1985

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AN ALTERNATIVE VIEW OF OPTIMAL SEIGNIORAGE

by

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June, 1985
(I) INTRODUCTION

This paper provides an analysis and rationalization of the fact that a
government may find it optimal to issue more than one type of liability. The
approach is similar to that of Bryant and Wallace [1984] in that it applies
price discrimination analysis to the study of monetary policy. Most of the
earlier literature on optimal seigniorage has focused on the appropriate rate
of expansion of fiat money in a partial equilibrium setting, or in a representative
agent economy (see, for example, Calvo [1978], Seigel [1978], Drazen [1979]).
However, these approaches do not take into consideration the fact that govern-
ments issue a multitude of liabilities which may be backed by nothing more than
other government liabilities. It would then seem fruitful to study the optimal
rate of expansion of one of these liabilities in conjunction with the optimal
rate of issuance of others. The existing literature on optimal seigniorage is
surprisingly void of any rationalization of why a government would issue more
than one liability.

It should be noted that Bryant and Wallace showed that in an environment
without capital, if the government adopted a policy of issuing several liabilities,
this could yield superior allocations for agents. In comparison, this model
suggests that, in an environment with capital, the conclusion of Bryant and Wallace
will hold and, as well, it is shown that governments may wish to issue liabilities
for purely selfish reasons: it can collect a larger amount of revenue from
such a policy.

This paper takes seriously the notion that the only distinction to be
made between government-issued nominal bonds and fiat money is the large
denomination of the former relative to the latter. The government which seeks to maximize revenue in a growing economy of heterogeneous agents may garner a greater revenue by issuing more than one type of liability. This will permit differential pricing of different government liabilities.

In the model, agents are of different types: some have larger endowments than others. Each agent is additionally endowed with a private investment project which permits him to transfer wealth from one period of his life to the next. There is, however, a minimum bound on the amount that must be invested in any one investment project if it is to yield a positive gross return. The bound is structured in such a way that only the rich agents are able to invest in these projects. This restriction, together with the fact that agents’ ages are private information, will imply that those agents who are relatively poor will hold fiat money from the one period to the next. The government may then issue an additional liability, of some minimal real size which the richer agents can alone purchase, in order to increase revenue. Under some circumstances, a given deficit may be financed through bond and money financing methods which would yield allocations superior to those that would be achieved in the absence of the bond issuance.

The model is consistent with the following observed facts:
(i) currency, bonds and capital can be held in equilibrium, (ii) all assets are valued only for their payoffs (see Bryant and Wallace [1980]), (iii) absence of transactions costs, (iv) the rate of return on currency can be dominated by the rate of return on other assets in equilibrium, (v) a measure of the velocity of money may be procyclical, (vi) the economy may be nonstationary and exhibit periods of positive and negative growth.
The remainder of the paper is written as follows. Section II describes the basic model and the circumstances under which bond financing methods can increase revenue in a stationary equilibrium. Section III describes why there might be grounds for cyclical changes in the rates of expansion of the bond and money supply. Section IV contains two illustrative examples. Some final remarks are contained in Section V.

(II) A MODEL OF A STATIONARY EQUILIBRIA

In the model time is discrete. Let $t$ denote the date and $t-1$ will be the initial starting date for the economy. At each date $t$, there are born $N^P(t)$ identical individuals who will be referred to as poor agents. Similarly, at each date $t$, there are born $N^R(t)$ identical individuals whom we will refer to as rich agents. Each member of generation $t$ is present in the economy in periods $t$ and $t+1$. It is assumed that the growth rates of the two groups of agents are identical. That is, $N^i(t) = nN^i(t-1)$ for $i=r,p$, and we let $n \geq 1$.

Each identical poor member of generation $t$ is endowed with $w^P_1$ units of the homogeneous consumption good in the first period of his life and $w^P_2$ units of the good in the second period. Similarly, each rich member of generation $t$ is endowed with $w^R_1$ units in the first period of their life and $w^R_2$ units in the second period. Each agent of type $i$ ($i=r,p$) who is a member of generation $t$ consumes $C^i_1(t)$ in the first period of his life and $C^i_2(t)$ in the second period. Each agent of type $i$ who is a member of generation $t \geq 1$ has preferences represented by a differentiable, increasing strictly concave utility function $U[C^i_1(t), C^i_2(t)]$. At date $t=1$ there are also $N^P(0)$ poor agents and $N^R(0)$ rich agents who live for only one period and maximize consumption quantities $C^P_2(0)$.
and \( C^R_2(0) \) respectively.

Each agent is also endowed with a private capital "project" in which he may wish to invest. An agent who invests a unit of the consumption good in the project in period \( t \) receives \( \theta \) units of the consumption good in period \( t+1 \). Further, there is a minimum amount \( \alpha \) which must be invested in the project before any return can be realized. It is assumed that \( w^p_1 < \alpha < w^R_1 \) so that poor agents are incapable of realizing a return from the project, even if they invested their whole endowment.

Lastly, it is assumed that each agent's age or type and asset portfolio is private information, and there is no mechanism to enable one agent to ascertain this information from another agent.

The government seeks to finance its consumption \( G_t \) of the consumption good in period \( t \geq 1 \). The policy \( \{ G_t \} \) may be one in which a specific expenditure must be financed, or the government may instead seek to maximize its own total consumption. This analysis will focus on issues of financing expenditures by permitting the government to issue two liabilities: fiat money and one-period default free discount bonds. Each bond issued at time \( t \) is a title to a known amount of currency at time \( t+1 \). Therefore, the government budget constraint can be written as:

\[
G_t = p(t)[M(t) - M(t-1)] + p(t)P_b(t)B(t) - p(t)B(t-1),
\]

where \( p(t) \) is the time \( t \) price of money in units of the time \( t \) consumption good. \( P_b(t) \) is the price at \( t \) in units of currency of an amount of bonds which pays one unit of currency at time \( t+1 \). \( M(t) \) is the aggregate stock of currency held by the public from period \( t \) to period \( t+1 \), and \( B(t) \) is the
face value of aggregate holdings of government bonds held from period $t$ to period $t+1$, and is in units of time $t+1$ currency. It is assumed that $M(0) + B(0)$ is the initial nominal wealth held by members of generation 0 at time $t=1$. The government seeks to finance its expenditures through the sale of bonds and currency. If the government wishes to maximize its own consumption then it will seek to maximize the expression in equation (1) with respect to $M(t)$ and $B(t)$. The government can also specify a minimum real purchase value $F > 0$ per bond. This will permit the government to offer differing rates of return to the different types of agents.

The environment is one in which there is an "imperfect" capital market because of the minimum bound on storage, as well as private information. The minimum bound on investment would not be a problem if a coalition of agents could form to invest a large quantity as a group. However, there would be an incentive for old agents to say they will do the investing and act as an intermediary—even though they will just consume the proceeds. Hence the economy will not have intermediation. However, it is exactly this imperfection which the government can exploit in order to gain revenue, or merely to provide superior allocations. The government securities do not face the same informational barriers as do the private securities. Hence the government can help to attain allocations which individual agents could not attain themselves. In addition, because of this imperfection in the capital market, the government may get more revenue by issuing more than one liability.

The optimization problem for an agent who is a type $i$ member of generation $(t)$ may be written as follows. The agent chooses non-negative
consumption \([c_1^i(t), c_2^i(t)]\), currency holdings \([m^i(t)]\), bond holdings \([b^i(t)]\), and capital \([k^i(t)]\) to maximize \(U[c_1^i(t), c_2^i(t)]\) subject to

\[
c_1^i(t) \equiv w_1^i(t) - p(t)m^i(t) - p(t)b_1^i(t) - k^i(t)
\]

\[
c_2^i(t) \equiv w_2^i(t) + p(t+1)m^i(t) + p(t+1)b_1^i(t) + \theta k^i(t)
\]

\[
p(t)b_1^i(t) \equiv F \quad \text{or} \quad b_1^i(t) = 0
\]

\[
k^i(t) \equiv \alpha \quad \text{or} \quad k^i(t) = 0
\]

for \(i = r, p\).

Before proceeding, a few remarks will help to simplify the analysis. Since \(w_1^p < \alpha < w_1^r\), the poor agents cannot invest in capital. Further, the government will choose \(F\) in such a way that no single poor agent could hold a bond and as a result, must hold currency. If \(F\) were chosen so that poor agents could hold bonds, the bonds would not sell at a discount relative to currency. That is, bonds and currency would be indistinguishable. By enabling the government to choose a face value for \(F\), it can utilize price discrimination in obtaining the optimal seignorage.\(^3\) The fact that an agent's type or age is private information will not permit, say, poor agents getting together and investing in capital or a nominal bond in a manner which each individual agent could not manage on their own. Agents in the second period of their life would have an incentive to issue ostensible titles to a share of nominal bonds or capital, which the agent would not repay in the following period.\(^4\)

In order that the agent's optimization problem is well-defined, it is assumed that agents have perfect foresight with respect to present and
future prices in the economy. Uncertainty plays no role.

Now let \(q^i_1(t) = p(t)w^i_1(t), q^i_2(t) = p(t)P^i_b(t)b^i(t), i = r, p, R_1(t) = p(t+1)/p(t)\) and \(R_2(t) = p(t+1)/[p(t)P^b(t)]\). Then the budget constraints for the poor agents may be rewritten as

\[
C^p_1(t) = w^p_1 - q^p_1(t)
\]
\[
C^p_2(t) = w^p_2 + R_1(t)q^p_1(t),
\]

while the budget constraints for the rich agents may be written as

\[
C^r_1(t) = w^r_1 - q^r_1(t) - q^r_2(t) - k^r(t)
\]
\[
C^r_2(t) = w^r_2 + R_1(t)q^r_1(t) + R_2(t)q^r_2(t) + \Theta k^r(t)
\]
\[
q^r_2(t) \equiv F \text{ or } q^r_2(t) = 0
\]
\[
k^r(t) \equiv \alpha \text{ or } k^r(t) = 0.
\]

The solutions to these optimization problems yield demand correspondences \(q^p_i(t) = d^p_i[R_1(t)], k^r(t) = k[R_1(t), R_2(t), F]\), and \(q^r_1(t) = d^r_1[R_1(t), R_2(t), F]\), for \(i = 1, 2\). A monetary equilibrium for the economy consists of a given \(F, M(0), B(0)\), positive sequences \([G_2], [p(t)], [P^b(t)]\), and non-negative sequences \([M(t)]\) and \([B(t)]\) such that for all \(t \geq 1\)

\[
N^p(t)d^p_1[R_1(t)] + N^r(t)d^r_1[R_1(t), R_2(t), F] = D^p_1[R_1(t), R_2(t), F, N^p(t), N^r(t)] = p(t)M(t)
\]

(2)

\[
N^r(t)d^r_2[R_1(t), R_2(t), F] = D^r_2[R_1(t), R_2(t), F, N^r(t)] = p(t)P^b(t)B(t)
\]

(3)

with equation (1) holding in equilibrium.
Figure 1 illustrates possible budget constraints which rich and poor agents may face. Clearly, the discontinuities complicate the decision problem of the rich agents.

In the remainder of this section the analysis will be restricted to the study of stationary monetary equilibria in which \( R_1(t) = R_1 \) and \( [G_t/(N^T(t) + N^P(t))] = g > 0 \) for all \( t \geq 1 \) and \( i=1,2 \). Hence the stationary version of equation (1) with equilibrium conditions imposed may be written as

\[
G_t = (1-R_1/n) D_1 [R_1, R_2, F, N^P(t), N^T(t)] + (1-R_2/n) D_2 [R_1, R_2, F, N^T(t)] \tag{4}
\]

The \((1-R_i/n)\) will then be the tax rates on currency holdings \( (i=1) \) and bond holdings \( (i=2) \). In order to formulate the government's revenue maximization problem, define the sets

\[
S_t (G(t), F) = \{(R_1, R_2): \ (1-R_1/n) D_1 [R_1, R_2, F, N^P(t), N^T(t)] \\
+ (1-R_2/n) D_2 [R_1, R_2, F, N^T(t)] = G_t \}
\]

Then for any pair \((G(t), F)\) such that \( S_t (G(t), F) \) is nonempty, there will exist rates of return on bonds and money such that the government consumption \( G_t \) can be financed. For \( t=1 \), there are initial conditions for \( M(0) + B(0) \), while equations (2) and (3) help to yield a solution for \( p(1) \) which satisfies

\[
G(1) = D_1 [R_1, R_2, F, N^P(1), N^T(1)] + D_2 [R_1, R_2, F, N^T(1)] - p(1) [M(0) + B(0)]. \tag{5}
\]

As already noted, the term \((1-R_1/n) D_1 [R_1, R_2, F, N^P(t), N^T(t)] \) will denote the seignorage tax levied through expansion of the fiat money supply. For a given level of \( R_2 \) and \( F \), this equation is shown in Figure 2. A similar
Figure 2

\[ \frac{G(t)}{N^P(t) + N^F(t)} \]

\[ (1 - \frac{R_1}{n}) [D_1[R_1, R_2, F, N^P(t), N^F(t)]] \]

\[ s^* \]
illustration could be made for bond seignorage. In the diagram, a maximal currency seignorage, per capita, of $g^*$ could be attained with a rate of return on currency of $R^*$.

It will be convenient to use the following definition.

**Definition:** A stationary monetary equilibria for this economy consists of scalars $F \in \{w^1_F, w^2_F\}$, $M(0) + B(0) > 0$, rates of return $R_1 \equiv R_2 \equiv 0$ and a sequence $\{G_t\}$ where $\frac{G(t)}{N(t) + N^P(t)} = g > 0$ for all $t \geq 1$, such that the functions $D_1[\ldots, \ldots, \ldots]$, $D_2[\ldots, \ldots, \ldots]$ described above satisfy equation (4).

The rates of return $R_1$ and $R_2$ are real rates, and the nominal gross rate of return on nominal bonds is then $(R_2/R_1) \equiv 1$. Of course, agents are indifferent to holding bonds or money if $R_2 = R_1$.

A government which seeks to maximize total revenue will, for each date, seek to find the largest $G(t) > 0$ for which there is an $F$ such that $S_t(G(t), F)$ is nonempty. This will then permit the government to finance the maximal consumption with some financing scheme.

Before proceeding with the discussion concerning seignorage, it may be useful to consider the following welfare result.\(^5\)

**Lemma 1:**

For given $F^* \in \{w^1_F, w^2_F\}$, $M(0) + B(0) > 0$, and sequence $\{G_t\}$ such that $[G(t)/N(t)] = g > 0$

if $(R^*, R^*) \in S_t(G(t), F^*)$

and $(R'_1, R'_2) \in S_t(G(t), F^*)$ $\forall t \geq 1$,

where $R'_2 \equiv R'_1 \equiv R^*$, with at least one of these inequalities being strict, then $p'(1) > p^*(1)$ where $p^*(1)$ is the solution to (5) for $(R^*, R^*, F^*)$ and $p'(1)$ is that for $(R'_1, R'_2, F^*)$. Further, allocations in the $(R'_1, R'_2, F^*)$ equilibrium are Pareto superior to that of the $(R^*, R^*, F^*)$ equilibrium.
Proof:

Since \((R^*, R^*, F^*)\) and \((R_1', R_2', F^*)\) are both \(\in S_t(G(t), F^*)\), then

\[
(1 - \frac{R^*}{n}) \left[ D_1 [R^*, R^*, F^*, N^P(t), N^F(t)] + D_2 [R^*, R^*, F^*, N^F(t)] \right]
\]

\[
= (1 - \frac{R_1'}{n}) D_1 [R_1', R_2', F^*, N^P(t), N^F(t)] + (1 - \frac{R_2'}{n}) D_2 [R_1', R_2', F^*, N^F(t)]
\]

\[
\leq (1 - \frac{R_1'}{n}) [D_1 [R_1', R_2', F^*, N^P(t), N^F(t)] + D_2 [R_1', R_2', F^*, N^F(t)]
\]

where the inequality is strict if \(R_2' > R_1'\). But then, since \(R_2' \equiv R_1' \equiv R^*\) with at least one inequality being strict,

\[
D_1 [R_1', R_2', F^*, N^P(t), N^F(t)] + D_2 [R_1', R_2', F^*, N^F(t)]
\]

\[
> D_1 [R^*, R^*, F^*, N^P(t), N^F(t)] + D_2 [R^*, R^*, F^*, N^F(t)].
\]

Hence \(p(1)' > p^*(1)\) from equation (5).

That the (') equilibrium is superior is clear since all generations born at \(t \equiv 1\) are faced with at least as high a rate of return, and the members of generation \(t = 0\) are better off since \(p(1)' > p^*(1)\).

The lemma is an illustration of a case where, for a given path of the deficit, some elements in the set \(S_t(G(t), F)\) lead to allocations which can be dominated by the allocations yielded by other elements in \(S_t(G(t), F)\). However, in general, the set \(S_t(G(t), F)\) will consist of some elements which give rise to Pareto-optimal allocations, and others which do not give rise to such allocations. It is easy to construct examples where a given level of expenditures financed wholly through money issuance may be financed in an alternative way--through some bond-money combination--which would lead to superior allocations.
It is clear that if \( R_2(t) > R_1(t) \), or if \( \theta > R_1 \) when the storage technology is utilized, then the allocations are not Pareto optimal. However, the existence of private information may not permit the attainment of Pareto-optimal allocations consistent with a given deficit which must be financed through the methods described.

The following lemma states a condition under which the issuance of government debt, which is held by the rich agents, will yield revenue to the government.

**Lemma 2:**

There exists \((C'_1, C'_2) \in \mathbb{R}^2_{++}\) such that a bond can be issued to a rich agent that will yield revenue if and only if \( n > \frac{U_1[C'_1, C'_2]}{U_2[C'_1, C'_2]} \).

**Proof:**

Let \((C_1^*, C_2^*) \in \mathbb{R}^2_{++}\) be the utility maximizing choice of first and second period consumption, respectively, of a rich agent who maximizes

\[
U[C_1^*(t), C_2^*(t)]
\]

subject to

\[
C_1^*(t) = w_1^* - k_1^*(t)
\]
\[
C_2^*(t) = w_2^* + \theta k_2^*(t)
\]
\[
k_2^*(t) = \alpha.
\]

Define the set

\[
S = \{(C_1^*, C_2^*) : C_1^* \equiv w_1^*, C_2^* \equiv w_2^* + \theta w_1^*, U[C_1^*, C_2^*] \equiv U[C_1, C_2]\}.
\]

Since \(S\) is closed and \(U[\cdot, \cdot]\) is strictly concave, there exists a hyperplane through \((w_1^*, w_2^*)\) tangent to \(S\) at, say \((x_1, x_2) \in S\).
If \( n \leq \frac{U_1[x_1, x_2]}{U_2[x_1, x_2]} \), then any real rate of return on an asset issued by a government must be \( \geq n \) if the asset is to be held by the rich agents. But then it yields no revenue.

Alternatively, if \( n > \frac{U_1[x_1, x_2]}{U_2[x_1, x_2]} \) then an asset of minimum real price \((w_1 - x_1)\) can be issued which yields any rate of return \( \in \frac{U_1[x_1, x_2]}{U_2[x_1, x_2]} n \). This security will make the agent as least as well off, and will yield revenue to the government. Hence \((x_1, x_2)\) satisfies the condition of the proposition.

Although Lemma 2 says that the rich will purchase a revenue raising security, it says nothing about the maximal revenue-raising return on this security. It may be that this is equal to the rate of return on money, and so the whole level of expenditures is financed through inflation.

An implication of this lemma is that for high real rates of return on capital, relative to the level of output (population) growth, there may not exist a way for the government to issue an asset which would yield revenue. In such an economy, all revenue must be financed by way of an inflation tax. Alternatively, the higher the level of output growth relative to the real return on capital, the more likely it will be that bond issue may yield revenue.

The most transparent case in which bonds will not yield revenue is when

\[
\theta = \frac{U_1[(w_1 - \alpha), (w_2 + \theta\alpha)]}{U_2[(w_1 - \alpha), (w_2 + \theta\alpha)]} \approx n.
\]

In this case the agent will hold a government bond only if the rate of return is \( \geq \theta \). However this bond will not yield revenue to the government.
It should also be clear that the government which seeks to maximize total revenue will choose values for the variables \((R_1', R_2', F)\) as a function of the state variables and, in particular, \(n\), the rate of growth of output. A different level of this growth rate would, in general, involve different levels of the choice variables which solve the government's optimization problem.

The optimal rate of inflation, even for a revenue-maximizing government might not be positive. This is not due, for example, to money balances appearing in the utility function (see Drazen [1975]). Instead if \(n > 1\), the revenue-maximizing rate of return may not entail inflation.

A revenue-maximizing government may actually choose rates of return on its liabilities which deters agents from holding capital. That is, this type of government may wish to minimize the capital stock. Alternatively, a government which wishes to achieve Pareto-optimal allocations for agents, for a given level of government consumption, may also issue multiple liabilities in order to deter agents from holding capital. This is illustrated in the following lemma.

**Lemma 3:**

If \((R_1', R_2') \in S(G(t), F), k[R_1', R_2', F] > 0, R_2' < n, \theta < n\) and either \(F \leq \alpha\) or \(D_2[R_1', R_2', F, N^F(t)] > 0\), then there exists \((R_1', R_2') \in S(G(t), F)\) with \(\tilde{R}_2' > R_2'\) with \(k[R_1', \tilde{R}_2', F] = 0\). Further, the \((R_1', R_2')\) equilibrium Pareto dominates the \((R_1', R_2')\) equilibrium.

**Proof:**

If \(D_2[R_1', R_2', F, N^F(t)] > 0\), then the equilibrium is one in which bonds and capital are both held in equilibrium. Hence rich agents who hold bonds
or capital must be equally well off. Therefore if the supply of bonds were augmented with a marginally higher increase in $R_2$, all agents who would otherwise hold capital can be induced to hold bonds. Since $R_2' < n$ the government gets at least as much revenue.

If $F < \alpha$ and $D_2[R_1', R_2', F, N^F(t)] = 0$, then by setting $\bar{R}_2 \equiv (\theta, n)$ the government can collect more revenue because $(1 - R_2/n)D_2[R_1', \bar{R}_2, F, N^F(t)] > 0$. Furthermore, all agents are at least as well off because $\bar{R}_2 > \theta$.

Hence this is an environment in which a high capital stock is not necessarily a good thing. The reason is that the rate of return on capital is not sufficiently high.

One might now inquire concerning the robustness of these results. In particular, it would be fruitful to know that the linear investment technology is not a critical assumption. In fact it is not. Consider a similar environment in which there is still a lower bound $\alpha$ to the amount of each investment project, but that $k(\alpha)$ units of the consumption good invested in the technology at time $(t)$ yields $\theta(k)$ units of the consumption good at time $(t+1)$. If $\theta(x) = 0$ for $x < \alpha$, and $\theta(\cdot)$ is increasing, differentiable, and concave, then the agent's problem is well-defined. Let $k$ be the equilibrium quantity of the consumption good invested by a rich agent under autarky. Then if $\theta'(k) < n$ the government can gain more revenue, or give agents Pareto-superior allocations, by issuing bonds which must then yield at least as high a return as capital. In this instance, the optimal policy of the government may not lead to the total elimination of capital, but it would certainly lead to a lower capital stock than when bonds were not issued.
(III) DYNAMIC EQUILIBRIA

The previous section considered only stationary equilibria in which the rate of growth of the economy-wide endowments (output) was \( n \geq 1 \) for all \( t \equiv 1 \). The resulting government policy variables \((R_1, R_2, F)\) were then fixed for all \( t \equiv 1 \).

Consider a similar environment to that described in the previous section in which the population growth rate of the rich in period \( t \) is \( n^r_t \) and the growth rate of the poor in period \( t \) is \( n^p_t \). Further, at time \( t=1 \), both the government and agents have perfect foresight with respect to the positive sequences \( \{n^p_t\}, \{n^r_t\} \). As the notation indicates, \( n^p_t \) and \( n^r_t \) may not be constant over time. The government which seeks to maximize revenue will then choose time varying policy variables \((R_1(t), R_2(t), F(t))\) which will then be functions of these growth rates. That is, the optimal rate of return on money and bonds, from the government's point of view, will depend upon the rates of growth of the various groups which make up the total population in that particular period. A version of Lemma 2 would now find that there might be some periods in which the government could only gather revenue from money financing, and not from bonds. Alternatively, there could be other periods in which both securities were issued. Specifically, periods in which the growth rate of the rich agents was high would be periods in which bond financing would be more likely to yield revenue. In an economy where the rich population was at least as large as the poor, and the growth rates of the two groups were similar on average, the government might be observed
utilizing bond issue more during periods when output growth was high (expansionary periods?) while relying on money financing during periods when output growth tended to be low (recessions?).

One could also consider how the optimal instruments might change as other variables such as endowments, $\theta$, or $\alpha$ changed over time.

Lastly, it is not difficult to see that certain measures at the velocity of money may appear to be procyclical. One such measure would be the ratio of total endowments to money holdings:

$$\frac{N^P(t-1)[w^P_2(t) + (n^P_2)w^P_1(t)] + N^F(t-1)[w^F_2(t) + (n^F_2)w^F_1(t)]}{D_1[R_1(t), R_2(t), F(t), N^P(t), N^F(t)]}$$

Alternatively, another measure could be the ratio of total "purchased" output to money holdings:

$$\frac{D_1[R_1(t), R_2(t), F(t), N^P(t), N^F(t)] + D_2[R_1(t), R_2(t), F(t), N^F(t)]}{D_1[R_1(t), R_2(t), F(t), N^F(t)]}$$

In either case, it is straightforward to see that if the growth rate of the rich ($n^{R}_t$) exhibits some variability then, with reasonable parameter values, total output and velocity will be positively correlated.
This section illustrates the problems described in the previous section with two examples. In both it is assumed that all agents' preferences can be described by the utility function $U[C_1(t), C_2(t)] = C_1(t) \cdot C_2(t)$.

**Example 1:**

It is assumed that the endowments of the poor agents are of the form $[w_1^P, w_2^P] = [4, 2]$, whilst those of the rich agents are $[w_1^R, w_2^R] = [10, 4]$. The following parameter values are assumed: $\theta = 1$, $\alpha = 2$. The government then chooses rates of return $(R_1, R_2)$ and a lower bound $F$ on real bond holdings to maximize government revenue as in equation (4).

In this case we have solutions $R_1 = 1.0, R_2 = 1.17, F = 5.05$; and the nominal rate of interest or nominal bonds is $(R_2/R_1) = 1.519$. Hence there is no inflation, although seignorage is gained from both bond and money financing. Total revenue per poor agent from money financing is $(1 - R_1/n)(w_1^P - w_1^P/R_1) = 1$ unit, whilst total revenue per rich agent from bond financing is $(1 - R_2/n)F = 2.10$ units. This example is illustrated in Figure 3. The allocation $(C_1^R, C_2^R)$ is that which results when the agent invests in capital. The government chooses $F$ and $R_2$ to maximize revenue, and leave the agent only as well off as if he had invested in capital. As can be seen, this policy results in the government choosing a level of $F$ which is binding for the rich agent.

Figure 3 also reveals that setting the levels of $F$ and $R_2$ equal to those shown in the diagram is equivalent to a lump-sum tax of $(w_2^R - C_1^R)$ in the first period of a rich agent's life, and a transfer of $(C_2^R - w_2^R)$ in the
second period of the agent's life. This allocation is also equivalent to a legal constraint raising the minimum storage amount to \((w_r^F - C_1^F)\) while subsidizing the return by \((R_2 - \theta)\), which would be financed through a lump-sum tax. Hence the distortionary taxes imposed through bond-financing allows the government to provide the same allocations as in the above tax-subsidy scheme.

**Example 2:**

This example considers an economy in which the growth rates of various groups in the economy vary over time, as described in the previous section. Let the endowment scheme and preferences be as in the previous example. Further, we let \(\alpha = 3\), \(\theta = 1\), and set \(F = 3\) for all \(t \geq 1\). It is assumed that the growth rates of the various groups are as follows

\[
\begin{align*}
    n_t^F &= \begin{cases} 3 & \text{for } t \text{ even} \\ 4 & \text{for } t \text{ odd} \end{cases} \\
    n_t^P &= \begin{cases} 2 & \text{for } t \text{ even} \\ 4 & \text{for } t \text{ odd} \end{cases}
\end{align*}
\]

The optimal stationary solution for gross real rates of return on bonds and money, respectively, which maximizes government revenue are

\[
\begin{align*}
    R_2 &= \begin{cases} 1.09 & \text{for } t \text{ even} \\ 1.26 & \text{for } t \text{ odd} \end{cases} \\
    R_1 &= \begin{cases} .632 & \text{for } t \text{ even} \\ .894 & \text{for } t \text{ odd} \end{cases}
\end{align*}
\]
The gross nominal rate of return on bonds is then

\[ \frac{R_2}{R_1} = \begin{cases} 
1.72 & \text{for } t \text{ even} \\
1.415 & \text{for } t \text{ odd.}
\end{cases} \]

The maximal seigniorage gained per rich and poor agent is then given in the following table.

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<th>Poor Agent</th>
<th>Rich Agent</th>
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<tr>
<td>even</td>
<td>0.57</td>
<td>4.0</td>
</tr>
<tr>
<td>odd</td>
<td>1.37</td>
<td>4.7</td>
</tr>
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As can be seen, the revenue-maximizing policy is one of varying the amount of bond and money issuance as a function of the state of the economy. In odd periods, as compared with even periods, output growth is high, inflation is low, real interest rates on bonds are high, while real rates on bonds are low and government revenue is high.

In this example the state variables which vary over time are \( (n^R_t, n^P_t) \). The optimal rate of bond issuance is positively related to the growth rate of output of a subgroup of the population, while the optimal inflation rate is related to the growth rate of output of another group of agents. Although not illustrated in this example, it would generally help to increase revenue if \( F \) were allowed to vary over time as a function of the state variables as well.
(V) REMARKS

This paper has developed a model in which the government may find it optimal to issue multiple liabilities. It was shown that if the government wishes to provide agents with optimal allocations, for a given path of government consumption, it may wish to issue both bonds and money in such a way as to deter investment in capital. Hence agents may be made better off with a lower capital stock. Alternatively, if the government wishes to maximize its own consumption, it may also do this by issuing more than one liability. The device which enables the government to do this is an imperfection in the capital market; there are securities which individual agents cannot issue which the government can issue. The paper employed an environment with two types of agents. This was clearly not crucial. Any economy in which there exists some heterogeneity among the population, and consequently where some state contingent trades are not possible, may yield a role for a government security to fill the void.

It should be clear that any factor which increases the demand for government liabilities thereby increases the amount of revenue which the government can potentially garner. For example, as noted by Fama [1980], the imposition of reserve requirements--requiring certain agents to hold a proportion of their assets as government liabilities--will increase the demand for government-issued securities. A government can be seen to raise more revenue through the imposition of such binding requirements, for a given rate of return on the asset. Alternatively, consider a government which wishes to finance a given deficit through an inflation tax, in the absence of a reserve requirement. The government may find it can finance the same deficit
with a lower level of inflation by imposing a binding reserve requirement on
at least some agents, which would then increase the demand for government
issued currency. To the extent that people feel that inflation is bad reserve requirements may be viewed as a substitute, since if the demand currency is increased, a lower rate of inflation is needed to yield a given amount of revenue.

The revenue gathering ability of an inflation tax is inhibited to the extent that there are substitutes for the government liability, such as various forms of inside money. Any government-imposed inhibitions on the issuance of inside money will increase the revenue-gathering potential of the inflation tax.

In the model of this paper, government can potentially increase revenue by issuing several liabilities. As noted by Bryant and Wallace [1984], in an economy in which there are a multitude of different agents the government may wish to issue as many liabilities as there are types of agents. This leads to a system of non-linear prices in order to achieve some form of price discrimination. The government may achieve this by issuing securities in different denominations, or securities with possibly the same face value but with different terms to maturity.

In the model developed herein, each period the government can evaluate the optimal degree of issuance of various liabilities without regard to the effects of such policies on future periods. Policy decisions undertaken in one period have no effect upon future real state variables and hence on decisions made by agents in future periods. Alternatively, one may consider an environment in which the periods are "tied together" through the existence
of a time-dependent state variable such as an *augmentable* capital stock. The government's revenue-maximizing inflation tax would then have to take into account the effects of inflation this period on the capital stock which might result in a change in money holdings in future periods. The government's decision problem would then be posed in a truly dynamic context wherein inflationary policies introduced today affect future seigniorage.

A consideration which we have not addressed is that the minimal bond size, "F" in the notation of this paper, may, for some reason be fixed in nominal rather than real terms. The policymaker must then consider the effects that inflation would have on the devaluation of the real value of this bound. Should there be a sustained period of inflation, the poorer agents could become rich enough (in nominal terms) to avoid some of the inflation tax by purchasing nominal bonds.
Footnotes

1 Although this is clearly a population growth rate, we also interpret it as an output growth rate since total endowments will be growing at this rate. We could have alternatively let the population be constant but let endowments in each period grow at this rate. Then it would be clear that this was an output growth rate. The only necessary serious modification to the subsequent analysis would be that the minimal bond size would vary over time.

2 This analysis abstracts from the issues involved when the government can also levy direct taxes. The government need not be restricted to issuing just two securities. This is done merely for simplicity.

3 This paper has also abstained from any tedious discussion of integer constraints involved in the discussion of the number of agents and bonds.

4 See also Freeman [1983] for another monetary model with private information.

5 This is similar to that given in Bryant and Wallace [1984].

6 In an environment where some agents hold government liabilities and others issue private securities, a higher rate of inflation may benefit some agents at the expense of others. Hence different rates of inflation may yield Pareto non-comparable allocations.
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