Public Debt and the Price Level *

Michael Woodford
Princeton University

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Abstract

This paper considers whether monetary and fiscal policy may sensibly be formulated independently of one another, and argues that the reasons for the two to be interconnected go well beyond the familiar but unappealing possibility of using seignorage as a source of revenue for the government. Particular attention is given to the effects of fiscal policy upon the price level through the wealth effect of variations in the value of the public debt; such effects are shown to be consistent with rational expectations and frictionless financial markets, contrary to the doctrine of "Ricardian equivalence", in the case of "non-Ricardian" fiscal policy. In this case, the effects of variation in the composition of the public debt (as to maturity and degree of indexation) are considered, as well as the effects of growth in its overall size.

A number of objections to the possibility of a non-Ricardian policy are considered, notably the assertions that it is not possible for a government to refuse to adjust its budget when its debts grow too large, and the assertion that equilibria in which the price level is determined by the government budget depend upon an implausible equilibrium selection in a model with multiple rational expectations equilibria. The effects of public debt upon the price level are also considered in the case that consumers have adaptive rather than rational expectations about their lifetime budgets.

Finally, the nature of optimal fiscal and monetary policy is considered, as a problem of dynamic Ramsey taxation. It is shown that an optimal policy regime may well involve a "non-Ricardian" fiscal policy, in which increases in govermment purchases do not result in corresponding increases in the present value of future tax collections, and so cause fluctuations in the equilibrium value of government bonds. At the same time, an appropriate choice both of monetary policy and of the composition of the public debt can make this sort of fiscal policy compatible with a substantial degree of price stability.

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Recent years have seen a worldwide movement toward greater emphasis upon the achievement of inflation targets as the primary criterion for judging the success of central banks' conduct of monetary policy. At the same time, the independence of central banks in their choice of the means with which to pursue this goal has also increased. The implication would seem to be that it is now widely accepted that the choice of monetary policy to achieve a target path for inflation is a problem that can be, and indeed ought to be, separated from other aspects of government policy, such as the choice of fiscal policy.[1] But is this really so clear? Or do the agencies responsible for inflation stabilization properly need to concern themselves with fiscal policy choices as well, while the agencies concerned with fiscal policy have a corresponding need to coordinate their actions with those of the monetary authority?

The argument for separation of decision-making about these two aspects of macroeconomic policy necessarily relies upon two theses: first, that fiscal policy is of little consequence as far as inflation determination is concerned, and second, that monetary policy has little effect upon the government budget. We shall argue here that neither proposition is true, for reasons that are related. The fiscal effects of monetary policy are often thought to be an insignificant consideration in the choice of monetary policy by the major industrial nations, because seignorage revenues are such a small fraction of total government revenues in these countries. But such a calculation neglects a more important channel for fiscal effects of monetary policy, namely the effects of monetary policy upon the real value of outstanding government debt, through its effects upon the price level (given that much of the public debt is nominal) and upon bond prices, and upon the real debt service required by such debt (insofar as monetary policy can affect real as well as nominal interest rates).[2]

Fiscal policy is often thought to be unimportant for inflation determination – at least when, as in countries like the U.S. and the U.K., a desire to obtain seignorage revenues plays no apparent role in the choice of monetary policy – on two different, though complementary,

[1] A particularly extreme example of a proposal to separate the two types of policy decisions is the European monetary union provided for by the Maastricht treaty, which will make monetary policy the responsibility of a supra-national European Central Bank, while fiscal policies continue to be the prerogatives of individual national governments.

[2] See King (1995) for discussion of this point, with some quantitative evidence.

grounds. On the one hand, it is often argued that inflation is purely a monetary phenomenon, and hence that only the choice of monetary policy matters for what level of inflation one will have. And on the other, the celebrated "Ricardian equivalence" proposition implies that insofar as consumers have rational expectations, fiscal policy should have no effect upon aggregate demand, and hence no effect upon inflation.

We shall argue that neither proposition is of such general validity as is often supposed. As a considerable recent literature has stressed,[3] fiscal shocks affect aggregate demand, and the specification of fiscal policy matters for the consequences of monetary policy as well, in rational expectations equilibria associated with policy regimes of the kind that we call "non-Ricardian" (Woodford, 1995, 1996), even when the monetary policy rule involves no explicit dependence upon fiscal variables of any sort. This happens, essentially, through the effects of fiscal disturbances upon private sector budget constraints and hence upon aggregate demand. Such effects are neutralized by the existence of rational expectations and frictionless financial markets *only* if it is understood that the government budget itself will always be subsequently adjusted to neutralize the effects, in present value, of any current fiscal disturbance. A "non-Ricardian" fiscal policy is one that does not have this property; we show that non-Ricardian policies may easily be consistent with the existence of a rational expectations equilibrium, which means that the expectation that the government will follow such a rule need never be disconfirmed.

This possibility, however, means that a central bank charged with maintaining price stability cannot be indifferent as to how fiscal policy is determined. At the very least, it matters whether the government budget is expected to adjust according to a Ricardian rule or not, and if not, then both the time path of the government budget and the composition of the public debt (for example, its maturity structure and its degree of indexation for

[3] The discussion of price-level determination under a non-Ricardian policy regime in section 2 below recapitulates results from Woodford (1994, 1995, 1996), drawing also upon the important contributions of Leeper (1991), Sims (1994), and Cochrane (1996). Important precursors of this literature include Sargent (1982), Begg and Haque (1984), Shim (1984), d'Autume and Michel (1987), and Auernheimer and Contreras (1990, 1993). Other recent discussions and extensions of this work include Benhabib *et al.* (1998), Bergin (1996), Buiter (1998), Canzoneri and Diba (1996), Canzoneri *et al.* (1997), Cochrane (1998), Dupor (1997), Loyo (1997a, 1997b), McCallum (1998), Schmitt-Grohé and Uribe (1997), and Sims (1995, 1997).

inflation) have consequences for inflation determination. It follows that it makes sense that the government agency responsible for the pursuit of price stability be allowed a voice in fiscal matters. At the same time, we show that the fiscal consequences of monetary policy decisions are not negligible, even when seignorage revenues make a negligible contribution to the government budget, because of the effects of price level changes upon the value of nominal government debt. This means that it is not obvious that monetary policy decisions can properly be made in complete independence of the government's fiscal needs. Indeed, we show in section 5 that from the point of view of optimal tax policy, it may be desirable for fiscal disturbances for affect the equilibrium price level; but achievement of the optimal equilibrium requires a proper conduct of monetary policy by the central bank, and not just a proper tax policy.

1 Does Fiscal Policy Matter for Inflation?

We begin by reviewing the role of fiscal policy in inflation determination. We shall first explain, in the context of a simple intertemporal equilibrium framework, why monetary policy is sometimes argued to determine equilibrium inflation independently of the specification of fiscal policy. We then demonstrate, through an example in the next section, why the argument is invalid in the case of certain types of fiscal regimes that we call "non-Ricardian". We then discuss the consequences of this possibility for the choice of a monetary and fiscal policy regime that favors price stability.

1.1 A Simple Model of Inflation Determination

We shall consider price-level determination in the context of a simple intertemporal equilibrium framework, in which we assume an infinite-lived representative household with rational expectations and access to perfectly frictionless financial markets. These familiar, though rather idealized, model elements are included so that we may recall the standard argument for Ricardian equivalence, before proceeding to show that it applies only to a particular type of fiscal policy. In this section, we shall also assume pure lump-sum taxation, for the same reason, though we consider the consequences of tax distortions for certain conclusions in section 5 below.

Let the economy consist of a large number of identical infinite-lived households, each of which seeks to maximize a lifetime objective

$$E\left\{\sum_{t=0}^{\infty}\beta^t U(c_t, y_t, M_t/P_t)\right\}, \tag{1.1}$$

where c_t denotes private consumption in period t of the single non-durable good, y_t denotes the quantity of goods supplied by the household, M_t denotes the money balances held by the household at the end of period t, and P_t is the period t price level (price of the good in terms of money). The period utility function U is assumed to be concave, twice continuously differentiable, increasing in its first argument, decreasing in the second, and increasing in the third (though there may be satiation in money balances at some finite level). The third argument indicates the existence of liquidity services from money balances, as in the model of Sidrauski (1967) and Brock (1975). We introduce this as a simple way of allowing non-interest-earning cash balances to co-exist with interest-earning public debt, though we shall abstract, for the most part, from both the fiscal consequences of this interest differential and the real consequences of the distortions indicated by the presence of this argument in the utility function.

Each period, a household chooses its consumption c_t, its supply of goods to the market y_t, its money balances M_t, and the vector of bond holdings B_t, subject to the flow budget constraint

$$P_t c_t + M_t + Q_t' B_t \leq W_t + P_t y_t - T_t, \tag{1.2}$$

where Q_t is the vector of end-of-period bond prices, W_t is the total nominal value of the household's portfolio of money at the beginning of period t, and T_t denotes the household's net nominal lump-sum tax obligation. When we allow for uncertainty at all, we shall assume that a sufficient number of distinct types of bonds are traded for financial markets to be *complete,* in the sense that any desired state-contingent value A_{t+1} of one's bond portfolio at the beginning of period $t+1$ may be achieved through an appropriate choice of the vector of bond holdings B_t (possibly involving short sales). The absence of arbitrage opportunities implies a unique price for any bond portfolio with state-contingent payoff A_{t+1}, given by $E_t[R_{t,t+1}A_{t+1}]$, where $R_{t,t+j}$ is a uniquely defined stochastic discount factor, for discounting nominal returns at date $t+j$ back to date t.[4] Under this assumption, and imposing a borrowing limit that prevents a household from having debts greater than the present value of its future after-tax income, the flow budget constraints (1.2) are equivalent to a sequence of *intertemporal* budget constraints of the form

$$E_t\left\{\sum_{j=0}^{\infty} R_{t,t+j}\left[P_t c_t + \frac{i_t}{1+i_t}M_t\right]\right\} \leq E_t\left\{\sum_{j=0}^{\infty} R_{t,t+j}\left[P_t y_t - T_t\right]\right\} + W_t, \tag{1.3}$$

where i_t is the nominal interest rate on a riskless one-period asset purchased in period t.

Household optimization then requires that the first-order conditions

$$\frac{U_y(c_t, y_t, m_t)}{U_c(c_t, y_t, m_t)} = -1, \tag{1.4}$$

$$\frac{U_m(c_t, y_t, m_t)}{U_c(c_t, y_t, m_t)} = \frac{i_t}{1+i_t} \tag{1.5}$$

and

$$\beta^j \frac{U_c(c_{t+j}, y_{t+j}, m_{t+j})}{U_c(c_t, y_t, m_t)} = R_{t,t+j}\frac{P_{t+j}}{P_t} \tag{1.6}$$

hold at all dates, where $m_t \equiv M_t/P_t$ denotes real money balances. In addition, it requires that the household exhaust its intertemporal budget constraint, so that (1.3) holds with equality, looking forward from any date t. This last condition requires that (1.2) holds with equality at each date, and also that the household's wealth satisfies a *transversality condition* of the form

$$\lim_{T\to\infty} E_t\{R_{t,T}W_T\} = 0. \tag{1.7}$$

[4]The same stochastic discount factor cannot be used to value money because of the additional liquidity services provided by money. Note that our formalism assumes a sharp distinction between monetary and non-monetary assets, as in monetarist models; thus our argument for the effects of public debt on the price level do not depend upon an assertion that public debt is at least partially money-like, as in the argument of Tobin (1974), or upon a denial that money supplies any special liquidity services, as in the argument of Wallace (1981). Because we shall assume in any event that the effects of monetary frictions upon both budget constraints and the real allocation of resources are negligible (despite accounting for the liquidity premium earned by money), allowance for multiple assets that earn liquidity premia is of little interest for our purposes.

Equilibrium requires that markets clear at each date, so that

$$c_t + g_t = y_t, \tag{1.8}$$

where g_t denotes government purchases of the good. Substituting this relation into (1.4), one obtains a relation that may be solved for equilibrium output, yielding an aggregate supply equation of the form

$$y_t = y(g_t, m_t). \tag{1.9}$$

Similarly, substituting (1.8) into (1.5), one obtains a relation that may be solved for equilibrium real money balances, yielding a "liquidity preference" relation of the form

$$M_t/P_t = L(y_t - g_t, i_t). \tag{1.10}$$

Finally, substitution of both (1.8) and 1.9) into (1.6) yields a simpler form for the stochastic discount factor,

$$R_{t,t+j} = \beta^j \frac{\lambda(g_{t+j}, m_{t+j})}{\lambda(g_t, m_t)} \frac{P_t}{P_{t+j}}, \tag{1.11}$$

where

$$\lambda(g, m) \equiv U_c(y(g, m) - g, y(g, m), m).$$

This allows us to relate the prices of assets to their subsequent payouts; for example, the short-term nominal interest rate must satisfy

$$i_t = \beta^{-1} \frac{\lambda(g_t, m_t)/P_t}{E_t[\lambda(g_{t+1}, m_{t+1})/P_{t+1}]} - 1. \tag{1.12}$$

It similarly allows us to express the transversality condition (1.7) in the form

$$\lim_{T \to \infty} \beta^T E_t\{\lambda(g_T, m_T) w_T\} = 0, \tag{1.13}$$

where $w_t \equiv W_t/P_t$ is the real value of total government liabilities. Alternatively, substitution of (1.8) and (1.11) into the condition of exhaustion of the intertemporal budget constraint (1.3) yields the equilibrium condition

$$\frac{W_t}{P_t} = E_t \left\{ \sum_{j=0}^{\infty} \beta^j \frac{\lambda(g_{t+j}, m_{t+j})}{\lambda(g_t, m_t)} \left[s_{t+j} + \frac{i_{t+j}}{1 + i_{t+j}} m_{t+j} \right] \right\}, \tag{1.14}$$

where $s_t \equiv (T_t/P_t) - g_t$ is the real primary government budget surplus.

If we assume additive separability between real money balances and the other arguments of U, the functions $y(g,m)$ and $\lambda(g,m)$ are independent of m. In this case, if government purchases are exogenous, as we shall assume, equilibrium output y_t may be treated as an exogenous process as well, and the same is true of λ_t and hence $R_{t,t+j}$ as well. In fact, we need not assume additive separability in order to make these latter assumptions, as they will also hold in a "cashless" limiting economy, in which the frictions that are responsible for the demand for non-interest-earning money have only a negligible effect upon the majority of transactions.[5] This is probably a reasonable approximation in the case of advanced industrial nations, and so we shall make frequent use of this simplification. We shall also frequently consider the case of a constant level of government purchases g, in which case (also assuming a cashless limiting economy), y_t and λ_t are also constant. In this case, (1.12) reduces to the simple Fisher equation

$$i_t = (\beta P_t E_t[P_{t+1}^{-1}])^{-1} - 1. \tag{1.15}$$

A complete description of equilibrium requires that we specify government policy. First, fiscal policy must specify the evolution of the government budget surplus s_t, perhaps as a function of government purchases and of endogenous variables such as interest rates and the real value of outstanding government liabilities. (Instead of separate specifications of the evolution of government purchases and net tax collections, we shall equivalently specify an exogenous process g_t, and also a rule for the determination of s_t.) Given such a specification, and given the private sector's demand for money balances, the government must issue a vector B_t of bonds of the various types, in quantities that satisfy its *flow budget constraint*

$$Q_t' B_t = W_t - P_t s_t - M_t. \tag{1.16}$$

Government liabilities carried into the next period will then depend upon the exact composition of the debt issued in this period; thus we must specify debt management policy as well.

[5] See Woodford (1998) for further discussion of this limit in the context of an explicit example in which the number of goods that are purchased using money is made arbitrarily small.

Let the set of types of bonds that are traded each period be specified by a vector C, specifying the coupon paid each period per unit purchased in the previous period of each type of bond, and a matrix D, specifying the number of units of each type of bond obtained in the current period per unit of each type of bond purchased in the previous period. Thus purchase of the portfolio B_t in period t results in a household's receiving coupon payments that total $C'B_t$ in period $t+1$, and holding a bond portfolio DB_t in period $t+1$, prior to any trading in that period.[6] Total government liabilities at the beginning of the next period are then given by

$$W_{t+1} = M_t + [C' + Q'_{t+1}D]B_t. \tag{1.17}$$

Equations (1.16) and (1.17) together describe the evolution of total government liabilities W_t from $t = 0$ onward, given initial conditions M_{-1}, B_{-1}, the paths of the money supply and of the primary budget surplus in periods $t = 0$, and the prices P_t and Q_t each period. The bond prices in turn must satisfy

$$Q'_t = E_t\{\sum_{j=1}^{\infty} R_{t,t+j}C'D^{j-1}\}. \tag{1.18}$$

In the case of the cashless limiting economy, similar equations apply, but we drop the M_t terms, treating the monetary base as a negligible part of total government liabilities.

Finally, monetary policy must specify the evolution of the short-term nominal interest rate i_t, which may be set as a function of endogenous variables such as the price level. Note that because of equilibrium condition (1.10), a rule for the evolution of the money supply may equivalently be expressed as a rule for the determination of the nominal interest rate as a function of the current price level, and this is the way in which we shall specify the monetary policy rule here. One advantage of such an approach is that it allows for the existence of a

[6] The introduction of the matrix D allows us to consider multi-period bonds. A two-period bond purchased in period t pays a coupon in period $t+1$ and leaves the holder with a one-period bond; a consol purchased in period t pays a coupon in period $t+1$ and leaves the holder with a consol. This notation allows only for riskless nominal bonds of varying maturities. In the case of uncertainty, the assumption of complete markets requires in general that we allow either C or D to be state-dependent. However, we assume here that the state-dependence affects only elements of C and D that refer to securities not issued by the government, which elements may be suppressed in equations such as (1.17) because the corresponding elements of B_t are zero. We also briefly consider the consequences of government issue of indexed bonds in section 2.1 below, but do not allow for this in our general notation.

well-behaved equilibrium price level even in as one passes to the cashless limiting economy, as explained in Woodford (1998).

Our analysis will often be considerably simpler if we restrict our discussion to the case of a *perfect foresight equilibrium,* in which all variables evolve deterministically. In the case, the above equilibrium conditions all hold, but we may drop the conditional expectations. A number of equilibrium relationships are simpler in this case. For example, in the absence of uncertainty, all non-monetary assets must earn the same rate of return in equilibrium. As a consequence, the time path for the short-term nominal interest rate suffices to determine the time path of all bond prices. For example, the price of the government bond must satisfy

$$Q'_t = \sum_{j=1}^{\infty} [\prod_{k=0}^{j-1} (1 + i_{t+k})^{-1} C' D^{j-1}]. \tag{1.19}$$

1.2 Arguments for the Irrelevance of Fiscal Policy

One standard argument for the irrelevance of fiscal policy is simly that once monetary policy has been specified, a sufficient number of equilibrium conditions exist to determine the equilibrium path of inflation, without any reference to the specification of fiscal policy. Let monetary policy be specified by a rule of the form

$$i_t = \phi(P_t, \ldots; y_t, \ldots; M_t, \ldots; i_{t-1}, \ldots; \nu_t), \tag{1.20}$$

where the dots indicate that some finite number of lags of each of the endogenous variables may matter, and the argument ν_t represents a possible source of exogenous variation in monetary policy over time. The important feature of this specification is that monetary policy is assumed to be independent of the evolution of fiscal variables such as s_t, B_t and W_t.[7] (Of course, even under the strictest monetarist view of the sources of inflation, fiscal developments affect inflation if monetary policy depends upon them, as when money growth

[7] There is no problem with allowing monetary policy to depend upon g_t, given that the irrelevance results stated below assert the irrelevance of variations in tax collections, taking as given the path of g_t, rather than the irrelevance of variations in government purchases. These results can be extended to assert the irrelevance of government purchases as well only under stronger assumptions, such as that government purchases are perfect substitutes for private consumption, or that the marginal utility of consumption is independent of the level of consumption by the representative household.

is determined by the need to raise a certain level of seignorage revenues.) We then have a system of four equilibrium conditions each period, (1.9), (1.10), (1.12), and (1.20), to determine the four endogenous variables P_t, M_t, y_t, and i_t each period, given initial values of the endogenous variables (if any lagged values of these enter as arguments in (1.20)) and the exogenous processes g_t and ν_t (if this last matters). There would thus seem to be a sufficient number of equations to determine this set of variables without independently of how the fiscal variables may evolve. The same conclusion holds if the function ϕ depends upon additional non-fiscal variables, such as other asset prices; one simply needs to adjoin the asset-pricing equations (1.18) to the set of equations that determine this group of endogenous variables.

We can make this discussion more concrete by assuming monetary policy to be specified by an interest-rate rule of the form

$$i_t = \phi(\pi_t), \tag{1.21}$$

where $\pi_t \equiv (P_t/P_{t-1}) - 1$ is the rate of inflation. This is the type of rule that according to Taylor (1993) describes recent U.S. monetary policy.[8] Let us also simplify matters by assuming a cashless limiting economy, and a constant level of government purchases g. Then (1.15) and (1.21) imply that the inflation process must satisfy

$$\beta E_t\{(1+\pi_{t+1})^{-1}\} = [1+\phi(\pi_t)]^{-1} \tag{1.22}$$

at all dates. This stochastic difference equation is plainly independent of all fiscal variables.

Let us suppose, following Taylor, that the policy rule incorporates a "target" inflation rate $\pi^* > \beta - 1$, with the property that

$$\beta(1+\phi(\pi^*)) = 1+\pi^*. \tag{1.23}$$

(We shall further suppose that there is only one solution $\pi^* > \beta - 1$ to this equation.) Then, since there is no initial condition (as π_t is not a predetermined state variable, but instead may "jump" in response to new information at date t), one solution to (1.22) is $\pi_t = \pi^*$

[8]Taylor assumes that the short-term rate targeted by the Fed, the Federal funds rate, is also a function of the level of real output. But in the cashless limit of our simple model, y_t is a function of the exogenous variable g_t, and so allowance for the additional argument would make no difference for our conclusions.

for all t. This solution is furthermore the "minimum state variable" solution, or solution in which (in the spirit of the "Markov perfect equilibrium" concept in game theory) the endogenous variable does not depend upon any states that do not affect either current or expected future equilibrium conditions. In general, there will correspond to this solution for inflation unique solutions for the other endogenous variables as well, and these solutions will represent a rational expectations equilibrium given the monetary policy (1.21).[9]

The nature of other possible solutions to (1.22) is most easily analyzed if we restrict attention to the case of perfect foresight equilibrium, in which case the equation reduces to the deterministic difference equation

$$\pi_{t+1} = \beta(1 + \phi(\pi_t)) - 1. \tag{1.24}$$

In general, there is a sequence π_t satisfying this equation corresponding to each possible choice of an initial value π_0. A typical non-stationary solution is represented graphically in Figure 1, in the case of an initial value $\pi_0 > \pi^*$. The graph drawn in the Figure is for the case in which $\phi(\pi)$ is a monotonically increasing function with

$$\phi'(\pi^*) > \beta^{-1}, \tag{1.25}$$

as assumed by Taylor.[10] We also assume that $\phi(\pi) \geq 0$ for all π, as the central bank cannot force short-term nominal interest rates to be negative, given the possibility of holding non-interest-earning money.[11] If there is not to be more than one fixed point $\pi^* > \beta - 1$ of the difference equation, this requires that the graph intersect the diagonal again at exactly $\pi = \beta - 1$, as shown.

In this case, any initial value $\pi_0 \neq \pi^*$ corresponds to a solution in which π_t eventually grows without bound (as in the figure), or eventually falls to a value arbitrarily close to

[9] There is a possible question of the consistency of this solution with the government's fiscal policy. Under the assumption of a "Ricardian" fiscal policy, as discussed below, there is necessarily no conflict.

[10] This condition means that the instantaneous short rate, $\log(1 + i_t)$ has a derivative greater than one with respect to the instantaneous inflation rate, $\log(1 + \pi_t)$, so that a sustained increase in the inflation rate would have to correspond to an increase in the real interest rate. This is the kind of monetary policy termed "active" by Leeper (1991).

[11] Note that this argument remains valid even in our "cashless limit"; this is an example of why it is important to consider a cashless limiting economy, rather than an actual barter economy in which money simply does not exist.

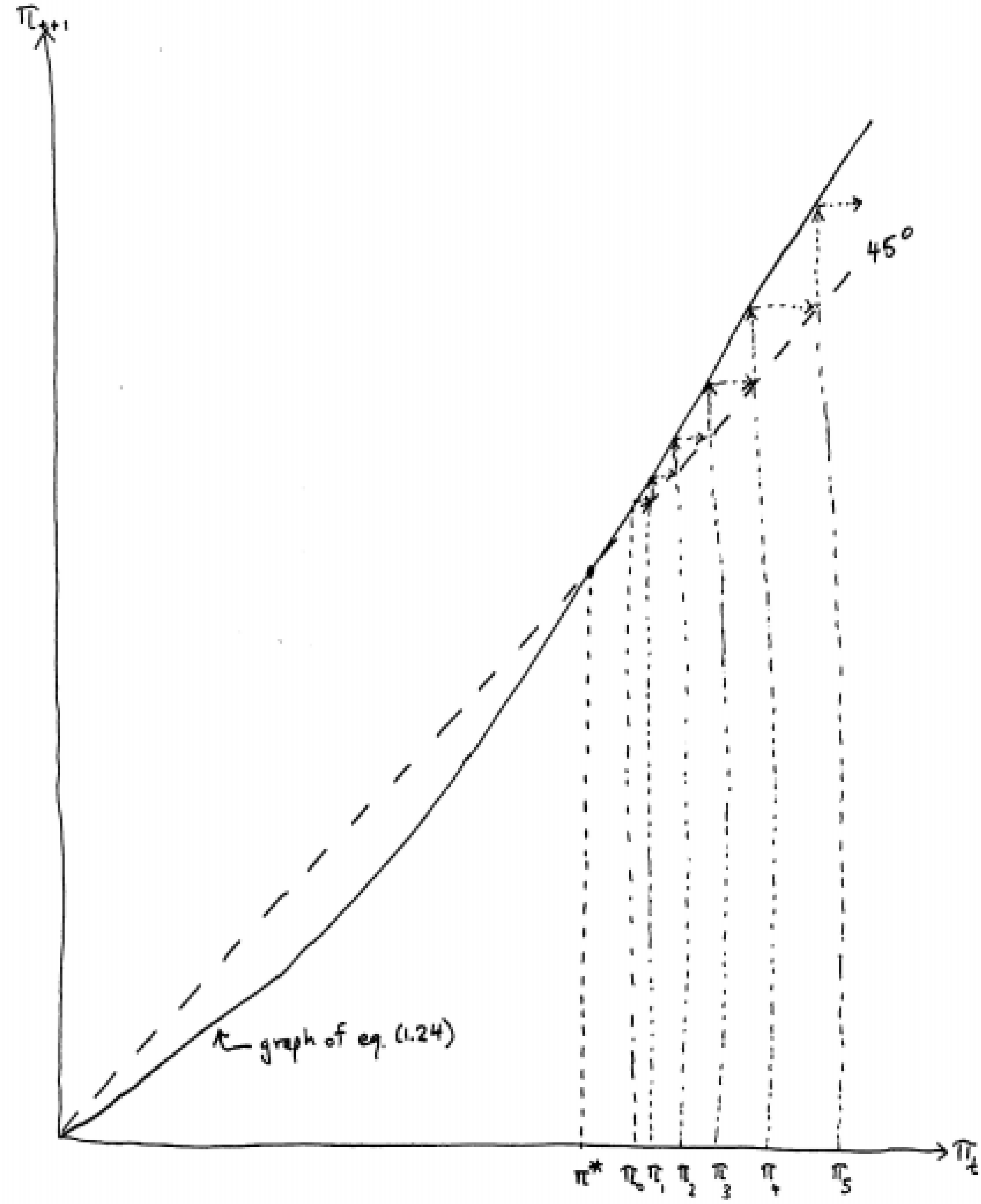


Figure 1.

the lower bound of $\beta - 1 < 0$. Thus even without considering whether these paths are consistent with the other requirements for an equilibrium, it is clear that for any lower bound $\beta - 1 < \underline{\pi} < \pi^*$ and any finite upper bound $\bar{\pi} > \pi^*$, the unique solution to (1.24) in which inflation remains forever within the bounds $\underline{\pi} \leq \pi_t \leq \bar{\pi}$ is given by $\pi_t = \pi^*$ for all t.[12] Furthermore, if one considers a sequence of small perturbations ν_t of the monetary policy rule (1.21), there exists a locally unique solution to the perturbed difference equation (1.24) in which π_t remains near π^* forever.[13] In these senses, it may seem sensible to select the solution $\pi_t = \pi^*$ as the model's prediction in the case of the policy rule (1.21). If so, equilibrium inflation is independent of fiscal developments.

A complementary argument is provided by the "Ricardian equivalence" proposition, formulated for real variables by Barro (1974) and applied to inflation determination by Sargent (1987, Prop. 5.3). Here the emphasis is not upon the sufficiency of monetary policy alone to determine equilibrium inflation, but upon the *absence* of any restrictions upon equilibrium inflation implied by a given specification of fiscal policy.

Let us say that fiscal policy is "Ricardian" if the rule that determines s_t each period, as a function of current and lagged endogenous variables (and possibly an exogenous disturbance term), implies that the "intertemporal government budget constraint" (1.14), or equivalently the transversality condition (1.7), is satisfied, *regardless* of how both government purchases and non-fiscal endogenous variables such as goods and asset prices may evolve. Such an assumption means that the government is committed to adjust its budget as necessary, in response to any developments that may change the value of its existing debt or the size of the associated debt service burden, so that the value of the government debt would not be allowed to explode (or, more precisely, not grow at a rate as fast as the equilibrium real rate of return).

An example of such a fiscal policy would be the type of rule discussed in Canzoneri *et al.*

[12] In fact, a similar result may be obtained within the broader class of solutions to (1.22), even when one allows π_t to vary in response to "sunspot" variables or random fiscal disturbances, following the argument in Woodford (1994).

[13] See Woodford (1998) for proof and further discussion of this.

(1998),

$$s_t = \lambda w_t - \left(\frac{i_t}{1+i_t}\right) m_t, \tag{1.26}$$

for some λ satisfying $0 < \lambda < 2$. As a result of (1.16), such a policy implies that at the end of each period,

$$\frac{Q'_t B_t}{P_t} + \left(\frac{1}{1+i_t}\right) m_t = (1-\lambda) w_t.$$

The two terms on the left-hand side of this expression, however, represent the (real) present value in period t of the public debt that is carried into period $t+1$ and the (real) present value of the stock of money that is carried into period $t+1$.[14] Thus the equation implies that

$$E_t[R_{t,t+1} W_{t+1}] = (1-\lambda) W_t,$$

iteration of which implies (1.7) and hence (1.14), as long as $|1-\lambda| < 1$. It is not, however, necessary for the argument that we assume the specific type of rule (1.26),[15] only that we assume that fiscal policy be Ricardian. This is in fact a tacit assumption in expositions of the doctrine of "Ricardian equivalence", as, for example, when it is assumed that a tax cut at one point in time must be accompanied by an expectation of corresponding tax increases at some later date, so that the present value of future surpluses on the right-hand side of (1.14) is not changed by the change in policy. The justification for such an assumption is that (1.14) is treated as a "budget constraint" that government fiscal policy must necessarily be formulated to satisfy.

Under this assumption, condition (1.14) can play no role in determining the equilibrium paths of inflation and the other non-fiscal endogenous variables, because (given the fiscal policy rule and the flow government budget constraint) it must be satisfied by *any* sequences for these variables. Thus the only conditions that matter for the determination of the non-fiscal endogenous variables are the other equilibrium conditions, (1.9), (1.10), (1.12), (1.20), and the various asset-pricing relations such as (1.18). But none of these other equations

[14] Note that the cost of obtaining money in period t is greater than the present value of the value it will have when carried into period $t+1$, because of the liquidity services that money also supplies.

[15] Canzoneri *et al.* point out that it is not necessary to assume that the coefficient λ take the same value every period in order for policy to be Ricardian.

involve in any way the fiscal variables s_t or B_t or W_t. Consequently, fiscal policy (which assuredly does affect the evolution of the fiscal variables) is irrelevant to the determination of the equilibrium values of the non-fiscal variables.

Despite the cogency of these arguments, we shall see that it *is* nonetheless possible for fiscal policy to affect inflation, both in the sense that disturbances to fiscal policy may cause inflation to vary, and in the sense that the equilibrium response of inflation to other sorts of disturbances (such as monetary policy shocks) may differ depending upon the fiscal policy rule. Such examples, which may also be found in Woodford (1995, 1996), and the other papers mentioned in the introduction, depend upon the consideration of fiscal policies that do *not* satisfy the Ricardian property just assumed. For that reason, the argument just given is invalid under such regimes. Furthermore, it turns out that the set of equations discussed in our presentation of the monetarist analysis (for example, equation (1.22) in the case of policy rule (1.21) do not suffice to fully determine the equilibrium path of inflation. These equations may, and indeed typically do, have multiple solutions, as indicated by Figure 1. In the case of a non-Ricardian fiscal policy, fiscal policy may determine which of these solutions is actually an equilibrium under the proposed policy regime. The next section gives a simple example of how this can occur.

2 When Government Bonds are Net Wealth

Perhaps the simplest and most familiar example of a non-Ricardian fiscal policy is one that specifies the path of the real primary government budget surplus s_t as an exogenous sequence, determined by decisions about the desirable level of government use of resources on the one hand, and the desirable level of taxation on the other, with neither decision being made contingent upon the evolution of endogenous variables such as goods prices, asset prices, or the value of the public debt.[16] This is plainly a non-Ricardian policy, since, given the

[16] Apart from the ubiquity of this assumption in theoretical exercises, it is sometimes recommended as a characteristic of optimal policy. For example, Friedman (1959) advocated a policy regime that would involve both a fixed level of government purchases and a fixed tax rate, which, in the event of an exogenous (supply-determined) level of output, would imply an exogenous evolution for the real primary surplus. Friedman

predetermined quantities of money and government bonds in the hands of the public at the beginning of the initial period, not all processes for goods and asset prices will happen to make the two sides of (1.14) equal in value; indeed, most will not.

Let us assume such a fiscal policy, along with a constant level of government purchases g, and a monetary policy given by (1.21), where ϕ is a non-decreasing function, that may or may not satisfy (1.25); and let us consider the nature of perfect foresight equilibrium in the cashless limiting economy.[17] The analysis is simplest if we assume that the government issues only one-period riskless nominal debt, so that (1.16) and (1.17) reduce to $B_t = (1 + i_t)[W_t - P_t s_t]$ and $W_{t+1} = B_t$, where now the scalar B_t is the nominal value at maturity of government debt outstanding at the end of period t. It follows that W_t is a predetermined state variable, with law of motion

$$W_{t+1} = (1 + \phi(\pi_t))[W_t - P_t s_t]. \tag{2.1}$$

In the perfect foresight cashless limit, equilibrium condition (1.14) reduces to

$$\frac{W_t}{P_t} = \sum_{j=0}^{\infty} \beta^j s_{t+j}. \tag{2.2}$$

Let us suppose that the initial public debt is positive ($W_0 > 0$), and that s_t is a positive sequence, or at least positive often enough for the right-hand side of (2.2) to be positive, looking forward from any date t. Then in the initial period, a unique equilibrium price level $P_0 > 0$ is determined by equation (2.2). Given this (and the initial condition $P_{-1} > 0$), (2.1) determines a value $W_1 > 0$, whereupon (2.2) determines a unique equilibrium price level $P_1 > 0$, and so on into the indefinite future. One determines in this way the unique perfect foresight equilibrium price sequence consistent with the assumed policy regime.

In this equilibrium, fiscal developments obviously affect the equilibrium price level: a different accumulated public debt W_t would imply a different price level in period t, for

proposed this even though, as authors such as Blinder and Solow (1973) and Tobin and Buiter (1976) noted, it was not obviously consistent with his monetary policy recommendation, which was for an exogenous, constantly growing path for the money supply. In section 5 below, we illustrate assumptions under which such a policy can be shown to be optimal in the sense of solving a Ramsey problem.

[17] For discussions of similar regimes in which the effects of monetary frictions are not neglected, see, e.g., Woodford (1995, 1996).

any given expectations regarding fiscal surpluses from then on, and news at date t that changed the expected sequence of surpluses from that date onward would in general cause the equilibrium price level in period t to change.[18] The way that fiscal disturbances affect the price level is through a wealth effect upon private consumption demand. A tax cut not balanced by any expectation of future tax increases would make households perceive themselves to be able to afford more lifetime consumption, if neither prices nor interest rates were to change from what would have been their equilibrium values in the absence of the tax cut. This would lead them to demand more goods than they choose to supply (both immediately and in the future). The resulting imbalance between demand and supply of goods drives up the price of goods, until the resulting reduction in the real value of households' financial assets causes them to curtail demand (or increase supply) to the point at which equilibrium is restored.

An obvious question is why Ricardian equivalence does not hold here. The answer is that the argument above depended upon the assumption that fiscal policy is Ricardian, which means that, by assumption, fiscal policy changes never have wealth effects of the kind just sketched. If fiscal policy were Ricardian, equation (2.2) would be satisfied by *any* price level P_t, for subsequent budget surpluses would be expected to adjust in response to the price change so as to ensure that the condition held. Under such an assumption, it would be correct to say that "government bonds are not net wealth" (Barro, 1984). But as the example above shows, government bonds may indeed be net wealth (in the sense that an increase in their value increases the lifetime budget set of the representative household) if future government budgets are not expected to be adjusted as a result of a change in the value of the public debt.

Note that our argument does not involve any denial that the value of the public debt must actually equal the present value of future government budget surpluses, *in equilibrium*.

[18] The only case in which the last assertion would *not* be true is if a reduction in the current surplus were exactly balanced by an expected increase in later periods' surpluses, so that the present value on the right-hand side of (2.2) remained unchanged. This is the only kind of fiscal policy change assumed to be possible in standard discussions of Ricardian equivalence.

What we deny is that condition (1.14) is a constraint upon government fiscal policy, that must be expected to hold regardless of the evolution of goods prices and asset prices. Instead of a "government budget constraint", the condition is properly viewed as an equilibrium condition, that follows from the joint requirements of private sector optimization and market clearing. But as an equilibrium condition rather than an implication of the fiscal policy rule, it can play a role in equilibrium inflation determination.

Another obvious question is why inflation is not instead determined by equation (1.24), and thus by monetary policy alone. Here it is important to note that the inflation sequence generated in the way just described *does* satisfy (1.24) each period. For (2.1) implies that the growth rate of outstanding government liabilities will satisfy

$$\begin{aligned}\frac{W_{t+1}}{W_t} &= (1+\phi(\pi_t))\left[1-\frac{P_t}{W_t}s_t\right] \\ &= (1+\phi(\pi_t))\frac{\sum_{j=1}^{\infty}\beta^j s_{t+j}}{\sum_{j=0}^{\infty}\beta^j s_{t+j}} = \beta(1+\phi(\pi_t))\frac{v_{t+1}}{v_t}.\end{aligned}$$

In the second equality we have used (2.2) to substitute for P_t/W_t, and in the final equality we have defined the exogenous variable v_t to equal the right-hand side of (2.2). Then since the equilibrium price level each period is given by $P_t = W_t/v_t$, this rate of growth of nominal government liabilities between periods t and $t+1$ implies a rate of inflation given by (1.24). Thus we have not neglected the earlier equilibrium condition.

But equations (2.1) and (2.2) do not simply imply (1.24), a condition previously derived without any reference to fiscal policy; they also imply an *initial* inflation rate π_0, which depends upon the initial size of nominal government liabilities and upon the expected path of government surpluses. Thus the fact that fiscal policy helps to determine the equilibrium path of inflation under such a regime depends upon the fact that equation (1.24) is consistent with a continuum of distinct solutions, one for each possible choice of π_0. All of these solutions correspond to perfect foresight equilibria in the case of a Ricardian fiscal policy, since fiscal developments place no additional restrictions upon the equilibrium price level, as explained above. Under a non-Ricardian policy rule of the kind just described, instead, fiscal policy supplies the additional restriction needed to select a unique element from that set as the perfect foresight equilibrium consistent with the specified policy.

Note that only fortuitously will the particular solution to (1.24) that is consistent with the specification of fiscal policy coincide with the one selected on the ground of its being the "minimum state variable solution". In the case of a monetary policy rule that satisfies (1.25), i.e., the case shown in Figure 1, then almost all expectations regarding the sequence of government budgets s_t will imply either an inflation rate that continues to fall until there is eventually deflation at the rate of time preference (the lowest possible equilibrium inflation rate, under the assumption of perfect foresight, because of the zero floor on nominal interest rates), or an inflation rate that grows forever without bound (as shown in the figure). The latter case is the kind of equilibrium proposed by Loyo (1997b) as an explanation for the explosion of inflation in Brazil in the early 1980's.

Similar conclusions are obtained in the case that longer-term government debt exists. In this case, W_t will not be a predetermined state variable; (1.17) implies that its value will depend upon the current value of the asset prices Q_t, and so the equilibrium condition (1.14) involves both the goods price level P_t and the vector of asset prices. However, as just noted, the inflation sequence must satisfy (1.24). This means that any given inflation rate π_t determines a unique sequence of inflation rates π_{t+j} for all $j \geq 0$, and hence a unique sequence of nominal interest rates i_{t+j} as well. The latter can then be substituted into (1.19) to solve for the vector Q_t, for any hypothesized value of π_t.[19]

Let the solution to this calculation for an arbitrary value of π_t be denoted by the vector of functions $Q(\pi_t)$. If we assume that all elements of C and D are non-negative (so that any type of government bond promises a non-negative stream of future payments), then the monotonicity of ϕ implies that each element of $Q(\pi)$ is a positive-valued, non-increasing

[19]Here we assume that the joint specification of the nature of government debt and of the monetary policy rule (1.21) are such that the infinite sum in (1.19) is well-defined, and a continuous function of the hypothesized value of π_t. This is necessarily true as long as all government bonds are of finite maturity, since in that case the sum has only a finite number of non-zero terms. In the case that consols are issued by the government, a further restriction on the behavior of the function $\phi(\pi)$ near $\pi = \beta - 1$ is necessary, in order to ensure that the infinite sum is well-behaved even in the case of an inflation sequence which asymptotically approaches that value.

function of π. Then (1.14) may be written

$$\frac{[C' + Q(\pi_t)'D]B_{t-1}}{(1+\pi_t)P_{t-1}} = v_t. \tag{2.3}$$

Here B_{t-1} and P_{t-1} are predetermined, while v_t is exogenous; the condition then determines the endogenous variable π_t as a function of these. Since each element of $(1+\pi)^{-1}Q(\pi)$ is a monotonically decreasing function of π, varying from a value arbitrarily close to zero for π large enough, to an arbitrarily large value for π small enough, it follows that (1.14) has a unique solution π_t, as long as all elements of B_{t-1}/P_{t-1} are non-negative (and at least one is positive), and v_t is positive.[20]

Now let us assume as initial conditions a positive public debt and a positive prior price level P_{-1}, and assume both a surplus sequence s_t satisfying the positivity restriction stated above, and a debt management policy that implies that the government will issue non-negative quantities of each kind of bond in any period when its debt remains positive. Then equation (1.14), together with the law of motion for the vector B_t implied by the flow government budget constraint and the debt management rule, will imply a unique equilibrium sequence π_t, which corresponds in turn to a unique positive price level sequence P_t, a unique non-negative interest rate sequence i_t, unique sequences of positive asset prices Q_t, and unique non-negative sequences for the outstanding quantities B_t of the different types of government debt. In this equilibrium, fiscal policy affects the equilibrium price level in essentially the same way as when there is only short-term debt; only the quantitative effect upon equilibrium inflation of a given size change in the expectation v_t differs depending upon the maturity structure of the outstanding government debt.

2.1 Consequences for Inflation-Stabilization Policy

The theoretical possibility of non-Ricardian fiscal policies of the sort just illustrated matters for the design of an anti-inflationary policy, for several reasons. First of all, insofar as the monetary authority cannot be certain that the fiscal authority is committed (and understood

[20] In fact, it would suffice that both have the same sign, but as above we restrict our attention to equilibria corresponding to a positive value of public debt.

by the public to be committed) to a Ricardian policy, it should be aware that fiscal policy changes may be a source of disturbances to the equilibrium inflation rate.

Indeed, the situation will be worse even than this may suggest. For our results do not imply simply that monetary policy, if it is to stabilize inflation, must respond attentively to changes in fiscal policy, as yet another of the types of disturbances of which monetary policy may have to take account. Instead, they imply that it may be *impossible* even in principle to fully insulate the price level from the effects of fiscal disturbances using monetary policy alone. Let us consider whether, in the case of an exogenous government budget sequence s_t, there exists *any* monetary policy, even allowing monetary policy to be chosen after the sequence s_t is revealed, that can keep the equilibrium price level equal to some constant target level, $P_t = P^*$ forever, regardless of the sequence s_t that may be announced. The reason that this may not be possible is easily seen if we consider again a cashless limiting economy with a constant level of government purchases. Because of the Fisher equation (1.15), anticipation of a constant price level requires that the nominal interest rate equal $i^t = \beta^{-1} - 1$ at all times. Equation (1.18) implies similar constant values for all bond prices, namely

$$Q'_t = \sum_{j=1}^{\infty} \beta^j C' D^{j-1}$$

for all t. But then there is no variable on the left-hand side of (2.3) that can adjust in response to fiscal news at date t that changes the value of v_t. We thus obtain a contradiction to the hypothesis that price-level stabilization was possible. Hence fiscal disturbances are even more problematic for price stability than is indicated by the textbook "IS-LM" analysis, according to which fiscal shocks are an example of an "IS shift", the effects of which upon aggregate demand can be fully neutralized, in principle, by an appropriate adjustment of the interest rate by the central bank.[21]

This conclusion may seem reminiscent of the celebrated "unpleasant monetarist arith-

[21] Note that our conclusion here does not depend upon an assumption that monetary policy is completely impotent. We do assume here that the central bank can control nominal interest rates, contrary to the assumption of authors such as Wallace (1981). And a similar conclusion is obtained even when one introduces sticky prices into the model, so that monetary policy can affect real variables as well (Woodford, 1996).

metic" of Sargent and Wallace (1981) – an analysis that is by now familiar to all students of monetary policy questions, but that is often dismissed as irrelevant to the circumstances of countries with relatively independent central banks (e.g., King, 1995). Sargent and Wallace also argue that a fiscal policy that fixes an exogenous path for the real primary government deficit may make inflation inevitable, regardless of the choice of monetary policy. Their argument, however, depends upon an assumption that the public debt will eventually reach some limit beyond which further government borrowing is impossible, and that when that occurs monetary policy will have to be subordinated to the creation of sufficient seignorage revenues to finance the deficit. A common reading of their paper is that it indicates a problem that can occur if a central bank's commitment to an independent monetary policy is in doubt, but that is not an issue in the case of a central bank that makes it clear that even in the event of a debt 'crisis' it would not budge from its commitment to an anti-inflationary monetary policy, so that the government budget would instead have to adjust.

The example above, by contrast, poses a challenge to the view that central banks can ignore the actions of the fiscal authority that is less easily dismissed. In the above examples, when the news of an intention to reduce the primary surplus results in increased inflation, this does not result from the central bank being forced at any time to change the nature of monetary policy, because of a debt crisis or any other reason. As is further shown in the next section, the logic of the example is unchanged even if we explicitly assume that the fiscal authority, rather than the monetary authority, would change its policy in the event that the country's "debt limit" were reached. (This is true even in the case of the "hyperinflationary" equilibrium shown in Figure 1.) The example does not depend upon seignorage revenues being an attractive source of government revenue; indeed, the logic of the fiscalist equilibrium is most easily expounded in the case of a cashless limiting economy, in which seignorage makes no contribution to the government budget at all (because the monetary base is of negligible size). Nor does the example depend upon a monetary policy that responds in any direct way to fiscal variables; our analysis here assumes a "Taylor rule" for monetary policy, but similar conclusions can also be obtained in the case of money growth targeting rules (Woodford, 1995).

It would seem, as a result, that a central bank charged to maintain price stability must be concerned about the conduct of fiscal policy as well. Its concern might be of one of two types. On the one hand, it might simply seek to ensure that the fiscal authority is committed to a Ricardian policy, without then feeling any further need to participate in the year-to-year conduct of fiscal policy.[22] This is one possible interpretation of the emphasis given to fiscal criteria for participation in the European monetary union under the Maastricht treaty, and to subsequent calls for a "stability pact" that would constrain member nations' fiscal policies after entry into the union. But on the other hand, a central bank that takes it for granted that fiscal policy is non-Ricardian would then have reason to wish to influence fiscal policy decisions on an ongoing basis, insofar as unexpected changes in the size of the government budget would be an important source of disturbances affecting the equilibrium price level.

In the event that fiscal policy were judged to be non-Ricardian, this would also have important implications for the central bank's conduct of monetary policy. A policy that might seem quite sensible, from the point of view of achieving price stability, in an environment of Ricardian fiscal policy, might be disastrous in the case of a non-Ricardian fiscal policy. For example, according to the simple model analyzed here, the kind of policy rule advocated by Taylor (1993) would have desirable properties when combined with a Ricardian fiscal policy rule: it would be consistent with an equilibrium in which inflation is constant at the (low) target rate π^*, and this equilibrium, as the "minimum state variable" solution and the unique bounded solution, might seem the one most likely to be realized under such a regime. But when the same monetary policy is combined with an exogenous path for the government surplus, the only possible equilibrium may be one in which the inflation rate explodes (as in Loyo's analysis of Brazil). Yet the same fiscal policy *would* have been consistent with low inflation forever, in the case of a different monetary policy. Contrariwise, a policy that might seem reckless in the case of a Ricardian fiscal policy might be desirable in the case

[22]The results of section 2.1 below, however, urge caution in deciding too easily that the fact that fiscal policy is Ricardian eliminates the possibility of fiscal disturbances to aggregate demand and to inflation.

of a non-Ricardian fiscal policy. For example, a policy of trying to peg the nominal interest rate is commonly denounced as a policy that leaves the equilbrium price level indeterminate, and so vulnerable to price-level variations due to self-fulfilling expectations (Sargent and Wallace, 1975). This would be correct, according to our model, in the case of a Ricardian fiscal policy. But in the case of an exogenous path for the government surplus, such a policy results in a determinate equilibrium price level, which may involve low and stable inflation.

A conclusion that fiscal policy is non-Ricardian would also give the central bank reason to concern itself with debt management issues, since under such a regime, the *composition* of the public debt matters for the behavior of equilibrium inflation, as Cochrane (1996) has stressed. The elasticities with respect to π of the different elements of the vector $[C'+Q(\pi)'D]$ that appears in the numerator of (2.3) will differ, depending upon how far in the future are the payouts associated with the different assets. Essentially, the longer the duration of the asset, the more sharply its value will decline with increases in inflation, since expected future price levels increase even more than does the current price level. But this means that the elasticity of the entire left-hand side of (2.3) with respect to inflation depends upon which elements of the vector B_{t-1} are relatively larger; essentially, the greater the fraction of the public debt that consists of long-maturity bonds, the greater this elasticity, and hence the *less* the equilibrium response of inflation to a given size unexpected change in the value of the exogenous fiscal variable v_t. Since the expected inflation rate in later periods is a monotonically increasing function of π_t by (1.24), a higher initial response of inflation to the fiscal shock means a larger response in all later periods as well; so inflation is unambiguously less affected by fiscal shocks when the public debt is of longer maturity.

We can give a quantitative illustration of this as follows. Let us suppose that the entire public debt consists of a single type of nominal bond, each unit of which pays one unit of currency the period after purchase, $\rho \geq 0$ units the period after that, ρ^2 units in the third period, and so on in perpetuity. This allows us to consider a range of possible assumptions about the duration of the public debt, from a debt consisting entirely of one-period obligations ($\rho = 0$) to a debt consisting entirely of consols ($\rho = 1$).[23] At the same time, the assumption of geometric decay is convenient, in that it implies that a one period old bond is equivalent to ρ new bonds, so that we need only consider a single type of bond. The variables B_t and Q_t then are scalars (referring to the quantity and price of the single type of bond); the vector C is now a scalar (equal to 1), as is the matrix D (equal to ρ).

In this case, (1.19) reduces to

$$Q_t = \sum_{j=1}^{\infty} \rho^{j-1} \prod_{k=0}^{j-1} (1 + i_{t+k})^{-1}. \tag{2.4}$$

Let us assume a monetary policy rule ϕ such that the target inflation rate $\pi^* = 0$, and such that $0 < \phi'(0) < \beta^{-1}$, so that monetary policy is "passive" in Leeper's sense. This last assumption has the conseqence that for any initial value π_t near zero, (1.24) implies that π_T will be even closer to zero for all $T > t$, and converge to zero as T becomes large. In this case, the total derivative of the right-hand side of (2.4) with respect to π_t can be calculated, substituting a function of π_t for each i_{t+k} term using (1.21) and (1.24), and this only requires us to compute the derivatives of (1.21) and (1.24) near the value $\pi_t = \pi^* = 0$. We obtain

$$Q'(0) = -\frac{\beta^2 \phi'(0)}{(1 - \beta\rho)(1 - \beta^2 \rho \phi'(0))},$$

from which the elasticity of Q with respect to $1 + \pi$ at this point is found to equal

$$\epsilon_Q(0) = -\frac{\beta \phi'(0)}{1 - \beta^2 \rho \phi'(0)}.$$

One observes that this elasticity is monotonically increasing (in absolute value) with respect to the duration parameter ρ, and may be arbitrarily large, in the case that ρ is near its upper bound[24] of β^{-1}, and $\phi'(0)$ is near its upper bound of β^{-1} as well. Equation (2.3) reduces to

$$\frac{(1 + \rho Q(\pi_t)) B_{t-1}}{(1 + \pi_t) P_{t-1}} = v_t, \tag{2.5}$$

[23]Government debt has no finite maturity in this model, but it has a finite *duration* that depends upon ρ. In the case of a constant short-term nominal interest rate $i \geq 0$, the duration of government debt equals $(1 + i)/(1 + i - \rho)$ periods.

[24]Note that we require $\rho < \beta^{-1}$ in order for the infinite sum in (2.4) to converge. This upper bound defines the limiting case of an "infinite duration" bond.

and the elasticity of the left-hand side of this equation with respect to $1 + \pi_t$ is seen to be $\beta\rho\epsilon_Q(0) - 1$, which increases (in absolute value) *a fortiori* with increases in ρ.

Combining these results, we find that a one percent unexpected decrease in v_t should cause an unexpected increase in π_t of $1 - \beta^2\rho\phi'(0)$ percent. This in turn implies (differentiating (1.24) an increase in the expected inflation rate in each future period $t + j$ of

$$\theta_j \equiv [1 - \beta^2\rho\phi'(0)](\beta\phi'(0))^j$$

percent. Thus longer duration government debt lowers the amount by which inflation is increased in all future periods. A larger value of $\phi'(0)$ reduces the inflation response as well; by making inflation fluctuations more persistent, such a policy ensures that bond prices move more for any given size change in the inflation rate, and this requires less of an increase in inflation to reduce the value of the public debt to the amount required to restore equilibrium in the goods market.

On the other hand, a larger value of $\phi'(0)$ also makes the disturbance to the equilibrium inflation rate more persistent (permanent, in the limiting case where $\phi'(0) = \beta^{-1}$). This increases the overall variability of inflation, when repeated fiscal shocks occur. Consider a stochastic version of the model, in which s_t fluctuates randomly in a small interval around its mean value $s^* > 0$. It follows that v_t fluctuates randomly in a small interval around the mean value $v^* \equiv s^*/(1-\beta)$. In the case of small enough fluctuations, we can approximate the equilibrium fluctuations in inflation by taking a log-linear approximation to the equilibrium conditions. In this log-linear approximation, the percentage deviation of inflation from its steady-state value $\pi^* = 0$ (the long-run equilibrium when $s_t = s^*$ forever), $\hat{\pi}_t \equiv \log(1 + \pi_t)$, can be expressed as a superposition of the responses to the entire series of past fiscal shocks. Thus one obtains

$$\hat{\pi}_t = -\sum_{j=0}^{\infty} \theta_j[\hat{v}_{t-j} - E_{t-j-1}\hat{v}_{t-j}],$$

where $\hat{v}_t \equiv \log(v_t/v^*)$, and the series of coefficients $-\theta_j$ represent the impulse response function to a fiscal surprise, computed above.

Assuming that the unforecastable changes in $\hat{v}_t$ are drawn independently each period from a distribution with variance σ_v^2, the fluctuations in equilibrium inflation are stationary, with a variance of

$$\mathrm{var}(\hat{\pi}) = \sum_{j=0}^{\infty} \theta_j^2 \sigma_v^2 = \frac{(1 - \beta^2 \rho \phi'(0))^2}{1 - (\beta \phi'(0))^2} \sigma_v^2. \tag{2.6}$$

This implies that the variance of inflation, like the impact effect θ_0, can be made arbitrarily small, by choosing ρ and $\phi'(0)$ both close enough to their upper bounds of β^{-1}. However, care must be taken in the pursuit of this goal, since the fraction in (2.6) is not well-defined for these limiting values; there also exist values of ρ and $\phi'(0)$ arbitrarily close to the limiting values, for which $\mathrm{var}(\hat{\pi})$ is arbitrarily *large*. The behavior of $\mathrm{var}(\hat{\pi})$ as we vary ρ and $\phi'(0)$ is shown in Figure 2, which plots the fraction in (2.6) as a function of $\phi'(0)$, for each of several possible values of ρ.[25] For any fixed value $\rho < \beta^{-1}$, $\mathrm{var}(\hat{\pi})$ grows unboundedly large as $\phi'(0)$ is made close enough to β^{-1}, as inflation fluctuations cease to be stationary at all in the limit.[26] However, $\mathrm{var}(\hat{\pi})$ is minimized by a value of $\phi'(0)$ only slightly less than β^{-1} when ρ is large,[27] and that minimizing value approaches the upper bound (while the minimum value of $\mathrm{var}(\hat{\pi})$ falls to zero) as ρ approaches β^{-1}. Thus despite the unattainability of the actual limit of zero inflation variability, it would seem reasonable to propose a substantial positive response of short-term interest rates to inflation, and nominal government debt of as long a duration as possible, as a way of reducing the equilibrium variability of inflation in response to fiscal shocks of this kind.

The indexation of government debt affects inflation variability in the case of non-Ricardian fiscal policy, on similar grounds. Let the above model be unchanged, except that in every period a fraction $\alpha < 1$ of the public debt (in terms of the value of the debt outstanding at the end of the period) consists of *indexed* debt, that pays a certain real return the next period. (Since in the cashless limit the real rate of return is always equal to the rate of time

[25] The vertical axis thus indicates $\mathrm{var}(\hat{\pi})$, normalized so that the inflation variability resulting in the case of purely short-term government debt is equal to one. For the numerical calculations, β is set equal to .95.

[26] This conclusion is only valid, of course, insofar as the log-linear approximation may be relied upon, and as the predicted inflation variations become large, it cannot be. We may, however, conclude from the log-linear analysis that the fluctuations in inflation exceed any *small* enough bound, for $\phi'(0)$ near enough to β^{-1}, regardless of how small σ_v^2 may be.

[27] One can show, for example, that the minimizing value always satisfies $\phi'(0) > \rho$.

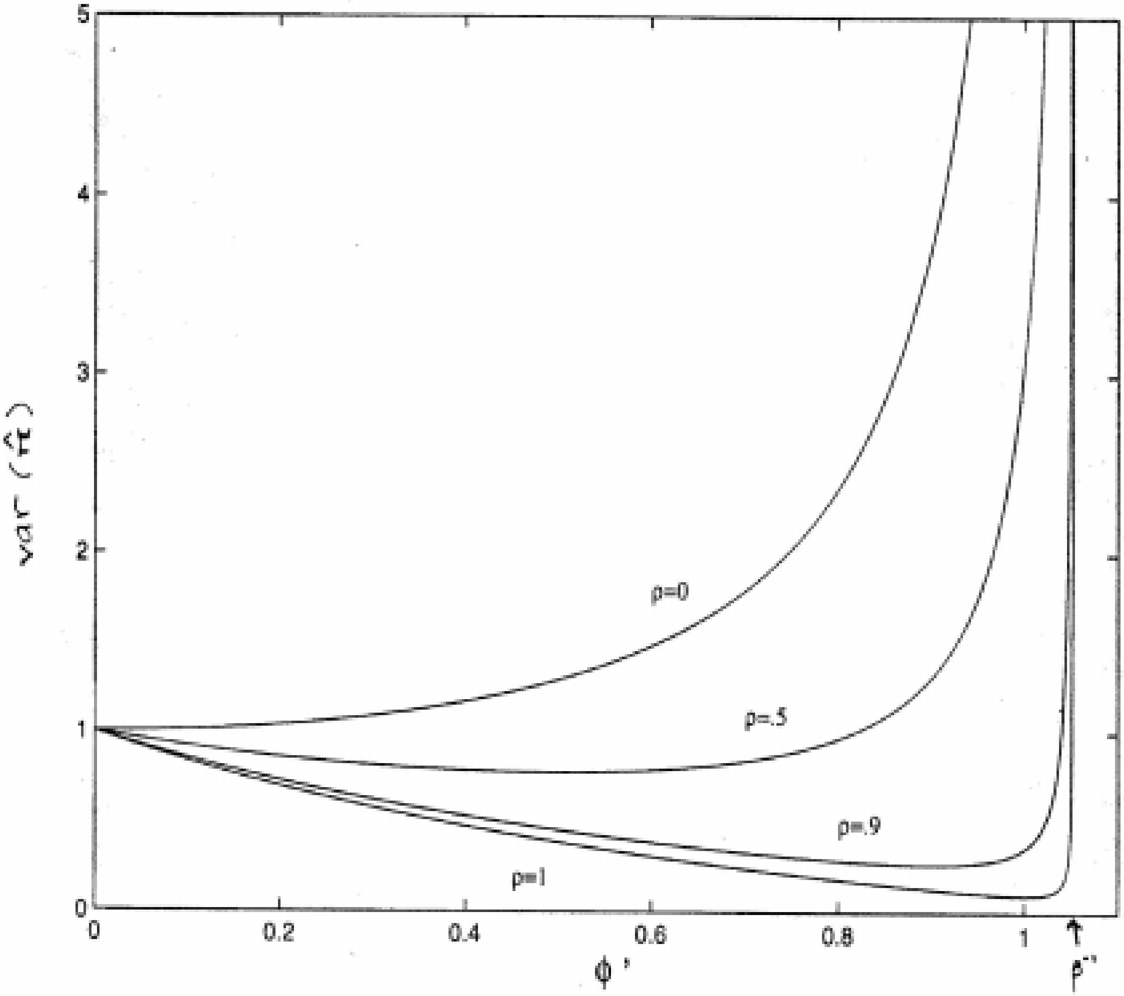


Figure 2.

preference, the maturity structure of the indexed debt has no consequences.) Letting B_t^1 be the quantity of nominal bonds (again a single type with duration parameter ρ) outstanding at the end of t, and b_t^2 the real value of the real debt at the end of period t, condition (2.5) becomes

$$\frac{(1+\rho Q(\pi_t))B_{t-1}^1}{(1+\pi_t)P_{t-1}} + \beta^{-1}b_{t-1}^2 = v_t.$$

The assumed debt composition implies that in equilibrium, $b_t^2 = \alpha\beta E_t v_{t+1}$. With this substitution, we obtain

$$\frac{(1+\rho Q(\pi_t))B_{t-1}^1}{(1+\pi_t)P_{t-1}} = v_t - \alpha E_{t-1}v_t.$$

Here the left-hand side has the same elasticity with respect to variations in $1+\pi_t$ as in the case of (2.5); however, a one percent unexpected decrease in v_t reduces the right-hand side of this equation by $1/(1-\alpha)$ percent. Since (1.24) continues to describe the perfect foresight inflation dynamics in this case, we conclude that the impulse response function of inflation to a fiscal surprise is the same as above, except multiplied each period by the factor $1/(1-\alpha) > 1$. In the case of stochastic fiscal policy, (2.6) continues to hold, except that the expression on the right must be multiplied by $(1-\alpha)^{-2}$.

It follows that partial indexation of the public debt should lead to increased inflation volatility, in the case of a non-Ricardian fiscal policy of this kind. Inflation volatility would be minimized by setting $\alpha = 0$, and having only nominal debt, if α is required to be non-negative. In fact, "anti-indexed" government debt would be even better from this point view, i.e., debt that promises a nominal return that *decreases* if inflation increases. For in this case, even less of an increase in inflation would be required to bring about the reduction in the value of the public debt required to restore equilibrium in the goods market following an expansionary fiscal shock. (Making such an instrument appealing to the investing public would, however, doubtless represent a significant marketing challenge.)

The possibility of a non-Ricardian fiscal policy would thus seem to be of considerable import for the concerns of a central bank. However, there are a number of objections that may be raised to the suggestion that the possibility represented by the above examples should be a practical concern of policymakers. Some may feel that even in theory, fiscal policy could not be of the type assumed in the above example, or that it does not make sense to expect an economy to ever find itself in an equilibrium of the kind described. Some of the leading theoretical objections are taken up in the next two sections. We then turn, in section 5, to the question of whether it would ever be *desirable* for a fiscal authority to behave the manner assumed in the previous example.

3 Mustn't Fiscal Policy Satisfy an Intertemporal Budget Constraint?

Perhaps the most obvious objection to the analysis in the previous section is that the policy regimes discussed do not imply that government policy necessarily satisfies an intertemporal "government budget constraint" of the form (1.14). As we have seen, this "non-Ricardian" aspect of the proposed policy rules explains why Ricardian equivalence fails to hold in those examples, fiscal disturbances affect the price level, and attempts to control inflation with monetary policy alone may instead exacerbate inflation. But, many readers will ask, is not satisfaction of such a "government budget constraint" a *necessary* property of any coherent policy rule?

The argument that it should be is by analogy with the budget constraint for private agents (households or firms). General equilibrium models always assume optimization subject to a set of budget constraints that *imply* an intertemporal budget constraint of the form (1.3), though they may be even more stringent (as it may not even be possible to borrow against all of a household or firm's expected future income). But it is not obvious that government fiscal policy must be modeled as subject to a similar constraint, for the situation of a government is different from that of a private agent in certain important respects.

First of all, if private agents were allowed to borrow (by issuing debt that promises to pay a market rate of return) without any limit related to the amount that their expected future income should make it possible for them to eventually repay, then an equilibrium would be impossible. For (assuming, as usual, that there is no satiation in the utility that may be obtained from further consumption) no plan involving finite amounts of borrowing and consumption at each date will be optimal for such an agent; it would always be preferred to borrow and consume even more, simply rolling over the additional debt forever. And if demands are unbounded at any prices, there cannot be any market-clearing prices. But there is no similar problem with a general equilibrium model in which government policy is assumed to be specified by a rule that does not satisfy a corresponding intertemporal budget constraint. As the example in the previous section shows, one may specify non-Ricardian policy rules that are nonetheless consistent with the existence of a rational expectations equilibrium.

In this example, both monetary and fiscal policies are specified by mechanical rules indicating how the government's state-contingent actions are determined, rather than by optimization subject to a budget constraint. Such specifications are common in economic analyses of government policy, and this is entirely appropriate rather than a lapse in rigor. It is not obvious that most (any?) government policies are actually optimal from the point of view of some coherent social welfare function, and economic analyses of government policies are generally motivated by the supposition that they are not.

Furthermore, even in the case of an optimizing government, the government should *not* optimize subject to given market prices and a given budget constraint, as private agents are assumed to in a competitive equilibrium. For the government is a large agent, whose actions can certainly change equilibrium prices, and an optimizing government surely should take account of this in choosing its actions. Such a government should also understand the advantages of committing itself to a rule (given the way that expected future government policy affects equilibrium), and should consider which rule is most desirable by computing the equilibria that should result under commitment to one sort of policy rule or another. Advice to such a government would then involve computing such equilibria under the assumption of one rule or another, as an input to the government's deliberations about optimal policy. There would be no reason to exclude non-Ricardian regimes from the rules that are considered in such an exercise, in those cases where they are in fact consistent with an equilibrium. (The question whether a non-Ricardian regime would actually be *chosen* by an optimizing government is deferred to section 5.)

In any event, even if one assumes that a government *is* forced to satisfy an intertemporal budget constraint of the form (1.14), as a result of a borrowing limit that is imposed upon it, this does not rule out the existence of equilibria in which the price level is determined by the government budget. Let us consider again the case of a single type of government debt, nominal debt with maturity parameter ρ, where again one unit of debt means a commitment to pay one unit of currency a period later (and ρ^j units of currency j periods later, for each $j \geq 1$), and Q_t is the nominal price of a unit of debt issued in period t. And let us now suppose that the markets will not allow the government to issue such claims in a quantity so great that the real value of outstanding government debt would exceed some debt ceiling $\bar{d}$, representing the country's "debt capacity". That is, in each period the government is constrained to choose a budget deficit such that

$$b_t \equiv \frac{Q_t B_t}{P_t} \leq \bar{d}, \tag{3.1}$$

which as a result of (1.16) implies an upper bound on the government budget deficit. In the cashless limit, and under the assumption of a constant level of government purchases, so that the rate at which real income is discounted depends solely upon the rate of time preference, condition (3.1) suffices to ensure that

$$\limsup_{T \to \infty} E_t\{R_{t,T} W_T\} \leq 0,$$

in the case of any sequences for goods prices and asset prices that are themselves consistent with the equilibrium asset pricing relations (1.18). Thus at least one half of (1.7) is guaranteed.

But such a constraint does not exclude regimes under which fiscalist equilibria of the kind described in section 2 would be possible. Suppose, for example, that the primary government budget surplus evolves exogenously, except when its desired evolution conflicts with constraint (3.1). That is, suppose that the *desired* real primary government budget surplus follows an exogenous stochastic process $\tilde{s}_t$, while the actual surplus is given by the maximum of this and the lower bound imposed by (3.1),

$$s_t = \max\{\tilde{s}_t, w_t - m_t - \bar{d}\}, \tag{3.2}$$

where $w_t \equiv W_t/P_t$ and $m_t \equiv M_t/P_t$. In the cashless limiting economy, this simplifies to

$$s_t = \max\{\tilde{s}_t, w_t - \bar{d}\}. \tag{3.3}$$

Now consider again the equilibrium discussed in section 2 for the case of an exogenous deterministic surplus sequence (and a constant level of government purchases). Let d_t refer to the exogenous sequence

$$d_t \equiv \sum_{j=1}^{\infty} \beta^j \tilde{s}_{t+j}.$$

Then if the surplus sequence $\tilde{s}_t$ is such that the implied sequence d_t satisfies

$$d_t < \bar{d} \tag{3.4}$$

at all dates, the previous equilibrium price and debt sequences satisfy (3.1) at all dates, as a result of (2.2). Thus the previous equilibrium is also consistent with a fiscal policy described by (3.2); in this equilibrium, the debt constraint turns out never to bind.

We may again consider a set of different deterministic sequences $\tilde{s}_t$, each of which satisfies (3.4), and suppose that it is learned only at some date t which of these sequences will be chosen by the government from that date onward. Then there is an equilibrium of the kind described corresponding to each of the fiscal policies that may be announced at date t, and, as explained earlier, the rate of inflation in period t and later will depend in general upon which fiscal policy is announced, even though the monetary policy rule is the same in each case. Thus the presence of the constraint (3.1) does not prevent fiscal disturbances from affecting inflation, or exclude a role for fiscal policy in determining the response of inflation to other shocks.

This result does not contradict the Ricardian equivalence proposition of section 1.2. And the reason is not that the constraint (3.1) is not strong enough to imply a Ricardian fiscal policy.[28] The proposition simply asserts that the inflation sequence associated with one fiscal policy should also be an equilibrium in the case of another fiscal policy. This can be true in the example just discussed, due to the existence of *multiple* perfect foresight equilibria consistent with a given fiscal/monetary policy specification. We showed in section 2 that there was a *unique* perfect foresight equilibrium associated with an exogenous-surplus policy regime, and that in that equilibrium fiscal policy mattered for inflation determination. We have just argued that the same inflation sequence continues to describe a perfect foresight equilibrium in the case of policy rule (3.2), but it need not be the *only* equilibrium consistent with this alternative policy. Indeed, the Ricardian argument indicates that there should be others.

These additional perfect foresight equilibria are considered further in the next section. Here I wish to note, however, that this multiplicity of solutions does not mean that the equilibrium inflation rate derived above is not determinate in the sense of being at least *locally* unique. It is clear from the previous analysis that the solution exhibited is the unique perfect foresight equilibrium with the property that (3.1) holds as a strict inequality at all times; for any equilibrium of this kind would also have to be an equilibrium under the policy where s_t is completely exogenous, and we have shown that there is only one possible equilibrium of that kind. Thus there exists an open interval of possible values for the variable b_t such that there is a unique perfect foresight equilibrium in which the variable always takes a value in that interval. This local uniqueness of the solution suffices to imply that there exists a well-defined response of the locally unique solution to small perturbations (fiscal shocks, endowment shocks, monetary policy shocks, and so on).

[28] We might, for example, add a lower bound in (3.1) as well, in which case the constraint would imply (1.13). However, the argument just given would still apply. There would exist a large set of sequences $\tilde{s}_t$ for which the implied d_t sequence satisfies both bounds at all dates, and for any such sequence, the previous equilibrium would still exist.

3.1 Consequences of Locally Non-Ricardian Fiscal Policy

Whether or not fiscal policy matters for inflation determination in the sense just proposed, i.e., whether or not fiscal policy may play a role in determining a locally unique equilibrium path of this sort, does not turn upon whether fiscal policy is Ricardian in the sense defined in the previous section. Rather, fiscal neutrality is guaranteed only if policy is also *locally* Ricardian, in the sense that adjustments of fiscal policy to keep the public debt from exploding occur not only *eventually* (in extreme regions of the state space), but also locally.

Let us consider a fiscal policy rule of the form

$$s_t = s(b_{t-1}, \ldots; x_t, \ldots), \tag{3.5}$$

where x_t is a vector of state variables consisting, say, of m_t, Q_t, i_t, and π_t,[29] and the dots indicate that several lags of each of the variables may also be arguments of the function. Combining this with (1.16) then implies a law of motion for b_t as a function of its own history and the evolution of the vector of variables x_t. Then we may call the policy rule (3.5) "locally Ricardian", near some reference path for the variables b_t and x_t consistent with both the policy rule and the government's flow budget constraint, if it implies a law of motion for b_t with the property that for any small enough $\epsilon > 0$, there exists a $\delta > 0$ such that, if b_{t-j} has always been (for all $j \geq 1$) within a distance ϵ of the reference path prior to some date t, and the variables x_{t-j} have always been (for all $j \geq 0$) within a distance δ of their reference paths, then b_t will be within the distance ϵ of the reference path once again.[30] Thus b_t will track the reference path sufficiently closely forever, for arbitrary variations in the paths of the x_t variables, as long as those paths are themselves close enough to the reference path.

[29] This particular list of arguments is not crucial to the argument, as should be clear.

[30] This seems to be the intention of Leeper's (1991) notion of "passive" fiscal policy, though he defines the term only for a particular parametric family of policy rules. A related example of a locally Ricardian fiscal policy would be the Canzoneri *et al.* (1998) rule (1.26), in the case that $1 - \beta < \lambda < 1 + \beta$; this rule is locally Ricardian near a steady-state path along which all of the variables b_t and x_t are constant over time. Note that the conditions under which a policy of this form is locally Ricardian are more stringent than those required for it to be Ricardian in the global sense defined earlier, for the rule may prevent the value of the public debt from growing as fast as the real rate of interest, even though it does allow it to grow unboundedly large.

Thus, in at least a local sense, fiscal policy will exclude explosive growth of the public debt, regardless of how goods and asset prices evolve.

Assuming that the reference path satisfies the transversality condition (1.13), as will be true if it represents an equilibrium, any sufficiently nearby path will satisfy that condition as well.[31] Then there exist values of ϵ and δ such that initial conditions for the size of the government debt within ϵ of the reference values, and a path for the variables x_t within δ of the reference path, imply not only that the flow budget constraint (1.16) can be satisfied forever, but that (1.13) and hence (1.14) are satisfied as well. In such a case, a local version of our Ricardian proposition is obtained.

If given sequences $\bar{b}_t$ and $\bar{x}_t$ represent a locally unique perfect foresight equilibrium under policy rule (3.5) – in the sense that there exist $\epsilon, \delta > 0$ such that no other sequences b_t within distance ϵ of $\bar{b}_t$ and x_t within distance δ of $\bar{x}_t$ also represent an equilibrium – and (3.5) is locally Ricardian near the reference paths $\bar{b}_t, \bar{x}_t$, then $\bar{x}_t$ must also be a locally unique solution to the other equilibrium conditions – in the sense that for some small enough $\delta' > 0$, no other sequences x_t within distance δ' of $\bar{x}_t$ also satisfy those equations. For the locally Ricardian property implies that we can choose $0 < \epsilon' \leq \epsilon$ and $0 < \delta' \leq \delta$ such that any x_t within δ' of $\bar{x}_t$ would imply a sequence b_t within ϵ' of $\bar{b}_t$, and thus satisfy condition (1.14). It follows that any such nearby x_t that satisfied conditions (1.9), (1.10), (1.12), (1.18) and (refirul) – a group that we shall call "the non-fiscal equilibrium conditions" – would constitute a nearby perfect foresight equilibrium, contrary to the hypothesis. Thus such a locally unique equilibrium would be determined solely by this last set of conditions, which are independent of fiscal policy. Any sequence of small enough disturbances to the fiscal policy rule (3.5) would continue to imply a locally unique equilibrium near $(\bar{b}_t, \bar{x}_t)$, and in that equilibrium, one would continue to have $x_t = \bar{x}_t$. Thus in at least this local sense, fiscal policy would be irrelevant to the determination of goods and asset prices.

On the other hand, in the case of a locally non-Ricardian policy (i.e., a policy that fails

[31] Here we assume that "distance" is measured in such a way that a bound on the distance of the various variables from their reference values implies a uniform bound on the percentage deviation in the values of both $\lambda(m_t)$ and w_t from their reference values.

to be locally Ricardian, near the reference path under consideration), there may be a locally unique equilibrium even though the path $\bar{x}_t$ is not a locally unique solution to the non-fiscal equilibrium conditions alone. And when one perturbs fiscal policy, there may continue to be a locally unique equilibrium (b_t, x_t) near the unperturbed equilibrium $(\bar{b}_t, \bar{x}_t)$, but which of the large number of nearby solutions x_t to the non-fiscal equilibrium conditions is selected will depend upon the perturbation of fiscal policy. In such a case, there exists a well-defined solution to the "comparative statics" exercise of a change in fiscal policy, in which fiscal policy affects the determination of inflation and asset prices. Similarly, the locally unique equilibrium response to perturbations of other sorts (changes in monetary policy, or changes in the expected endowment path) will depend in general upon the details of the locally-Ricardian fiscal policy rule. For the non-fiscal equilibrium conditions do not suffice to determine it, while the requirements that b_t be consistent with (1.16) and (3.5), and that the path b_t remain forever near the reference path $\bar{b}_t$, add additional restrictions upon the equilibrium path x_t.

This possibility may be illustrated in the case of the policy rule (3.2), which is an example of a rule of the form (3.5). Let us suppose that $\tilde{s}_t = s$, a positive constant, at all dates, that government purchases are also constant, and that

$$\bar{d} > \beta s/(1-\beta). \tag{3.6}$$

Finally, suppose that monetary policy is described by a rule of the form (1.21) where $\phi(0) = \beta^{-1} - 1$ and $0 \leq \phi'(0) < 1$; this is a "passive" monetary policy in Leeper's (1991) sense, consistent with a steady-state inflation rate of zero.

For simplicity, we report our calculations only for the cashless limiting economy. In the case of an initial condition

$$\frac{B_{-1}}{P_{-1}} = \frac{1-\beta\rho}{1-\beta} s,$$

there is a perfect foresight equilibrium in which $\pi_t = 0, i_t = \beta^{-1} - 1, Q_t = \beta/(1-\beta\rho)$, and $b_t = \beta s/(1-\beta)$ at all dates. Note that in this equilibrium, $b_t < \bar{d}$ at all dates. The equilibrium is also locally unique, for we have shown earlier that equilibrium is unique in the case of an exogenous government surplus, and it follows that under policy rule (3.2), this must be the unique equilibrium in which $b_t < \bar{d}$ at all dates.

On the other hand, these paths for π_t, i_t, and Q_t do not represent a locally unique solution to the non-fiscal equilibrium conditions. Those conditions will be satisfied by any inflation sequence π_t that satisfies (1.24); given a solution to this equation, the implied i_t sequence is given by the monetary policy rule, and the implied Q_t sequence by (1.19). But (1.24) is a difference equation of the form $\pi_{t+1} = f(\pi_t)$, where $f(0) = 0, 0 \leq f'(0) < 1$. These properties of the function f imply that for any small enough $\delta > 0$, $|\pi| < \delta$ guarantees that $|f(\pi)| < \delta$ as well. Then there exists a sequence π_t satisfying (1.24) at all dates corresponding to each value of π_1 such that $|\pi_1| < \delta$, and each such sequence has the property that the distance of π_t from the reference value (zero) is less than δ at each date. Thus no matter how small a value of δ we choose, there is necessarily a continuum of solutions to (1.24) in which π_t is always within a distance δ of the reference path. The functions defining the sequences i_t and Q_t given the π_t sequence are continuous at the reference sequence, and as a result, by choosing δ small enough, it can be ensured that each solution also implies sequences i_t and Q_t within any desired distance of their reference values as well. Thus there exists a continuum of solutions for π_t, i_t, and Q_t within any desired distance of the reference sequences.

Equilibrium is locally unique, despite this, because the fiscal policy rule (3.2) is locally non-Ricardian. The implied law of motion for b_t is given by

$$b_t = \min\{b_{t-1}\frac{1+\rho Q_t}{Q_{t-1}}\frac{1}{1+\pi_t} - s, \bar{d}\}. \tag{3.7}$$

For values of the state variables near enough to their reference values, the first term in the brackets always applies. It follows that near the reference paths, a log-linear approximation to (3.7) is given by

$$\hat{b}_t = \beta^{-1}[\hat{b}_{t-1} + \beta\rho\hat{Q}_t - \hat{Q}_{t-1} - \hat{\pi}_t],$$

where $\hat{b}_t, \hat{Q}_t$ and $\hat{\pi}_t$ denote the deviations of $\log b_t, \log Q_t$ and $\log(1+\pi_t)$ from their reference values. Because the coefficient on the $\hat{b}_{t-1}$ term is $\beta^{-1} > 1$, the dynamics of $\hat{b}_t$ implied by this equation are unstable; for almost all initial values $\hat{b}_0$ and sequences $\hat{Q}_t$ and $\hat{\pi}_t$, $\hat{b}_t$

eventually grows explosively, and in particular, eventually leaves any bounded interval. The same is true of the exact, nonlinear difference equation (3.7), at least in the case of any small enough bounds on the size of the deviations: even if the initial condition is restricted to satisfy $|\hat{b}_0| < \epsilon$, and the sequences $\hat{Q}_t$ and $\hat{\pi}_t$ are restricted to remain always smaller in size than δ, almost all choices will imply that $|\hat{b}_t| > \epsilon$ eventually. This is why the additional requirements that the sequences satisfy (3.7), and that b_t remain near the reference value forever, add additional restrictions upon the sequences Q_t and π_t, that suffice to determine a locally unique equilibrium.

We would like to stress that this result depends upon fiscal policy being *locally* non-Ricardian. This does not, however, exclude a policy being *globally* Ricardian. And in particular, it does not exclude the existence of a constraint upon how large a government's real debt may become, before it is forced to modify its fiscal policy by a simple inability to issue more debt, as the above example shows.

4 Do Fiscalist Analyses Depend upon an Implausible Equilibrium Selection?

The preceding discussion assumes the interest of observing how a locally unique perfect foresight equilibrium may be affected by the specification of fiscal policy. But we have not asserted that the equilibrium being characterized is unique, and some might suspect that the analysis relies upon a perverse choice of which equilibrium should be regarded as a relevant prediction, in the case of a model that allows many. Perhaps there is only one equilibrium that ought really to be expected ever to occur in such an economy, and it is generally not the locally unique one considered above. Indeed, McCallum (1997) argues that in models similar to the one considered above, there is also a "traditional" or "monetarist" equilibrium, in which fiscal policy is irrelevant. He furthermore suggests that this alternative solution "is arguably the more plausible since it represents the model's fundamentals or bubble-free solution, whereas the fiscalist price level solution involves a bubble component."

To assess this argument, we begin by considering the complete set of equilibria under the policy regime just considered. McCallum argues that the equilibrium described in section 2 is not the unique equilibrium, in the case of a policy that seeks to maintain an exogenous path for the real primary government surplus, because the government can be forced to increase its budget surplus if the private sector refuses to buy more than a certain quantity of its debt. We may accept, for the sake of the argument, that this is correct; we accordingly specify fiscal policy by a rule of the form (3.2), instead of an exogenous path for s_t. We have shown above that when the bound $\bar{d}$ is large enough relative to the target surplus level s, the equilibrium previously considered continues to be possible. But there are other possible equilibria as well, in which the debt limit eventually binds, and forces the government to run surpluses larger than the target level s.

4.1 The Multiplicity of Equilibria in the Case of a Debt Limit

The analysis is simplest if we again assume a cashless limiting economy and a constant level of government purchases, and work in terms of the state variable w_t, the real value of private sector claims on the government (which, in this model, equals private financial wealth) at the beginning of period t. Using the fact that in a perfect foresight equilibrium, all financial assets (and in particular, all government liabilities) must earn the nominal return i_t determined by monetary policy, the flow government budget constraint (1.16) may be written

$$w_t = s_t + \beta w_{t+1}. \tag{4.1}$$

Substituting the fiscal policy rule (3.2), this implies

$$w_{t+1} = \beta^{-1} \min\{w_t - s, \bar{d}\}. \tag{4.2}$$

In the case of perfect foresight, the transversality condition (1.13) becomes simply

$$\lim_{t \to \infty} \beta^t w_t = 0. \tag{4.3}$$

Thus any perfect foresight equilibrium must involve a sequence w_t that satisfies both (4.2) and (4.3). There is no initial condition w_0 for the difference equation (4.2); instead, the value of w_t may "jump" in response to new information at date t, that affects the price of goods and/or government bonds. However, the initial value w_0 must imply a sequence that satisfies the terminal condition (4.2). In the case that $\bar{d} = \infty$ (i.e., there is no debt limit), the terminal condition uniquely determines the sequence; the only solution is $w_t = w^* \equiv s/(1-\beta)$ for all t, corresponding to the unique equilibrium discussed earlier. On the other hand, when $\bar{d}$ is finite, but satisfies (3.6), this ceases to be true. In particular, there is another possible stationary solution, $w_t = w^{**} \equiv \bar{d}/\beta > w^*$ for all t. There is also a non-stationary solution corresponding to each value of w_0 in the interval $w^* < w_0 < w^{**}$. These solutions involve a monotonically increasing series w_t, up until some finite date T, after which $w_t = w^{**}$. (See Figure 3.)[32]

As before, the monetary policy rule (1.21) implies that inflation dynamics must satisfy (1.24) in any perfect foresight equilibrium, and there is no initial condition π_0 for this difference equation, either, as π_t may "jump" in response to new information at date t. Again these inflation dynamics allow us to derive a function $Q(\pi)$ such that one must have $Q_t = Q(\pi_t)$ at all times in any perfect foresight equilibrium. Finally, the equilibrium values of π_t and w_t must be linked through the relation

$$\frac{B_{t-1}}{P_{t-1}} \frac{1 + \rho Q(\pi_t)}{1 + \pi_t} = w_t. \qquad (4.4)$$

In the initial period, B_{-1}/P_{-1} is given as an initial condition, so that the relation (4.4) links the equilibrium values of π_0 and w_0 to one another. In subsequent periods, the paths of π_t and w_t implied by (1.24) and (4.2) respectively are always consistent with (4.4), because this latter condition determines the equilibrium value of B_t/P_t each period, given the expected values of π_{t+1} and w_{t+1}. Thus there exists a perfect foresight equilibrium corresponding to each pair of values (π_1, w_1) satisfying (4.4) in the initial period, and such that the sequences (π_t, w_t) implied by these initial values, iterating the difference equations (1.24) and (4.2), do not violate (4.3).

[32] Solutions to (4.2) with $w_0 < w^*$ still violate the transversality condition (4.3). If, however, we assume that there is also a lower bound on the value of government debt, at which the government is expected to adjust its budget surplus to avoid becoming too large a creditor, then there would also be a continuum of solutions of this kind, consistent with (4.3).

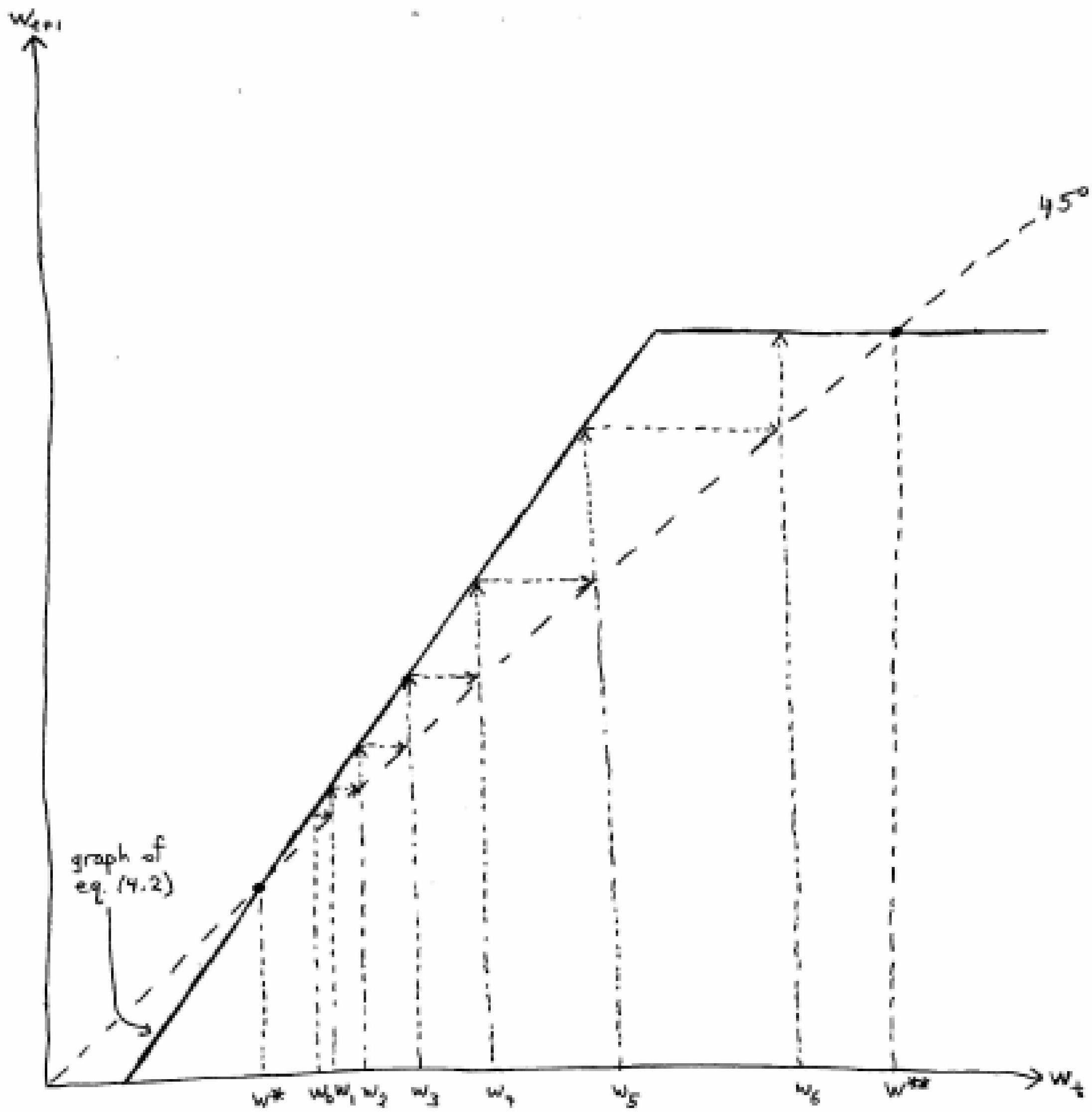


Figure 3.

We have already discussed the continuum of values of w_0 consistent with (4.3). We next observe that each of these is associated with a unique π_0 that satisfies (4.4), given an initial condition $B_{-1}/P_{-1} > 0$. For again the factor $1+\rho Q(\pi)/(1+\pi)$ is a monotonically decreasing function of π, that varies from arbitrarily large positive values to arbitrarily small positive values. Thus each of the continuum of solutions to (4.2) discussed above represents a perfect foresight equilibrium.

McCallum's "traditional" or "monetarist" equilibrium is the one in which $\pi_t = \pi^*$ for all t, where π^* is a steady inflation rate consistent with (1.24), i.e., a solution to (1.23). Let us suppose that there is a unique such solution for which $\pi^* > \beta - 1$ (so that the nominal interest rate is positive); this is then the solution that corresponds, under the present regime, to the one chosen by McCallum.[33] There will exist such an equilibrium, under the policy regime described by equations (1.21) and (3.2), as long as the initial condition satisfies

$$\frac{B_{-1}}{P_{-1}} \geq \left(\frac{1+\pi^* - \beta\rho}{1-\beta}\right) s,$$

so that the value of w_0 implied by $\pi_0 = \pi^*$ satisfies $w_0 \geq w^*$.[34]

Furthermore, there continues to exist such an equilibrium if we perturb the specification of fiscal policy (within limits). If we consider a different, possibly non-constant, sequence $\tilde{s}_t$, all of the equilibrium conditions just stated are unchanged, except the difference equation (4.2), in which the constant s must be replaced by $\tilde{s}_t$. Let us suppose that $0 \leq \tilde{s}_t \leq (1-\beta)\bar{d}/\beta$ at all times, and that $\tilde{s}_t > 0$ infinitely often. Then one can show that the solution to the

[33] McCallum's example involves a constant money supply, which amounts – under the assumption of a constant equilibrium output and a time-invariant money demand function – to an interest-rate rule that makes i_t an increasing function of the price level, rather than of the inflation rate. Under such a rule, the equilibrium condition corresponding to (1.24) is a difference equation for the price level, rather than the inflation rate. McCallum's preferred equilibrium in that example is the one in which the price level equals at all times the unique steady price level consistent with that difference equation. One may alternatively write the law of motion as a difference equation for the inflation rate, in which case $\pi^* = 0$ is a steady inflation rate consistent with the difference equation. There will often be another steady inflation rate also consistent with this difference equation, namely $\beta - 1$. Here $\pi^* = 0$, inflation at the rate of growth of the money supply, is McCallum's "monetarist" equilibrium.

[34] If one assumes that the government will also depart from the specified exogenous path for its budget surplus in the event that the value of net government debt reaches a *lower* bound, then the transversality condition will be satisfied even if $w_0 < w^*$. In that case, McCallum's "traditional" equilibrium always exists, for any $B_{-1}/P_{-1} > 0$.

modified difference equation satisfies (4.3) in the case of any initial value

$$w_0 \geq \sum_{t=0}^{\infty} \beta^t \tilde{s}_t.$$

(If w_0 exactly equals this lower bound, the debt limit never binds, and the solution is the unique solution in the absence of a debt limit. If w_0 takes any higher value, the debt limit eventually binds forever. If w_0 takes any lower value, the debt limit never binds, and the transversality condition is violated, as it would be in the absence of a debt limit.) Now $\pi_t = \pi^*$ for all t is a solution to (1.24) regardless of the sequence of desired budget surpluses. This corresponds to a solution w_0 to equation (4.4) that satisfies the necessary lower bound if and only if the initial condition satisfies

$$\frac{B_{-1}}{P_{-1}} \geq (1 + \pi^* - \beta\rho) \sum_{t=0}^{\infty} \beta^t \tilde{s}_t.$$

Thus such an equilibrium continues to exist for a wide range of possible fiscal disturbances, and if we expect this equilibrium to occur, we observe that the equilibrium path of inflation is independent of the fiscal disturbances.

But does this particular equilibrium really deserve to be singled out as the one determined by "fundamentals", while all other equilibria represent "bubble" phenomena? There is no obvious reason to think this. McCallum's argument seems to be the following. Equilibrium inflation should be determined by the difference equation (1.24). This has a continuum of solutions, corresponding to different possible choices of π_0. (Recall Figure 1, which depicts the case in which $\phi'(\pi^*) > \beta^{-1}$, or "active" monetary policy in Leeper's sense.) The solution in which inflation is determined solely by "fundamentals" (meaning monetary policy) is the one in which π_t is constant forever, just as the monetary policy rule is (and the determinants of money demand, such as equilibrium output, are). The other solutions involve "arbitrary though self-justifying bubble or bootstrap components," because inflation depends upon time while the form of the difference equation (1.24) does not. Values of π_t different from π^* are sustained as equilibrium phenomena only by the expectation that π_{t+1} will differ from π^* as well, and so on into the indefinite future; and such a belief, while consistent with the model, seems arbitrary.

But the appeal to symmetry (or a "minimum state variable" principle) provides no basis for preferring this particular equilibrium, once one considers the complete set of equilibrium conditions. In particular, equation (4.2) is a difference equation to solve for the path of w_t; this, too, is a non-predetermined state variable the value of which, under the kind of fiscal policy assumed here, depends upon what its value is expected to be in the future. By exactly the same sort of appeal to a "minimum state variable" principle, one might argue that the "fundamental" solution to (4.2) is the one in which $w_t = w^*$ at all dates; solutions also exist with $w_t > w^*$, but this is sustained only by the expectation that the real value of the public debt will exceed w^* by an even greater amount in the future.

In fact, the case for calling solutions with $w_t > w^*$ "bubble solutions" is clearer here than in the case of solutions to equation (1.24). For equation (4.1) is in fact an equilibrium condition that states that w_t is related to s_t in the same way as the price of a speculative asset is related to the the dividend received on it, when future returns are discounted using a constant discount factor β, and the solution in which $w_t = w^*$ for all t corresponds to the "fundamental" solution in the case of a constant surplus s. In the non-stationary solutions that nonetheless satisfy (4.3), w_t also equals the present value of future surpluses. However, that higher present value can be anticipated only because the debt limit will eventually bind, and the debt limit will eventually bind only because the value of the public is expected to follow the explosive path. Thus there is a clear justification for calling such an explosion of the value of the public debt a "bubble" that is due purely to self-fulfilling expectations. The "fundamental" equilibrium selected on grounds of this sort would be exactly the one discussed in section 1.3, where the debt limit never binds, and inflation depends upon the expected path of government budget surpluses.

Of course, the problem with this sort of formal criterion for equilibrium selection is that in general one cannot demand *both* that $\pi_t = \pi^*$ and that $w_t = w^*$, for the π_t sequence uniquely determines a w_t sequence, and vice versa, and only under very special circumstances will the two criteria be mutually consistent. Thus it is not possible, on such grounds alone, to determine which equilibrium ought to be realized in the case of a policy regime described by equations (1.21) and (3.2). This means, however, that there is no reason for confidence that the monetary policy commitment *alone* suffices to guarantee the desired inflation path; it seems appropriate to worry, in the case of a fiscal regime described by (3.2), that the private sector might instead settle upon expectations of the sort that bring about the equilibrium in which $w_t = w^*$.

4.2 The Effects of Fiscal Policy under Adaptive Expectations

Theoretical analysis of whether, or under what conditions, this is likely to occur would involve modelling the process by which private sector expectations are formed. Thus one might conclude that one equilibrium involves beliefs that are more likely to be *learned* on the basis of experience. For example, an important argument against many familiar examples of "bubble" equilibria is that they require people to expect a future path for the economy that diverges farther and farther from its current state or any state it has been in in the past, and that it is hard to see why people would come to hold unusual expectations of that kind on the basis of what they have already observed. However, the sort of expectations required for fiscal determination of the price level are not implausible on such grounds. One can easily exhibit simple models of adaptive behavior which result in inflation dynamics of the kind represented by the fiscalist equilibria presented above.

Consider the case of consumers who behave as in a version of Friedman's "permanent income hypothesis", where income expectations are based upon a simple "adaptive expectations" formula. Let us suppose that endowments each period are given by an exogenous sequence y_t, and that the government levies a real tax obligation each period in the amount s_t, used solely to pay interest on (or retire) the government debt; for simplicity, we let government purchases of goods be zero each period. (Thus s_t is also the real primary budget surplus.) Consumers begin each period with nominal claims on the government W_t, and determine how much to consume and save after observing the current period price level P_t.

A simple hypothesis is that consumers seek to consume at the level that they expect to be able to maintain forever, given by

$$c_t = (1-\beta)\frac{W_t}{P_t} + y_t^e, \tag{4.5}$$

where β is the reciprocal of the expected gross real rate of return on financial wealth, and y_t^e represents consumers' estimate of their "permanent" level of after-tax endowment income $y-s$. At least under certain special circumstances, this would represent optimal behavior, if the belief represented by y_t^e were correct. Rather more generally, this rule-of-thumb behavior has the property that if the economy settles eventually into a long-run steady state in which y_t, s_t and w_t are all constant, and y_t^e converges eventually to the true (constant) value of $y-s$, the consumption demand described by (4.5) will be asymptotically optimal.[35]

Let us also suppose that consumers form their expectations regarding their "permanent income" using a simple "adaptive expectations" rule of the form

$$y_{t+1}^e = \lambda y_t^e + (1-\lambda)(y_t - s_t), \tag{4.6}$$

where y_0^e is given as an initial condition, and $0 \leq \lambda < 1$ measures the degree of inertia in expectations. Note that this familiar forecasting rule has the property that if y_t and s_t eventually settle down to constant values y and s, beliefs y_t^e will eventually converge to the true value $y-s$. Hence a *steady state* (described by constant values $c, y, s,$ and w) consistent with behavioral rules (4.5) and (4.6) will also be a steady state consistent with intertemporal optimization and perfect foresight, and vice versa.

Now let us suppose again that monetary policy is described by a rule of the form (1.21) and fiscal policy by a rule of the form (3.2), and consider the *temporary equilibrium* dynamics resulting from consumer behavior described by (4.5) and (4.6). Market clearing each period requires that $c_t = y_t$, so that

$$\frac{W_t}{P_t} = \frac{y_t - y_t^e}{1-\beta}. \tag{4.7}$$

This condition indicates that goods and asset prices must adjust each period so as to bring the real value of outstanding government debt into line with expectations regarding future

[35] This last proposition assumes that β is also consumers' discount factor.

budget surpluses; it is essentially an adaptive-expectations variant of the condition (1.14) that was required for a rational expectations equilibrium. Substituting this into (3.2), the government surplus each period will be given by

$$s_t = \max\left\{\tilde{s}_t, \frac{y_t - y_t^e}{1-\beta} - \bar{d}\right\}.$$

Substituting this in turn into (4.6), we obtain

$$y_{t+1}^e = \lambda y_t^e + (1-\lambda)\min\left\{y_t - \tilde{s}_t, \frac{y_t^e - \beta y_t}{1-\beta} + \bar{d}\right\}, \qquad (4.8)$$

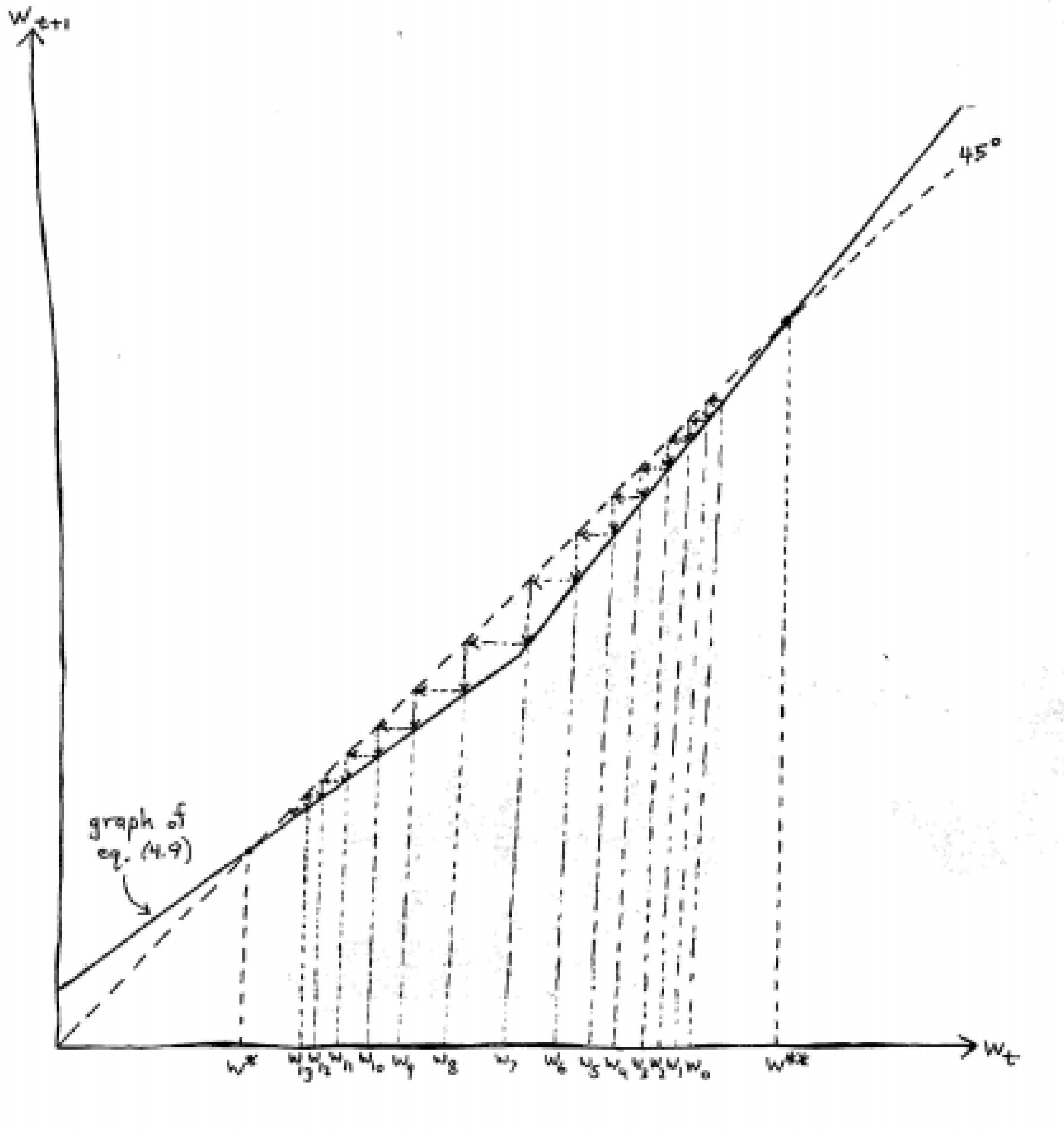
as a law of motion for expectations y_t^e, given the exogenous series y_t and $\tilde{s}_t$.

In order to understand the consequences of (4.8), it is useful to rewrite the equation in terms of the implied dynamics of w_t, which we may do given the linear relation between the two variables given by (4.7). In the case that both y_t and $\tilde{s}_t$ are constant at some values y, s for all dates $t \geq T$, (4.8) implies that

$$w_{t+1} = \lambda w_t + \frac{1-\lambda}{1-\beta}\max\{s, w_t - \bar{d}\} \qquad (4.9)$$

for all $t \geq T$. This difference equation allows us to solve for the complete temporary equilibrium dynamics of w_t, given an initial condition w_T, which is determined through (4.7) by the initial expectations y_T^e, a predetermined state variable. The dynamics for w_t implied by (4.9), graphed in Figure 4, may usefully be compared to the perfect foresight equilibrium dynamics defined by (4.2) and graphed in Figure 3. One observes, under assumption (3.6), that there are two steady-state values consistent with the difference equation, $w^* \equiv s/(1-\beta)$ and $w^{**} \equiv \bar{d}/\beta$, exactly as in the case of the perfect foresight analysis.

However, it is no longer possible for the system to "jump" to either of these steady states, depending upon the arbitrary expectations of households. Instead, initial expectations are given as a predetermined state variable, and a unique path for w_t is implied by (4.7) given this initial condition. As the figure makes clear, one steady state, w^*, is *stable* under the temporary equilibrium dynamics, in the sense that any initial condition $w_0 < w^{**}$ results in a path along which w_t converges asymptotically to the value w^*. (An example of a non-stationary trajectory of this kind is shown in Figure 4, starting from an initial condition



w_{t+1}
w_t
45°
graph of eq. (4.9)
w^*
w_{13} w_{12} w_{11} w_{10} w_9 w_8 w_7 w_6 w_5 w_4 w_3 w_2 w_1 w_0
w^{**}

Figure 4.

$w^* < w_0 < w^{**}$.) The steady state w^{**} is instead *unstable*, in the sense that w_t will remain near w^{**} in the long run only if the initial condition is $w_0 = w^{**}$ exactly. (And even supposing such an initial condition, the economy will remain near this steady state asymptotically only if there are never any disturbances to fiscal policy, endowments, or the rules describing consumer behavior, to perturb the value of the public debt even infinitesimally from the value consistent with the unstable steady state.) It is interesting to note that these results reverse the stability properties of the two steady states under the perfect foresight dynamics shown in Figure 3. It is the steady state (w^*) with the property that perfect foresight trajectories beginning near it diverge from it that is *stable* under the temporary equilibrium dynamics, and the steady state (w^{**}) with the property that a continuum of nearby perfect foresight trajectories converge to it that is *unstable*.[36]

Thus we conclude from the temporary equilibrium analysis that the real value of government debt w_t should evolve along a trajectory that is determined independently of monetary policy, and that in the event that the desired surplus $\tilde{s}_t$ is constant, w_t should eventually be constant at the value w^*, equal to the present value of the desired surpluses. Thus the exogenous path of desired surpluses determines the real value of the government debt, rather than the accumulated debt determining the level of government surpluses. Prices must follow a path that keeps the real value of the government debt on this trajectory.

The temporary equilibrium dynamics of the price level are most easily solved for in the case of only one-period nominal government debt. In this case, $W_t = B_{t-1}$ is a predetermined state variable; this together with the predetermined value of w_t then determines the equilibrium value of P_t. The nominal value of government debt, in turn, evolves according to

$$W_{t+1} = (1 + i_t)[W_t - P_t s_t] = (1 + i_t)P_t \min\{w_t - \tilde{s}_t, \bar{d}\}, \tag{4.10}$$

as a result of which

$$P_{t+1} = (1 + i_t)P_t w_{t+1}^{-1} \min\{w_t - \tilde{s}_t, \bar{d}\}.$$

[36] This sort of "stability reversal" when one compares temporary equilibrium dynamics with perfect foresight dynamics often occurs; see, e.g., Grandmont (1985), or Marcet and Sargent (1989).

Then substituting (1.21) and (4.9) into this, we obtain

$$\pi_{t+1} = (1 + \phi(\pi_t))G(w_t) - 1, \tag{4.11}$$

where

$$G(w) \equiv \frac{(1-\beta)\min\{w - s, \bar{d}\}}{\lambda(1-\beta)w + (1-\lambda)\max\{s, (w-\bar{d})\}}.$$

Given the path of w_t, this difference equation determines the evolution of π_t, starting from an initial value given by $1 + \pi_T = W_T/P_{T-1}w_T$. (Note that W_T and P_{T-1} are predetermined variables, and that w_T is given by (4.4) as a function of the predetermined variable y_T^e.)

Once w_t converges to the value w^* (or if we start from an initial condition equal to that value), the factor $G(w_t)$ takes the value $G(w^*) = \beta$ each period, and the inflation dynamics are given by an equation that is identical to (1.24), the difference equation that defines perfect foresight inflation dynamics. However, in the case of the temporary equilibrium dynamics, it is clear that we cannot "solve the equation forward," or demand, as McCallum proposes, that the solution be $\pi_t = \pi^*$ for all t, regardless of the size of the public debt or expectations regarding fiscal policy. Instead, we must iterate the equation forward from an initial condition that depends upon fiscal variables and that will in general not allow the trajectory $\pi_t = \pi^*$. This uniquely determined temporary equilibrium path corresponds to one of the continuum of possible perfect foresight equilibria identified above, namely, the locally unique equilibrium in which $w_t = w^*$ for all t.

The above analysis assumes that all government debt is short-term. But similar conclusions are obtained in the case of longer-duration government debt; it simply becomes necessary to add to the temporary equilibrium model a specification of how government debt is priced. In the case considered above, of government debt with a duration parameter ρ, nominal government liabilities evolve according to

$$W_{t+1} = \frac{1 + \rho Q_{t+1}}{Q_t}[W_t - p_t s_t]. \tag{4.12}$$

The question is how the price of government debt, Q_t, evolves when the short-term nominal interest rate is set by (1.21). An attractive assumption is to suppose that government debt is priced in a way that implies that there will be no arbitrage opportunities that could be exploited by a trader who understood the temporary equilibrium dynamics. This means that Q_t must be given by (1.19) at all times, where the right-hand side is evaluated on the basis of *perfect foresight* about the deterministic evolution of the short-term nominal interest rate i_t.[37]

In this case,

$$\frac{1+\rho Q_{t+1}}{Q_t} = 1 + i_t$$

at all times, and (4.12) implies (4.10), regardless of the value of ρ. We thus obtain (4.11) for the temporary equilibrium dynamics of the inflation rate. The only difference is that when $\rho > 0$, W_t is no longer a predetermined state variable. Thus W_T/P_{T-1} is not given as an initial condition, though B_{T-1}/P_{T-1} is. The initial inflation rate π_T must then satisfy

$$\frac{B_{T-1}}{P_{T-1}} \frac{1+\rho Q_T}{1+\pi_T} = w_T = \frac{y - y_T^e}{1-\beta}.$$

Initial values (π_T, w_T) imply complete sequences (π_t, w_t) using the laws of motion (4.2) and (4.11), and thus a unique value for Q_T using (1.19) and (1.21). Let this solution be described by a function $\tilde{Q}(\pi_T, w_T)$. Then the initial inflation rate is given by the solution to

$$\frac{B_{T-1}}{P_{T-1}} \frac{1+\rho \tilde{Q}(\pi_T, w_T)}{1+\pi_T} = w_T,$$

where w_T is again determined by initial expectations y_T^e. Note that $\tilde{Q}(\pi, w^*) = Q(\pi)$, the function defined earlier for the case of a perfect foresight equilibrium. Thus as long as the initial condition w_T is close to w^*, the initial temporary equilibrium inflation rate π_T will be close to the value associated with the locally unique perfect foresight equilibrium in which $w_t = w^*$ forever, and the entire temporary equilibrium path for inflation will be close to the path associated with that particular perfect foresight equilibrium.

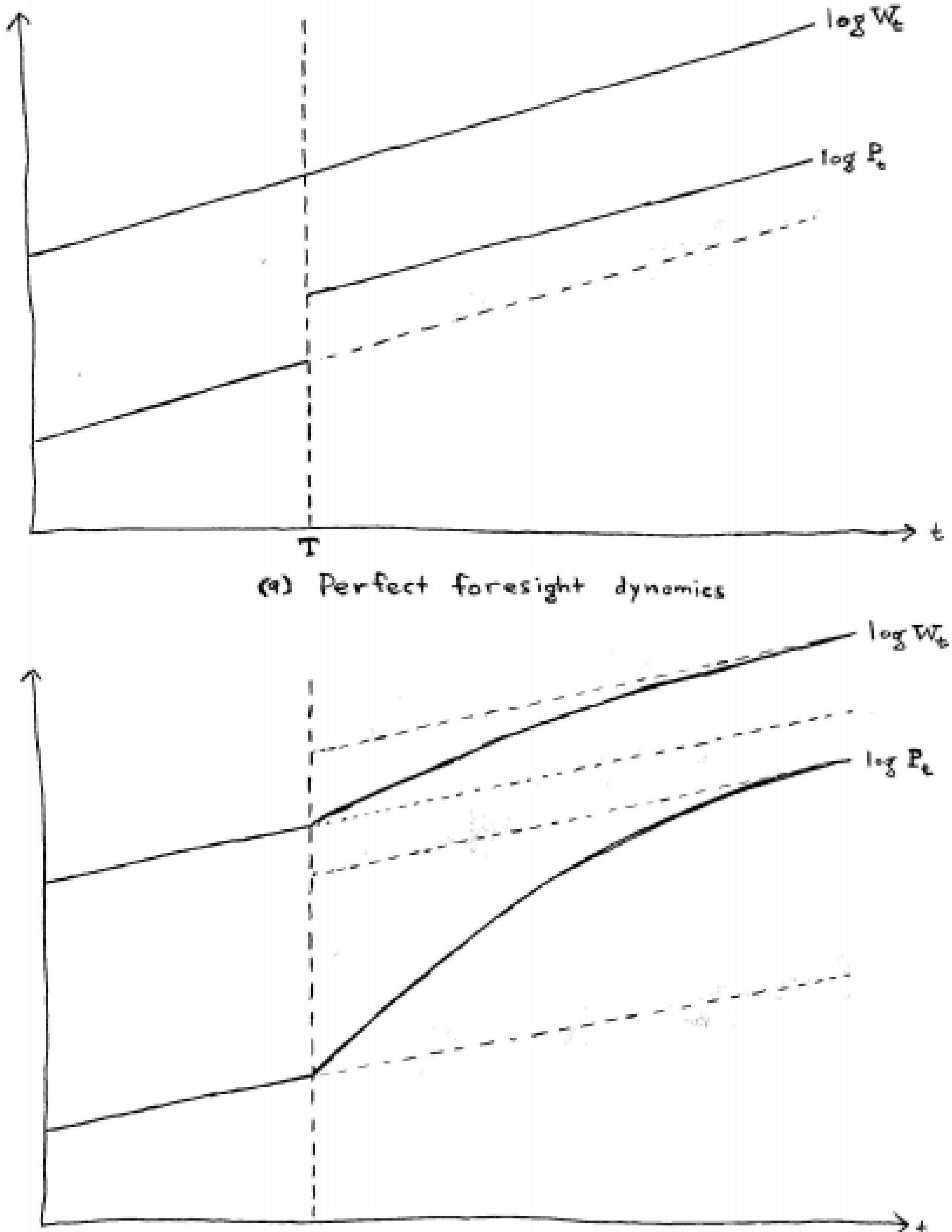
[37]The assumption of perfect foresight on the part of speculators who eliminate arbitrage opportunities in the bond market, while assuming adaptive expectations on the part of consumers, involves no contradiction. There is no way that the speculators can earn arbitrage profits from the simple fact that consumers choose a consumption path that does not maximize their discounted utility stream. Nor is there a contradiction in our previous neglect of the consumption demand of the speculators. Because the temporary equilibrium dynamics are deterministic, any failure of (1.19) to hold would imply a pure arbitrage opportunity, so that speculators could afford to exploit it through arbitrarily large trades even if their capital – and hence the consumption they can afford in equilibrium – is negligible.

The overall picture of inflation determination that one obtains from this temporary equilibrium analysis is quite similar to the one given by the fiscalist analysis in section 2. Assuming an initial condition $w_T = w^*$ (which is the value to which the economy should have converged, if $y - s$ has been stable for a sufficient period of time), the response to a one-time, permanent change in the monetary policy rule ϕ is exactly the same under the temporary equilibrium analysis as it would be under the perfect foresight analysis, selecting in the latter case the locally unique equilibrium with $w_t = w^*$ forever. Thus, for example, the analysis predicts that shifting from a rule in which $\phi'(\pi^*) < \beta^{-1}$ to one in which $\phi'(\pi^*) > \beta^{-1}$ should result in explosive divergence of inflation from the steady-state level π^*, as in Loyo's (1997b) analysis, and not (as McCallum would presumably argue) in an equilibrium with $\pi_t = \pi^*$ and an explosion of the real value of the public debt, until the debt limit is reached that would trigger an increase in the government budget surplus.

In the case of a fiscal disturbance, instead, the short-run effects are different, as a result of the lack of perfect foresight on the part of consumers. Consider, for example, the effects of a permanent reduction of the size of the desired government surplus from s to s', where $0 < s' < s$, beginning in period T. For simplicity, suppose that monetary policy is described by a pure interest-rate peg, $\phi(\pi) = \beta^{-1}(1 + \pi^*) - 1$. Under perfect foresight (and assuming that the change in fiscal policy is a surprise at date T), the economy jumps immediately to the new steady state associated with the lower surplus; as shown in panel (a) of Figure 5, the price level jumps immediately in order to allow w_t to fall to the lower level $s'/(1 - \beta)$. There is no change in the path of nominal government liabilities W_t, and inflation continues at the constant rate π^* after the one-time jump in the price level at the time of the announcement of the policy change.[38]

Under adaptive expectations, instead, there is no immediate change in expectations y^e_T, as a result of which there is no jump in the temporary equilibrium price level. However, as shown in panel (b) of the figure, the reduced budget surplus implies faster growth of

[38]In the continuous-time limit of this model, the price level is continuous at T, as shown in the figure, whereas it is discontinuous at T under perfect foresight.



(a) Perfect foresight dynamics

(b) Temporary equilibrium dynamics

Figure 5.

the public debt, and as W_t grows faster, the price level rises faster as well, in order to satisfy (4.4). In addition, consumers eventually come to expect the higher level of after-tax income that they consistently receive, and the increase in y_t^e requires a further increase in the price level. Eventually, both W_t and P_t grow at the same constant rate π^* as in the perfect foresight equilibrium, though the cumulative increase in the price level due to the fiscal shock is larger (as well as occurring later) because of the delay in the adjustment of expectations. Again, the effects upon both inflation and the real value of the public debt are qualitatively similar to those predicted by the fiscalist analysis of section 2, and not at all like those of the "traditional" or "monetarist" equilibrium favored by McCallum.

These results contrast with the conclusions of Howitt (1992), who argues that attempting to peg the nominal interest rate will be undesirable, even when it is associated with a unique rational expectations equilibrium with low inflation, because adaptive learning dynamics do not converge to that equilibrium, and may instead involve explosive inflation, through a process similar to Wicksell's (1898) "cumulative process". Here we show how a non-Ricardian fiscal policy may result not only in a well-behaved low-inflation rational expectations equilibrium, in the case of a monetary policy that raises nominal interest rates only modestly if at all in response to increases in inflation, but also in qualitatively similar dynamics under adaptive expectations.

Of course, this is only one simple example of an analysis of learning dynamics. It is quite possible that other assumptions about how consumers learn would lead to other conclusions about the effects of disturbances upon equilibrium inflation. But the fact that such a simple hypothesis about learning leads to outcomes similar to those obtained under the equilibrium selection proposed in the previous section should at least confirm that it would be possible for an economy to react to shocks in the way indicated by the fiscalist analysis. If such an outcome is undesirable (as, for example, in the case where it implies ever-accelerating inflation), then it would seem important to guard against such an outcome by choosing a policy that would not allow an equilibrium of that kind.

5 Must an Optimal Policy Regime be Ricardian?

Thus far we have considered only the question whether a non-Ricardian (or at least locally non-Ricardian) regime is conceivable, and whether it would make sense for an economy to realize a fiscalist equilibrium in such a case. We now turn instead to the question whether such an equilibrium (and hence such a policy) could ever be desirable, or whether we should instead regard a commitment to a Ricardian fiscal policy as a *sine qua non* of sound policy. Our answer to this question obviously bears upon the question with which we began, whether it is desirable for budgetary issues and price stability to be considered independently of one another, by separate and autonomous authorities. Taking up this problem also requires a certain change in perspective – from consideration of how fiscal decisions impinge upon price stability to a consideration, instead, of how alternative paths for the price level affect the government budget.

Upon first thought, one might think that results such as the celebrated Barro (1979) analysis of optimal tax smoothing imply that an optimal fiscal policy is Ricardian; they indicate that events (such as wars) that increase the public debt should be followed by higher taxes in subsequent years, sufficient to eventually pay off the increased debt (in present value). But such results only display an optimal policy that is Ricardian because they have *assumed* that policy must be of this type. They do not actually consider whether or not fiscal shocks should be allowed to affect the price level and hence the value of existing government debt. When one considers that question, one easily sees that it may be advantageous to allow fiscal shocks to affect the value *ex post* of the government debt held by the public. Lucas and Stokey (1983) show that the solution to a dynamic Ramsey taxation problem, when government debt with state-contingent returns is allowed among the available fiscal instruments, will typically involve government debt of that kind. The reason is that surprise adjustments of the value of private claims on the government represent a substitute for changes in tax rates, that, unlike changes in tax rates, have no incentive effects. One might, in principle, imagine implementing such a regime through the sale of explicitly state-contingent government debt.

But (because of the complexity of the terms that one would need to specify) it may be more practical to issue nominal debt, and use a state-contingent aggregate price level to achieve the aggregate wealth transfers between private and public sector that are desired.

Of course, even granting that it is desirable for fiscal shocks to affect the equilibrium price level, one might imagine bringing about the desired inflation variations through either a Ricardian or a non-Ricardian policy regime. For example, one might suppose that taxes should be adjusted over time according to a Ricardian rule such as (1.26), while undesirable variation in tax rates would be headed off by engineering timely variations in the inflation rate, through a state-contingent money growth rule. We do not expect to be able to give any definitive answer to the question of whether a Ricardian or a non-Ricardian regime is optimal, in theory, since in general a given desired equilibrium may be supported by many different combinations of policy rules, that differ only in what they prescribe for situations that *never occur in equilibrium*. Nonetheless, we shall show that a non-Ricardian regime may provide not only one possible combination of policies consistent with the optimal equilibrium, but may be *simpler* in terms of the information required by the government in order to implement it. As we have seen, under a non-Ricardian regime, the price level may vary in response to fiscal shocks, without any need for the monetary policy rule to make explicit reference to fiscal variables. This means that the desired state-contingent price level may be achieved without the central bank having to be aware of the exact nature of the current state in order to conduct monetary policy. Furthermore, it may be able to explain to the public the rule that it intends to follow, and demonstrate its commitment to that rule, without having to explain to the public how it determines the nature of the current fiscal state. Thus the transparency and credibility of central bank policy may be enhanced under such a regime, relative to an alternative, Ricardian regime, that also seeks to bring about the optimal pattern of price-level variation.

We can illustrate this possibility with the following simple example.[39] Consider again

[39]See Chari and Kehoe (1997) for a review of dynamic Ramsey taxation problems of this sort. The result here that a zero nominal interest rate is optimal in the case of preferences of the form (5.1) follows from Proposition 4 of Chari *et al.* (1996).

the model of section 1.1, but assume in (1.1) the specific form of period utility function

$$U(c, y, m) = u(c, m) - v(y), \tag{5.1}$$

where v is an increasing, strictly convex function, and $u(c, m)$ is a homogeneous degree one function that is concave, increasing in c, and increasing in m up to some finite satiation level $m = \alpha c$, but constant in m thereafter.[40] Suppose in addition that $V(y) \equiv yv'(y)$ is an increasing, strictly convex function.[41] Suppose furthermore that lump-sum taxes are unavailable, and that instead all taxes must take the form of a proportional tax rate τ_t on output, so that the right-hand side of (1.2) must instead be written $W_t + (1 - \tau_t)P_t y_t$, and similarly with the other budget constraints.

Let g_t be an exogenous stochastic process. The government's problem is then to choose rules for the evolution of τ_t, the tax rate, for i_t, the nominal interest rate, and for the composition of the public debt, that are consistent with a rational expectations equilibrium that achieves the highest possible level of expected utility (1.1) for the representative household. We suppose that the government's choice is constrained by a commitment to choose a regime associated with an equilibrium in which the value (in units of marginal utility of the representative household) of the government liabilities held by the public at the beginning of period $t = 0$ achieves some value x_0; that is, we assume that the government is constrained to consider only equilibria in which

$$U_c(c_0, y_0, m_0)\frac{W_0}{P_0} = x_0. \tag{5.2}$$

In the absence of a constraint of this kind, the solution to the Ramsey problem will generally not be time-consistent; for example, if there is an initial nominal public debt, it will be optimal for the government to inflate away its value to zero, even though it will also be optimal to commit not to similarly inflate away the value of the debt with certainty in any future periods. But if we suppose that at each date t, when the government reconsiders its

[40] See Woodford (1998) for an example of an explicit transaction technology that would lead to an indirect utility over c and m with these properties.

[41] An example of a function v with these properties would be $v(y) = y^{1+\eta}/1 + \eta$, where $\eta > 0$.

policy it must choose a policy that satisfies a constraint of the form (5.2), where x_t may depend upon the state that is realized at date t, then we find that the continuation of the optimal commitment policy chosen at date $t = 0$ will still be considered optimal at any later date t.

We turn now to the set of equilibrium allocations that may be achieved through an appropriate monetary and fiscal policy regime. Under the assumption of the tax rate τ_t on output, first-order condition (1.4) becomes instead

$$\frac{U_y(c_t + g_t, y_t, M_t/P_t)}{U_c(c_t + g_t, y_t, M_t/P_t)} = -(1 - \tau_t), \tag{5.3}$$

while first-order conditions (1.5) and (1.6) are unchanged. If we substitute $T_t = \tau_t y_t$ into the equilibrium condition that the intertemporal budget constraint (1.3) be exhausted, then use the three first-order conditions (1.5), (1.6), and (5.3) to express relative prices in terms of quantities, and finally substitute (5.2) for the value of initial private sector claims on the government, we obtain

$$E\{\sum_{t=0}^{\infty} \beta^t G(c_t, y_t, m_t)\} = x_0, \tag{5.4}$$

where

$$G(c, y, m) \equiv U_c(c, y, m)c + U_y(c, y, m)y + U_m(c, y, m)m.$$

In any rational expectations equilibrium, the processes (c_t, y_t, m_t) will accordingly have to satisfy the *implementability constraint* (5.4), in addition to satisfying the market-clearing condition (1.8) each period. Contrariwise, we can show that any collection of processes (c_t, y_t, m_t) that satisfy (1.8) each period and satisfy (5.4) as well do correspond to a rational expectations equilibrium; i.e., given such quantities, we can choose associated price processes so that the first-order conditions, and indeed all equilibrium conditions are satisfied. Thus it suffices to consider the *primal* Ramsey problem of choosing processes (c_t, y_t, m_t) to maximize (1.1) subject to constraints (1.8) and (5.4).

This is simplified by our assumption of preferences of the form (5.1). This specification implies that $G(c, y, m) = u(c, m) - V(y)$, and so that G is concave. Because both the objective function U and the function G defining the implementability constraint are concave, we know that there must exist a Lagrange multiplier μ for the implementability constraint, such that the optimal plan maximizes

$$E\{\sum_{t=0}^{\infty}\beta^t[(u(c_t,m_t)-v(y_t))+\mu(u(c_t,m_t)-V(y_t))]\} \tag{5.5}$$

subject to the constraint that (1.8) hold each period. We can furthermore show that in the case that $x_0 > 0$, the Lagrange mulitplier $\mu > 0$, because a lower value of x_0 would relax the implementability constraint, allowing a higher level of expected utility to be attained. It follows that increasing m necessarily increases (5.5), as long as it increases $u(c,m)$. Hence the optimal plan involves real balances at the satiation level at all times, $m_t = \alpha c_t$ for all t. Now writing $u(c,\alpha c) = \lambda^* c$, and substituting (1.8) into the objective (5.5) to eliminate c_t, we observe that the process y_t must maximize

$$E\{\sum_{t=0}^{\infty}\beta^t[(\lambda^*(y_t-g_t)-v(y_t))+\mu(\lambda^*(y_t-g_t)-V(y_t))]\}. \tag{5.6}$$

Since the g_t terms are additively separable, we see that at each date, y_t must maximize

$$[\lambda^* y - v(y)] + \mu[\lambda^* y - V(y)].$$

Letting the maximizing value be denoted y^*, we observe that the optimal plan involves $y_t = y^*$ for all t, and hence $c_t = y^* - g_t$, and $m_t = \alpha(y^* - g_t)$.

The solution for y^* depends, of course, upon the value of μ; this is determined as the value that leads to a solution that exactly satisfies (5.4). One observes that y^* is therefore the larger of the two roots of the equation

$$\lambda^* y^* - V(y^*) = (1-\beta)(x_0 + \lambda^* f_0),$$

where

$$f_0 \equiv E\{\sum_{t=0}^{\infty}\beta^t g_t\}$$

is the present value of government purchases from date 0 onwards. Note that the continuation of this solution from any date T onward (i.e., $y_t = y^*, c_t = y^* - g_t, m_t = \alpha(y^* - g_t)$, for all

$t \geq T$) is also the solution to the corresponding planning problem at date T, if the date T constraint corresponding to (5.2) involves a commitment to a utility value of the public debt

$$x_T = \frac{\lambda^* y^* - V(y^*)}{1-\beta} - \lambda^* f_T,$$

where f_T is the present value of government purchases from date T onwards. Note that this value for x_T is just the value that is anticipated in the equilibrium corresponding to the commitment solution chosen at date 0, and so re-optimization results in no desire to change policy, if it is subject to this state-contingent constraint.

The prices and tax rates associated with the optimal equilibrium can then be inferred from the first-order conditions. From (1.5) we observe that satiation in money balances implies that $i_t = 0$ at all times, and from (5.3) we observe that $\tau_t = \tau^*$ at all times, where the constant tax rate $0 < \tau^* < 1$ satisfies

$$\tau^* = 1 - \frac{v'(y^*)}{\lambda^*} = \frac{(1-\beta)(x_0 + f_0)}{\lambda^* y^*}.$$

The evolution of the price level can be determined from how the value of the public debt must vary in order for these interest rates and tax rates to be consistent with equilibrium. In this equilibrium, the value of government liabilities W_t at the beginning of any period is just the total value of all coupon and principal payments promised on all government bonds, summed without discounting, plus the value of the monetary base; W_t is thus a predetermined state variable. The equilibrium price level at each date must satisfy $P_t = W_t/v_t$, where v_t is again the right-hand side of (2.2), or $\tau^*/(1-\beta) - f_t$. The evolution of nominal government liabilities is in turn given by

$$W_{t+1} = W_t - P_t s_t = \beta P_t E_t v_{t+1} = P_t \left\{ \frac{\beta}{1-\beta} \tau^* - \beta E_t f_{t+1} \right\}.$$

Using these equations, the predetermined variable W_t and the current fiscal state f_t allow us to determine the equilibrium price P_t, and this together with the expected future fiscal state $E_t f_{t+1}$ allow us to determine the value of W_{t+1} at the start of the next period.

One observes that the optimal equilibrium will involve stochastic variations in the price level in response to fiscal shocks; an unexpected increase in the present value of government purchases f_t will result in an unexpected increase in the price level P_t, as well as in the expected price levels in all future periods, $E_t P_{t+j}$. Note that this conclusion has nothing to do with the more familiar suggestion that it might be desirable to use seignorage as a source of government revenue, in order to reduce the need for other sorts of distorting taxes (Phelps, 1973). Here the desired price-level response to fiscal shocks remains non-trivial in the cashless limit, though the usefulness of seignorage as a source of revenue becomes negligible. Furthermore, our assumed preferences (5.1) imply that it is *not* desirable to allow a nominal interest rate – and hence an average inflation rate – higher than that called for by Friedman (1969), despite the government's need to raise revenues through a distorting tax; for they imply that the deadweight loss resulting from expected inflation is greater than that resulting from an increase in the income tax rate that raises an equal amount of revenue, contrary to Phelps' analysis.[42] But this does not mean that variations in *unexpected* inflation – or more generally, unexpected capital gains and losses on government debt – are not a useful fiscal measure.

This does not in itself tell us whether the policy regime should be Ricardian or non-Ricardian; it only tells us that if fiscal policy is Ricardian, optimal monetary policy would have to respond to fiscal variables in such a way as to bring about the price-level response to fiscal shocks just described. Presumably one could design a Ricardian regime with a sufficiently complicated kind of fiscally-dependent monetary rule that would be consistent with this equilibrium.

But it is clear that the optimal equilibrium can be implemented by a non-Ricardian regime. In fact, the policy rules are quite simple: fiscal policy simply keeps the tax rate fixed at the level τ^*, regardless of how the present value of government purchases f_t evolves, and monetary policy simply keeps the short-term nominal interest rate pegged at zero, regardless of how the price level and the public debt evolve. This is a non-Ricardian regime of the kind analyzed in section 2, since it makes the real primary government budget surplus

[42] The reason for this is essentially the same as in the cash-in-advance model analyzed by Lucas and Stokey (1983). See Chari and Kehoe (1997) for further discussion.

s_t an exogenous stochastic process; as shown before, such a regime has a unique rational expectations equilibrium, in which price-level fluctuations of exactly the desired type occur in response to fiscal shocks. Such a regime has the advantage that the monetary and fiscal authorities do not even have to current information about government spending needs or expected future government purchases in order to implement the optimal regime: it is enough that the private sector be aware of them in order for the price-level fluctuations characteristic of the optimal regime to occur, as a consequence of the wealth effects of the fiscal news.

This shows that the aggregate demand effects of fiscal shocks in a non-Ricardian regime are not necessarily undesirable. However, the simple model used here to analyze optimal policy assumes perfectly flexible prices for all goods, and so abstracts from any reason for price stability to matter in the welfare calculations. A more realistic analysis would recognize that aggregate price-level instability creates distortions, due to the fact that not all wages and prices are adjusted simultaneously,[43] and would for that reason probably not recommend a regime in which the price level jumps as much in response to fiscal shocks as occurs in the equilibrium just described. But this need not mean that stochastic variation in the present value of government purchases would have to be matched by variations in the tax rate, as would be required in a Ricardian regime. For we have seen in section 2.1 that a non-Ricardian regime in which the government budget fluctuates exogenously may involve arbitrarily small fluctuations in equilibrium inflation, if the duration of government debt is sufficiently long, and interest rates respond strongly enough to variations in inflation. Such a regime could allow complete tax smoothing *and* almost complete price stability; the only cost would be accepting low positive short-term nominal interest rates, and the associated distortion resulting from lack of complete satiation in cash. In the case of an economy where the frictions responsible for money demand are small, this tradeoff would likely be an acceptable one, and one may conjecture that a policy regime of the kind discussed in section 2.1 might well approximate optimal policy. But this deserves a thorough analysis, in the

[43] See Appendix 3 of Rotemberg and Woodford (1998) for a utility-based analysis of the contribution of price stability to welfare in the case of staggered price changes.

context of a model where nominal rigidities are treated explicitly, both in the analysis of the effects of alternative policy regimes and in the welfare calculations.

An obvious problem with the non-Ricardian regime is that, if it is understood that spending increases will not imply any increase in taxes, this may make opportunities for increased government spending even more difficult for politicians to resist. The preceding analysis of optimal policy has assumed that the process for government purchases g_t is independent of the fiscal and monetary policy regime, but it would surely be difficult to ensure this in practice. Central bankers, as guardians of the interests of investors in government paper, are unlikely to find this prospect appealing. And indeed there would seem to be a need for some institutional mechanism that would remind legislators of the resource cost of their spending plans. Thus rather than simply implementing an interest-rate rule and letting the government budget evolve as it may, it would be appropriate for the central bank to play an active role in commenting upon the inflationary consequences of proposed changes in fiscal policy, and similarly in ensuring that the composition of the public debt favors price stability, by maximizing the extent to which the adjustment in response to fiscal shocks occurs through changes in long bond yields rather than through variations in the inflation rate. Through such recognition on the part of the fiscal and monetary authorities of the interconnectedness of their respective concerns, it may be possible to enjoy the benefits of a tax policy aimed at microeconomic efficiency rather than budget balance, without sacrificing the advantages that flow from stable prices.

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