{\theta}[p_t(i_{t+1}/(1+i_{t+1}) - - (p_{t+1}\pi_{t+1}M_t + \Sigma_{t+1}^{\infty} p_s \pi_s\ {}_{\theta}B_s)(\pi_t \beta^t U_{mmt}/\pi_{t+1}p_{t+1})]\}dm_t = 0.$$

Suppose now that Government θ-1, $\theta = 1\ldots\infty$, leaves its successor with a debt structure such that

$$(4.3) \qquad \Sigma_{t+1}^{\infty} p_s \pi_s \,{}_\theta B_s = -p_{t+1}\pi_{t+1}M_t - (1+1/\lambda_\theta)(\pi_{t+1}p_{t+1}U_{mt}/\pi_t U_{mmt}),$$

where we have used that $p_t i_{t+1}/(1 + i_{t+1}) = \beta^t U_{mt}$ from (2.6) - (2.8). Then (4.2) is satisfied identically and there is no incentive for Government θ to deviate from the m_t that was chosen by Government θ-1. Obviously, there will be an equation like (4.3) for each $t \geqslant 0$. These equations together with (4.1) thus yield a unique nominal debt structure $\{_\theta B_t\}_\theta^\infty$ that Government θ-1 should leave to its successor to make the optimal plan for $\{m_t\}_\theta^\infty$ incentive-compatible. We note also that (4.3) is precisely defined for a given value of λ_θ. To obtain the appropriate λ_θ value we turn to the other (indirect) policy instruments, namely the choice of $\{c_t\}_\theta^\infty$.

By the analog to (3.4), Government θ maximizes welfare with respect to c_t by solving

$$\begin{aligned}(4.4) \qquad dL = \{&\beta^t(U_{ct} - U_{xt}) + \lambda_\theta[p_t \frac{d(\tau_t(y_t - x_t))}{dc_t} + \\ &+ ({}_0z_t + \pi_t\, {}_0Z_t)(dp_t/dc_t) + \\ &+ ((p_t\pi_t M_{t-1} + \Sigma_t^{\infty} p_s\pi_s\, {}_\theta B_s)/p_t)(dp_t/dc_t) - \\ &- ((p_{t+1}\pi_{t+1}M_t + \Sigma_{t+1}^{\infty} p_s \pi_s\, {}_\theta B_s)\pi_t/\pi_{t+1}p_{t+1})(dp_t/dc_t)]\} = 0.\end{aligned}$$

However, using equation (4.3) and rearranging a little, we may rewrite (4.4) as

$$\begin{aligned}(4.5) \qquad dL = (dp_t/dc_t)\{&[\beta^t(U_{ct}-U_{xt})(dc_t/dp_t) - \frac{\pi_t U_{mt-1}}{\pi_{t-1}U_{mmt-1}} + \frac{U_{mt}}{U_{mmt}}] \\ &+ \lambda_\theta[\frac{d(\tau_t(y_t-x_t)}{dp_t} - \frac{\pi_t U_{mt-1}}{\pi_{t-1}U_{mmt-1}} + \frac{U_{mt}}{U_{mmt}}] + \lambda_\theta({}_\theta z_t + \pi_t\, {}_\theta Z_t)\}\, dc_t \\ &= 0.\end{aligned}$$

To save on notation, rewrite (4.5) as

(4.6) $$dL = (J_t + \lambda_\theta K_t + \lambda_\theta\, {}_\theta\tilde{z}_t)dp_t = 0,$$

where we note that J_t and K_t only depend on the real allocation. Multiplying the bracketed expression in (4.6) by p_t and summing over t, we get

(4.7) $$\lambda_\theta = -\Sigma_\theta^\infty p_t J_t / \Sigma_\theta^\infty p_t K_t.$$

Now we have a value for λ_θ and thus also values for $\{{}_\theta B_t\}_\theta^\infty$ from (4.3). If we substitute these into (4.5) we get unique indexed debt obligations $\{{}_\theta b_t\}_\theta^\infty$ which will make (4.5) identically satisfied for each $t \geqslant \theta$. In other words, we have found a unique indexed debt structure that government $\theta-1$, $\theta = 1\ldots\infty$, should leave to its sucessor to sustain the optimum choice of $\{c_t\}_\theta^\infty$.

In summary, we have shown that for every government there is a unique maturity structure of the nominal as well as the indexed part of the public debt that remove the incentives to deviate from the optimal policy $\{\tau_t, M_t\}_0^\infty$ chosen and announced by Government 0.

Let us finally say something about how the debt structures of successive governments differ, that is characterize the restructuring scheme of the debt that each government has to perform to impose time-consistency on its successor. To that end we write the $\theta-1$ analogs to (4.6) and (4.7),

(4.8) $$dL = (J_t + \lambda_{\theta-1} K_t + \lambda_{\theta-1}\, {}_{\theta-1}\tilde{z}_t)dp_t = 0 \quad \text{and}$$

(4.9) $$\lambda_{\theta-1} = -\Sigma_{\theta-1}^\infty p_t J_t / \Sigma_{\theta-1}^\infty p_t K_t.$$

To get more definite results, we also make the unrestrictive assumption that J_t is negative for all t. Sufficient conditions for this is that the utility function displays constant reltive risk aversion in m_t, and that the optimal solution is such that τ_t is positive and M grows with time.[10]

From (4.6) - (4.9) it then follows that

(4.10) $$\lambda_\theta \gtrless \lambda_{\theta-1} \quad \text{if and only if} \quad {}_{\theta-1}\tilde{z}_{\theta-1} \gtrless 0.$$

Government θ thus will have a higher tax distortion than Government θ-1 if and only if the total cash-flow at date θ-1 is negative, something which squares well with intuition. By (4.6) and (4.8) we then have

$${}_\theta\tilde{z}_t = - J_t/\lambda_\theta - K_t \text{ and}$$

$${}_{\theta-1}\tilde{z}_t = - J_t/\lambda_{\theta-1} - K_t.$$

Thus

(4.11) $$({}_\theta b_t + \pi_t\ {}_\theta B_t) - ({}_{\theta-1}b_t + \pi_t\ {}_{\theta-1}B_t) = {}_{\theta-1}\tilde{z}_t - {}_\theta\tilde{z}_t =$$
$$= J_t(1 - \lambda_{\theta-1}/\lambda_\theta)/\lambda_{\theta-1},$$

which gives us the scheme for the restructuring of aggregate debt that has to take place at date θ-1. Combining (4.10) and (4.11) and assuming $J_t < 0$, we see that

$$({}_\theta b_t + \pi_t\ {}_\theta B_t) - ({}_{\theta-1}b_t + \pi_t\ {}_{\theta-1}B_t) \lessgtr 0$$

$$\text{if and only if} \quad {}_{\theta-1}\tilde{z}_{\theta-1} \gtrless 0$$

for all t. This means that a negative cash-flow at θ-1 (that is government income from taxes and money creation falls short of government consumption and debt service) should be financed by issuing some debt of <u>all</u> maturities.[11]

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[10] The first term in J_t, $\beta^t(U_{ct}-U_{xt})/(U_{cct}-U_{cxt})$, is negative if goods and leisure are normal. Also, the sum of the second and third term can be rewritten $-\pi_t(M_t-M_{t-1})/r$, where $r \equiv -m_t U_{mmt}/U_{mt}$

[11] These results are analoguous to those in Persson and Svensson (1984) regarding indexed debt in a model without money.

What about the indexed versus nominal components in this restructuring scheme? From (4.3) and its θ-1 analog, we may derive for $t \geqslant \theta+1$,

$$(4.12) \qquad {}_{\theta}B_t - {}_{\theta-1}B_t = N_t(1 - \lambda_{\theta-1}/\lambda_{\theta})/\lambda_{\theta-1},$$

where $N_t \equiv (U_{mt-1}/U_{mmt-1})(\pi_t p_t/\pi_{t-1}) - (U_{mt}/U_{mmt})(\pi_{t+1}p_{t+1}/\pi_t)$. The sign of N_t is not unambiguous, in general, but our presumption is that on average it is negative.[12] Comparing to (4.11) we see that nominal and indexed debt might well have to be restructured in opposite directions for some t. Note, however, that (4.12) applies only for $t \geqslant \theta+1$, that is for maturities of two periods and longer. From (4.1) and its θ-1 analog, we know that the growth in the market value of the government's total nominal claims on the private sector satisfies

$$(4.13) \qquad -(\Sigma_{\theta}^{\infty} p_s \pi_s \, {}_{\theta}B_s - \Sigma_{\theta}^{\infty} p_s \pi_s \, {}_{\theta-1}B_s) =$$
$$= p_{\theta-1}\pi_{\theta-1}[{}_{\theta-1}Z_{\theta-1} - i_{\theta}M_{\theta-1}/(1 + i_{\theta})]$$

where we have used (2.7) and the definition of ${}_{\theta}Z_t$. In other words the government at date θ-1 should use its nominal cash-flow minus the proceeds from the inflation tax to buy nominal bonds from the private sector. Whatever the operations in long-term nominal bonds described above result in, Government θ-1 thus has to adjust its purchases of short-term (one-period) securities so that its total open market operations in nominal bonds fulfill (4.13).

5. Conclusions

We have shown that optimal fiscal and monetary policy under commitment can be made time-consistent under discretion, in the following

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12 Take the case with constant relative risk aversion in m_t discussed above. Then N_t can be written as $N_t = (m_t p_{t+1}\pi_{t+1}/\pi_t - m_{t-1}p_t\pi_t/\pi_{t-1})/r$. Suppose real balances and inflation are both relatively stable over time. Then we have $m_t\pi_{t+1}/\pi_t \approx m_{t-1}\pi_t/\pi_{t-1}$ and thus N_t is negative (provided $p_t > p_{t+1}$).

way. First, the incentive for each government to engage in a surprise inflation is removed by each government leaving nominal claims with a total market value equal to the money stock to its successor. Second, the incentive to manipulate future real money balances, inflation rates and nominal interest rates is removed by leaving a suitable maturity structure of the nominal debt. Third, the incentive to manipulate income taxes, real interest rates and real bond prices is removed by a suitable choice of the maturity structure of the total debt, including both nominal and indexed bonds.

The determination of fiscal and monetary policy can then be described as follows. The time path of tax rates and monetary expansion is determined in the intertemporal optimal taxation problem. This also determines total borrowing and total debt in each period. The composition of this debt is determined so as to give each government total nominal claims equal to the money stock. This can be formulated as a simple rule of thumb. In each period, the government should be a net creditor, in nominal bonds, to the private sector, and the total value of the outstanding stock of nominal bonds should be equal to the money stock. This is accomplished by open market operations where the government at each date uses its entire nominal cash flow minus the proceeds from the inflation tax to buy nominal bonds from the private sector. The maturity structure of the nominal claims is determined by the requirement that there shall not exist any incentives to manipulate future inflation rates and nominal interest rates.

Total indexed debt is determined as the difference between total debt, as determined by the optimal taxation problem, and the nominal claims referred to above. It remains to determine the maturity structure of the indexed debt. The maturity structure of the total debt is determined by the requirement that incentives to manipulate taxes and real interest rates are removed. The maturity structure of the nominal debt is determined as specified above. Hence, the maturity of the indexed debt is determined as the resulting residual.

Therefore, it is crucial that both nominal and indexed debt exist together, although they are used for different purposes. Nominal debt/claims are used to balance the money stock, whereas the required net borrowing is done via indexed debt. One reason why previous literature have not found the solution to time-consistent monetary policy that we suggest may be that the anlysis has been arbitrarily restricted to considering nominal debt only.

We shall also add some qualifications and mention some possible extensions.

As in Lucas and Stokey (1983), our solution involves a commitment to honor previous debt, and taxes on debt are not allowed. If there were capital, a commitment not to tax capital would be required. Our solution does hence not contribute to explaining time-consistency in debt and capital taxation. It may be argued that reputational considerations might be able to explain the absence of both surprise taxation on capital and debt and surprise inflation, and hence be preferable to our solution.

Uncertainty is easy to introduce, along the lines of Lucas and Stokey (1983), as long as perfect markets for contingent debt is assumed. Then the debt structure is determined not only with regard to maturity and nominal/indexed composition but also with regard to its contingency structure.

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