

NBER WORKING PAPER SERIES

FISCAL REQUIREMENTS FOR PRICE STABILITY

Michael Woodford

Working Paper 8072
<http://www.nber.org/papers/w8072>NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
January 2001

Official text of the 2000 Money, Credit and Banking Lecture, presented at Ohio State University on May 1, 2000. I wish to thank Michael Bordo, Matt Canzoneri, Steve Cecchetti, Larry Christiano, John Cochrane, Paul Evans, Eduardo Loyo, Bennett McCallum, Hélène Rey, Stephanie Schmitt-Grohé and Chris Sims for helpful discussions, Gauti Eggertsson for research assistance, and the National Science Foundation for research support through a grant to the NBER. The views expressed herein are those of the author and not necessarily those of the National Bureau of Economic Research.

© 2001 by Michael Woodford. All rights reserved. Short sections of text, not to exceed two paragraphs, may be quoted without explicit permission provided that full credit, including © notice, is given to the source.

Fiscal Requirements for Price Stability
Michael Woodford
NBER Working Paper No. 8072
January 2001
JEL No. E31, E42, E61

ABSTRACT

This paper argues that maintaining price stability requires not only commitment to an appropriate monetary policy rule, but an appropriate fiscal policy rule as well. “Ricardian equivalence” does not imply that fiscal policy is irrelevant, except in the case of a certain class of policies (called “Ricardian” policies). The role of fiscal developments in inflation determination under a non-Ricardian regime is illustrated through an analysis of the U.S. bond-price support regime of the 1940s. Several recent theoretical challenges to the logical possibility of a non-Ricardian regime are addressed, and a number of consequences are then drawn for the choice of policies to ensure price stability. An example of a monetary-fiscal regime with attractive properties would combine a “Taylor rule” for monetary policy with nominal-deficit targeting as a fiscal policy commitment.

Michael Woodford
Department of Economics
Princeton University
Princeton, NJ 08544
and NBER
woodford@princeton.edu

“Proposals for a *monetary* rule require a supplementary proposal of a *fiscal* rule.”

Karl Brunner (1986), p. 54.

1 Introduction

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. An 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. I 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

¹A particularly striking example of an attempt to separate the two types of policy decisions is the European monetary union, in which monetary policy is the responsibility of a supra-national European Central Bank, while fiscal policies continue to be the prerogatives of individual national governments.

(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, 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.

I 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 I shall 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

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

³The discussion of price-level determination under a non-Ricardian policy regime in section 2 below recapitulates results from Woodford (1994, 1995, 1996, 1998c), drawing also upon the important contributions of Leeper (1991), Sims (1994), and Cochrane (1999). 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 Bassetto (2000), Benhabib *et al.* (2000a, 2000c), Bénassy (2000), Bergin (1996), Buiter (1998, 1999), Canzoneri and Diba (1996), Canzoneri *et al.* (1998, 1999), Carlstrom and Fuerst (2000), Christiano and Fitzgerald (2000), Cochrane (1998, 2000), Cushing (1999), Daniels (1999), Dupor (2000), Gordon and Leeper (1999), Kenc *et al.* (1997), Kocherlakota and Phelan (1999), Leith and Wren-Lewis (1998), Loyo (1997, 1999, 2000), McCallum (1998, 1999), Schmitt-Grohé and Uribe (2000), and Sims (1997, 1998, 1999).

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. To be concrete, I shall argue that the mere commitment of a central bank to conduct monetary policy according to a rule such as the “Taylor rule” (Taylor, 1993) is insufficient to ensure a stable, low equilibrium rate of inflation. On the one hand, (non-Ricardian) fiscal expectations inconsistent with a stable price level may frustrate this outcome, even when monetary policy is itself consistent with price stability. Indeed, the combination of a Taylor rule with certain kinds of fiscal policy may result in an inflationary or deflationary spiral. And on the other hand, even when fiscal policy is *consistent* with stable prices, the policy regime (including the commitment to a Taylor rule) may not preclude *other* equally possible rational expectations equilibria, such as equilibria involving self-fulfilling deflationary spirals.⁴ Alternative fiscal policy commitments may instead exclude these undesired deflationary equilibria (as discussed in Woodford, 1999a), and thus in this way help to ensure stable prices. As a practical proposal that addresses both of these issues, I shall suggest that a Taylor rule for monetary policy should be accompanied by targets for the size of government budget deficits.

2 Price-Level Determination under a Bond Price-Support Regime

Before turning to a discussion of Taylor rules, it will be useful to take up the more general question of how fiscal policy can affect the determination of the equilibrium price level. The role of fiscal developments as a source of disturbances to the price level can be seen most clearly in policy regimes sometimes said to involve “fiscal dominance”. These are policy regimes, often associated with the special fiscal pressures of war finance, in which other goals of central bank policy are subordinated to the goal of assisting in the financing of the

⁴Benhabib *et al.* (2000b) criticize regimes involving a Taylor rule on this ground, though it is important to note that the problem that they identify is in no way special to the Taylor rule.

government budget. However, it is important to note that this does *not* necessarily mean that fiscal developments affect the price level only because the central bank adjusts monetary policy in response to them.

A familiar textbook account of fiscally-dominant regimes runs as follows: fiscal exigencies determine the size of a real government budget deficit that must be financed; this budget shortfall is then assigned to the central bank as a level of seignorage revenue that it must generate through money creation; the monetary base is increased by whatever amount suffices to generate the required revenues; and finally, the rate of money growth determines the equilibrium rate of inflation, through the usual quantity-theoretic mechanism. Under this account, fiscal developments affect the rate of inflation, but *only* because they affect monetary policy, under this particular sort of monetary policy rule; inflation is still a “purely monetary” phenomenon. Such an account is still perfectly consistent with the view that commitment to an anti-inflationary monetary policy is sufficient to ensure price stability. Furthermore, the model just sketched might seem to apply only to a few less-developed economies, not to advanced economies such as the U.S. or the European Union. For it would seem not to apply in the case of an independent central bank, that need not accept seignorage targets dictated by the Treasury; nor would it seem likely to apply to an economy with sophisticated financial markets, in which it is difficult for the government to raise large seignorage revenues, because of people’s ability to substitute away from non-interest-earning assets. Thus the part of the world in which such a regime would even be a potential outcome might seem to be rapidly shrinking.

Instead, I shall argue that fiscal policy can affect the price level even when the central bank pursues an *autonomous* monetary policy, by which I mean a rule for setting its instrument (in practice, a nominal interest rate) that is *independent of fiscal variables*. Thus it will not be enough, to avoid price-level instability resulting from fiscal disturbances, to simply adopt an institutional arrangement under which the central bank receives no directives from the Treasury dictating changes in policy; nor will it be enough that the central bank commits itself to an interest-rate rule, like the Taylor rule, that involves no direct feedback

from variables such as the the government budget. Furthermore, the potential effects of fiscal disturbances described here will continue to exist even in what I shall the “cashless limit” (Woodford, 1998a) — the hypothetical limiting case of an economy in which financial innovation has proceeded to the extent that available seignorage revenues are negligible. This is because these effects in no way depend upon attempts to use monetary policy to generate seignorage revenues. Thus the possibility that fiscal policy may interfere with the achievement of price stability cannot be so easily dismissed, even for advanced economies.

In fact, “fiscally dominant” regimes often do not involve any direct assignment of a seignorage target to the central bank, as in the textbook analysis. Instead, “fiscal dominance” manifests itself through pressure on the central bank to use monetary policy to *maintain the market value of government debt*. A classic example is provided by U.S. monetary policy from 1942 up until the Treasury-Fed “Accord” of March 1951.⁵

Beginning in April 1942, the Fed and the Treasury agreed to an interest-rate control program, the declared aim of which was to maintain “relatively stable prices and yields for government securities”.⁶ The yield on 90-day Treasury bills was pegged at 3/8 of a percent; this peg was maintained through June 1947, and as shown in Figure 1(a), until that point the price of bills was completely fixed, as the Treasury offered both to buy and sell bills at that price. An intention was also announced of supporting 1-year Treasury certificates at a price corresponding to a 7/8 percent annual yield; this policy continued after 1947, though at a slightly higher yield. Finally, the prices of 25-year Treasury bonds were supported at a price corresponding to a 2 and 1/2 percent annual yield; this price floor was maintained up until the time of the “Accord”. The commitment to supporting the price of long-term bonds seems to have been the central element of Fed policy in the late 1940s. In particular, when bond prices rose during the first half of 1949, the Fed sold over three billion dollars of its bond holdings (Eichengreen and Garber, 1991, p. 184); thus the Fed acted to stabilize bond prices (and in the face of criticism at the time, over the contractionary consequences of

⁵See, e.g., Friedman and Schwartz (1963), chap. 10; Eichengreen and Garber (1991); and Timberlake (1993), chap. 20; and Toma (1997), chap. 8.

⁶Eccles (1951), p. 350; quoted by Timberlake (1993), p. 304.

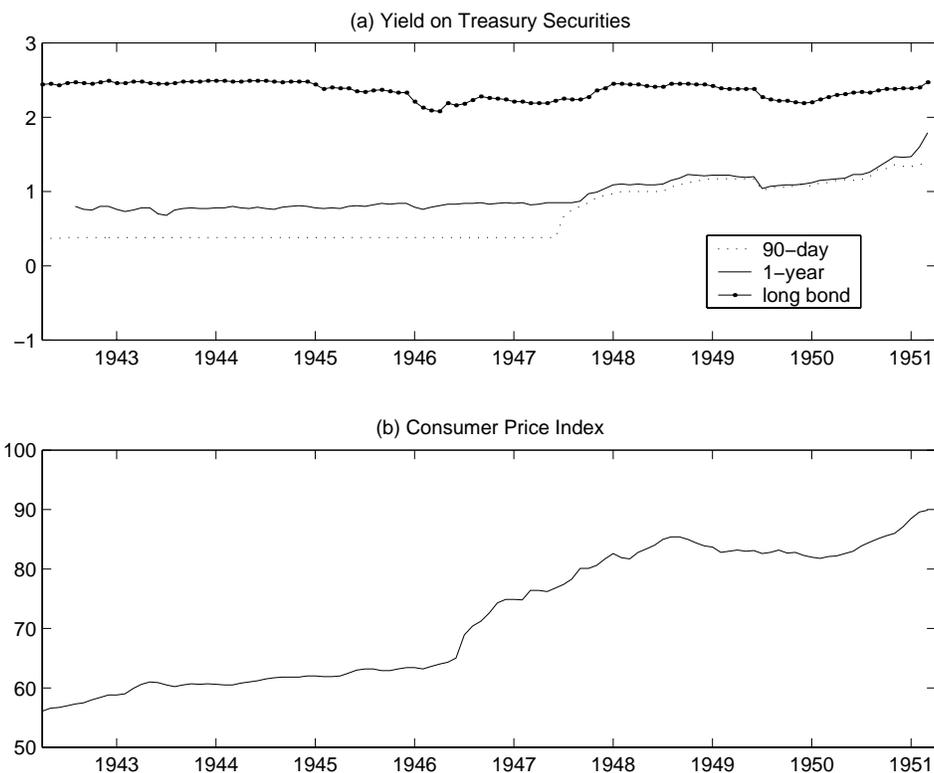


Figure 1: The U.S. bond-price support regime, 1942-51. (a) Yields on Treasury securities. (b) Evolution of the consumer price index.

the policy during a recession period), rather than refusing to intervene as long as the price remained above the floor.

This sort of relation between a central bank and the treasury is not uncommon in wartime, and may have characterized at least some central banks at other times as well, in cases where the perceived constraints on fiscal policy have been similarly severe.⁷ The interest of the case for our present purposes is that while the Fed during this period is typically described as thoroughly subordinate to Treasury policy, this is actually an example of an autonomous monetary policy, in the sense defined above. A policy of conducting open-market purchases and sales so as to stabilize the prices of Treasury securities is one that requires no central

⁷For example, Fratianni and Spinelli (1997) describe the Bank of Italy as operating under a regime of “fiscal dominance” during most of its history, from its founding in the late 19th century until the so-called “divorce” between the Bank and the Treasury in 1981. In this case as well, “fiscal dominance” seems to have meant above all the inability to set an independent interest-rate policy; instead, interest rates had to be kept low to allow the sale of government debt at a high price.

bank monitoring of fiscal developments for its implementation, nor any directives from the Treasury about how to respond to fiscal developments. It is in fact an especially simple example of an interest-rate rule, essentially equivalent to an *interest-rate peg*. Any effect of fiscal shocks upon the growth the monetary base under this regime was purely a general-equilibrium phenomenon, and not a consequence of any direct dependence of the Fed's interest-rate targets upon such shocks.

Yet fiscal developments clearly have a major impact upon the course of inflation under such regimes. For example, in the case of the U.S. in the 1940s, the regime was inflationary during the war period, though wage and price controls suppressed much of this inflation until their relaxation in several stages during 1946. (The burst of inflation in 1946-47 seen in Figure 1(b) should not be attributed to any surge in aggregate demand at that time, but rather to the allowance of prices to finally rise to their equilibrium level.) On the other hand, the price-support regime resulted in *deflation* over the period 1948-50. This corresponds to a period in which the large wartime deficits had ended, and the U.S. government budget was instead chronically in surplus. With the outbreak of the Korean war in June 1950, inflation suddenly began again. It was only at this time that the bond price-support regime came to be denounced as “an engine of inflation”, and was for that reason suspended.⁸

How is one to explain these effects upon the general level of prices of variation in the fiscal situation? It cannot be through any *direct* effect of fiscal developments upon monetary policy, understood to refer to the Fed's rule for setting interest rates. Rather, such effects indicate that the government budget can play a role in price-level determination in addition to the specification of monetary policy.

Might one still salvage a traditional quantity-theoretic view of inflation determination by saying that in such a regime, the money supply depends upon the government budget, as well as the interest-rate rule? *In equilibrium*, it is true that it does; fiscal disturbances affect the equilibrium growth rate of the money supply. But the causality is *not* from the

⁸See Brunner and Meltzer (1966) for an important discussion of this period, stressing that the inflationary or deflationary character of the regime depended upon fiscal policy.

government budget to the growth of the money supply, and then only from the change in the money supply to prices. Rather, the government budget affects the general level of prices, and *only because prices change* does it also affect the money supply (as higher prices result in higher money demand, which the Fed passively accommodates under such a regime). Thus one cannot explain the change in the price level as being due to the increase in the money supply.

Upon first thought, one might suppose that under a bond price-support regime, there is a direct connection between the government budget and growth in the monetary base. One might reason that a commitment by the Fed to act as the residual purchaser of government debt will require the Fed to increase the monetary base, in order to increase its holdings of government debt, whenever the Treasury issues more debt, which is to say, whenever (and to the extent that) the government runs a budget deficit. But this superficial analysis implicitly assumes that the public's demand for government bonds is fixed, so that (in the absence of a price change) the Fed will have to acquire the additional issues, while it assumes at the same time that there is no obstacle to increasing the public's money holdings by an arbitrary amount, without any change in the relative yield on money and bonds.

Instead, economic theory implies that if anything, the *opposite* relations should obtain. There are good reasons why it may not be possible for the Fed to increase the monetary base without having to accept a change in the yields on Treasury securities. A money demand relation of the conventional sort (e.g., equation (2.16) below) implies that the public's desired money balances will be a function of the price level, of the quantity of real transactions, and of the interest differential between money and bonds, but *not* of fiscal variables such as the stock of public debt. Thus it is generally supposed that the Fed cannot change the monetary base without accepting a change in the level of interest rates, something that is precluded under the bond price-support regime. At the same time, there are equally good reasons why an increase in government borrowing might well increase the public's willingness to hold government bonds, even in the absence of any change in bond yields. Indeed, the doctrine of Ricardian Equivalence asserts that government borrowing automatically creates an increase

in desired private bond holdings of exactly the same size (due to an increase in expected future tax obligations), so that bond yields need not change at all to maintain equilibrium in the bond market.

The analysis that I shall propose here will not imply that Ricardian Equivalence obtains (in that case, there would be no inflationary impact of an expectation of budget deficits, either). But it *will* assume a conventional money demand relation, so that the quantity of money that must be supplied in order to maintain bond prices at their target levels is a function solely of prices and real activity. Thus the government budget will be able to affect the money supply *only* because it is able to affect equilibrium prices through another channel; prices will not be affected only because of the change in the money supply.

2.1 A Simple Model

Let us consider price-level determination under such a regime using a simple monetary framework, namely, a representative-household model of the kind introduced by Sidrauski (1967) and Brock (1974, 1975). I shall suppose that the representative household seeks to maximize a discounted sum of utilities of the form

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t U(c_t + g_t, M_t/P_t) \right\}, \quad (2.1)$$

where $U(c, m)$ is an increasing, concave function of both arguments, and the discount factor satisfies $0 < \beta < 1$. The second argument of U indicates the liquidity services provided by end-of-period money balances M_t ; these depend upon the real purchasing power of those balances, so that M_t is deflated by the price level P_t . In the specification (2.1), I assume that (real) government purchases g_t are perfect substitutes for (real) private consumption expenditure c_t . This simplification allows us to focus solely upon the effects of fiscal policy upon private budget constraints; government purchases have exactly the same effect on the economy as transfers to households of funds sufficient to finance private consumption of exactly the same amount. (I shall assume that taxes are lump-sum for the same reason; a tax increase will then have the same effect as a reduction in transfers that reduces household budgets in the same amount.)

The representative household is subject each period to a flow budget constraint of the form

$$M_t + E_t[R_{t,t+1}(W_{t+1} - M_t)] \leq W_t + P_t y_t - T_t - P_t c_t, \quad (2.2)$$

stating that end-of-period financial wealth (money balances M_t plus bonds) must be no greater in value than financial wealth W_t at the beginning of the period, plus income from the sale of period t production y_t , net of tax payments and consumption expenditure. The variable T_t represents (nominal) tax obligations net of any government transfers; the two components need not be distinguished, as taxes are assumed to be lump-sum. The difference $W_{t+1} - M_t$ represents the (nominal) value in period $t + 1$ of the household's bond portfolio at the end of period t ; as I assume complete financial markets, this portfolio may include state-contingent claims of many sorts. The (nominal) market value of such a bundle of state-contingent claims in period t is given by $E_t[R_{t,t+1}(W_{t+1} - M_t)]$, where the random variable $R_{t,t+1}$ is a stochastic discount factor for pricing arbitrary (non-monetary) financial claims.⁹ Note that the household, as a price-taker in financial markets (as well as goods markets), takes the evolution of the stochastic discount factor as being independent of its own portfolio decisions (indicated by the evolution of M_t and W_t).

The nominal interest rate i_t on a one-period riskless claim purchased in period t must satisfy

$$1 + i_t = E_t[R_{t,t+1}]^{-1}. \quad (2.3)$$

Using this, we may rewrite (2.2) in the form

$$P_t c_t + \frac{i_t}{1 + i_t} M_t + E_t[R_{t,t+1} W_{t+1}] \leq W_t + [P_t y_t - T_t], \quad (2.4)$$

in which $i_t/(1 + i_t)$ appears as the effective cost of holding wealth in monetary form. Let us also assume a borrowing limit each period, according to which the household's portfolio

⁹The existence of such a pricing kernel follows from the absence of arbitrage opportunities; the pricing relation applies, of course, only to financial assets that (unlike money) do not yield additional non-pecuniary benefits. Under our assumption of complete markets, $R_{t,t+1}$ is uniquely defined.

(including any short positions) must satisfy

$$W_{t+1} \geq - \sum_{T=t+1}^{\infty} E_{t+1}[R_{t+1,T}(P_T y_T - T_T)] \quad (2.5)$$

in each possible state in period $t + 1$; this states that the household must never have debts greater than the present value of all future after-tax income.¹⁰ The sequence of flow budget constraints (2.4) combined with (2.5) is then equivalent to the intertemporal budget constraint¹¹

$$\sum_{T=t}^{\infty} E_t R_{t,T} \left[P_T c_T + \frac{i_T}{1+i_T} M_T \right] \leq W_t + \sum_{T=t}^{\infty} E_t R_{t,T} [P_T y_T - T_T]. \quad (2.6)$$

We may thus state the household's problem, looking forward from any date t , as the choice of a consumption plan and planned money holdings to maximize (2.1) subject to (2.6), given financial wealth W_t .

Necessary and sufficient conditions for household optimization¹² are then that the first-order conditions¹³

$$\frac{U_m(c_t + g_t, m_t)}{U_c(c_t + g_t, m_t)} = \frac{i_t}{1+i_t}, \quad (2.7)$$

$$\frac{U_c(c_t + g_t, m_t)}{U_c(c_{t+1} + g_{t+1}, m_{t+1})} = \frac{\beta}{R_{t,t+1}} \frac{P_t}{P_{t+1}} \quad (2.8)$$

hold at all times, and that the household exhaust its intertemporal budget constraint, *i.e.*, that

$$\sum_{T=t}^{\infty} E_t R_{t,T} \left[P_T c_T + \frac{i_T}{1+i_T} M_T \right] = W_t + \sum_{T=t}^{\infty} E_t R_{t,T} [P_T y_T - T_T] < \infty. \quad (2.9)$$

This last condition states both that the left and right-hand sides of (2.6) are equal, and that both infinite sums converge.¹⁴ This condition for optimality could equivalently be replaced by the stipulation that the household's planned expenditure has a finite present value,

$$\sum_{T=t}^{\infty} E_t R_{t,T} \left[P_T c_T + \frac{i_T}{1+i_T} M_T \right] < \infty, \quad (2.10)$$

¹⁰Here the discount factor $R_{t+1,T}$ for discounting income in period T back to period $t + 1$ is defined as the product of factors $R_{s,s+1}$ for s running from $t + 1$ through $T - 1$; it is equal to one when $T = t + 1$.

¹¹See Woodford (1999a) for details.

¹²For simplicity, we ignore the possibility of corner solutions.

¹³In writing these, I use the notation $m_t \equiv M_t/P_t$ for real money balances.

¹⁴The latter stipulation is necessary, as both left and right-hand side being infinite would *not* imply that the household could not afford to consume more. Indeed, in such a case, (2.5) would impose no limit on borrowing, and "Ponzi schemes" would be possible, allowing unbounded consumption at all dates.

together with a transversality condition on wealth accumulation,¹⁵

$$\lim_{T \rightarrow \infty} E_t[R_{t,T}W_T] = 0. \quad (2.11)$$

A rational expectations equilibrium is then a collection of state-contingent paths for the various endogenous variables that satisfy these conditions for household optimization, together with the market-clearing conditions

$$c_t + g_t = y_t, \quad (2.12)$$

$$M_t = M_t^s, \quad (2.13)$$

$$W_{t+1} = W_{t+1}^s \quad (2.14)$$

at all dates and in all possible states.¹⁶ Here the aggregate supply of goods y_t is an exogenously specified stochastic process, whereas the money supply M_t^s and the market value of total beginning-of-period government liabilities W_{t+1}^s evolve in accordance with the specification of monetary and fiscal policy (to be clarified below).

Substituting (2.12) – (2.13) into (2.7), we obtain the equilibrium condition

$$\frac{U_m(y_t, M_t^s/P_t)}{U_c(y_t, M_t^s/P_t)} = \frac{i_t}{1 + i_t}. \quad (2.15)$$

Under standard assumptions on preferences,¹⁷ this equation can be solved for a unique equilibrium level of real money balances,

$$\frac{M_t^s}{P_t} = L(y_t, i_t), \quad (2.16)$$

where the “liquidity preference function” L is increasing in its first argument and decreasing in the second. Thus our model incorporates an equilibrium condition stating that the price level is at all times such that the implied real value of the money supply is equal to desired

¹⁵Again, see Woodford (1999a) for details.

¹⁶Equilibrium from some date T onward requires that (2.12) – (2.14) be expected to hold at all dates $t \geq T$. The fact that $W_T = W_T^s$ would follow from the specification of the initial portfolio of the representative household, rather than being a market-clearing condition.

¹⁷In addition to those noted earlier, we assume that both consumption and liquidity services are normal goods, and also assume boundary conditions guaranteeing an interior solution to (2.15).

real balances; but as we shall see, this need not mean that the evolution of the price level is best *explained* by the evolution of the money supply.

A similar substitution of (2.12) – (2.13) into (2.8) allows us to solve for the stochastic discount factor, obtaining

$$R_{t,t+1} = \beta \frac{U_c(y_{t+1}, M_{t+1}^s/P_{t+1})}{U_c(y_t, M_t^s/P_t)} \frac{P_t}{P_{t+1}}. \quad (2.17)$$

Substitution of this into (2.3) then yields

$$1 + i_t = \beta^{-1} \left\{ E_t \left[\frac{U_c(y_{t+1}, M_{t+1}^s/P_{t+1})}{U_c(y_t, M_t^s/P_t)} \frac{P_t}{P_{t+1}} \right] \right\}^{-1}. \quad (2.18)$$

This equilibrium relation is a sort of “Fisher equation”, linking nominal interest rates to expected inflation, but also involving the real factors that determine the equilibrium real rate of interest. In the familiar textbook case of a utility function U that is additively separable between consumption and liquidity services (or in the “cashless limit” discussed below), (2.18) reduces to

$$1 + i_t = \beta^{-1} \left\{ E_t \left[\frac{u'(y_{t+1})}{u'(y_t)} \frac{P_t}{P_{t+1}} \right] \right\}^{-1}, \quad (2.19)$$

where $u(c_t + g_t)$ is the part of U that depends upon consumption (or the value of U in the “cashless limit”). In this special case, the expected rate of inflation is the only endogenous variable on the right-hand side of the equation.

Under similar substitutions, the remaining requirements for optimality, (2.10) and (2.11), become

$$\sum_{T=t}^{\infty} \beta^T E_t [U_c(y_T, m_T) c_T + U_m(y_T, m_T) m_T] < \infty, \quad (2.20)$$

$$\lim_{T \rightarrow \infty} \beta^T E_t [U_c(y_T, M_t^s/P_t) W_T^s/P_t] = 0. \quad (2.21)$$

Here I have substituted (2.17) to eliminate the stochastic discount factors, and in (2.20) have also substituted (2.15) for the factor $i/(1+i)$. Let us suppose furthermore that the share of government purchases in the total national product is bounded, *i.e.*, that $0 \leq g_t \leq \gamma y_t$ at all times, for some bound $0 < \gamma < 1$. Then we must have

$$c_T \leq y_T \leq (1 - \gamma)^{-1} c_T$$

at all times, so that (2.20) is equivalent to the condition

$$\sum_{T=t}^{\infty} \beta^T E_t F(y_T, M_T^s/P_T) < \infty, \quad (2.22)$$

where

$$F(y, m) \equiv U_c(y, m)y + U_m(y, m)m.$$

Thus both of the remaining equilibrium conditions, (2.21) and (2.22), place bounds upon how far the price level can diverge asymptotically from proportionality to the nominal asset supplies M_t^s and W_t^s .

The transversality condition for optimal wealth accumulation can alternatively be expressed by the equality in (2.9). A similar substitution of conditions (2.12) – (2.14) and into this equation yields

$$\sum_{T=t}^{\infty} \beta^{T-t} E_t \frac{U_c(y_T, m_T)}{U_c(y_t, m_t)} \left[(y_T - g_T) + \frac{i_T}{1 + i_T} \frac{M_T^s}{P_T} \right] = \frac{W_t^s}{P_t} + \sum_{T=t}^{\infty} \beta^{T-t} E_t \frac{U_c(y_T, m_T)}{U_c(y_t, m_t)} \left[y_T - \frac{T_T}{P_T} \right] \quad (2.23)$$

as a substitute for (2.21). One notes that the present value of the $y_T - g_T$ terms on the left-hand side must be finite, as a consequence of (2.22) and the assumed bound on government purchases. Subtracting these terms from both sides and rearranging, one obtains the equilibrium condition

$$\frac{W_t^s}{P_t} = \sum_{T=t}^{\infty} \beta^{T-t} E_t \frac{U_c(y_T, m_T)}{U_c(y_t, m_t)} \left[s_T + \frac{i_T}{1 + i_T} \frac{M_T^s}{P_T} \right], \quad (2.24)$$

where s_t denotes the real primary government budget surplus

$$s_t \equiv \frac{T_t}{P_t} - g_t.$$

This condition states that the real value of net government liabilities must equal the present value of expected future primary budget surpluses, corrected to take account of the government's interest saved on the part of its liabilities that the public is willing to hold in monetary form. Note however that this relation necessarily obtains in a rational expectations equilibrium, *not* because we have assumed it as a constraint upon the government's

fiscal policy, but rather because it follows from private sector optimization, together with market clearing. (This point will be of considerable importance for the discussion below.)

To sum up, a *rational expectations equilibrium* is a collection of stochastic processes $\{P_t, i_t, M_t^s, W_t^s\}$ that satisfy (2.16), (2.18), and (2.22), as well as either (2.21) or (2.24), along with the equations specifying monetary and fiscal policy. These equations suffice to determine equilibrium in the case that both the monetary policy rule and the law of motion for government liabilities given the fiscal policy rule can be specified without reference to asset prices other than i_t . (An example of such a case is presented in the next subsection.) Once an equilibrium (*i.e.*, solution to these equations) is found, the implied equilibrium processes for all other asset prices are then given by (2.17). If instead monetary and/or fiscal policy cannot be specified without reference to longer-term bond prices, the necessary bond pricing equations must be adjoined to the system of equations listed above, and the bond prices in question added to the list of endogenous variables that are jointly determined.

2.2 A Treasury-Bill Peg

Let us now consider the equilibrium price level under a bond price-support regime. As a first simple example, suppose that monetary policy pegs the price of a one-period Treasury bill; thus it is equivalent to specification of an exogenous process $\{i_t\}$ for the short-term nominal interest rate. We shall assume that $i_t > 0$ at all times.¹⁸ Let us suppose furthermore that fiscal policy is described by an exogenous primary-surplus process $\{s_t\}$. Since y_t is assumed to be exogenous, such a fiscal specification might correspond to an exogenous process $\{g_t\}$ for real government purchases, together with an exogenous process for a proportional tax rate $\{\tau_t\}$, with aggregate tax collections then evolving as $T_t = \tau_t P_t y_t$. Such a specification of fiscal expectations is particularly likely to apply in wartime, when government purchases vary for reasons largely independent of the state of the economy or the government's budget, and

¹⁸The theory extends directly to the case of a zero yield, as long as preferences involve satiation in money balances at some finite level. In that case, the equilibrium path of the price level would still be uniquely defined, but the equilibrium money supply would be indeterminate (it could take any value greater than or equal to the satiation level) in all periods with $i_t = 0$.

when the government's ability to further increase tax rates may also be tightly constrained.

Suppose also, for simplicity, that the public debt consists entirely of (riskless nominal) one-period Treasury bills. Then total government liabilities at the beginning of any period t are equal to

$$W_t^s = M_{t-1}^s + (1 + i_{t-1})B_{t-1}^s,$$

where B_t^s denotes the supply of Treasury bills at the end of period t (measured by their market value at the time of issuance). The flow budget constraint for the government implies that the supply of bills must satisfy

$$B_t^s = W_t^s - P_t s_t - M_t^s.$$

It follows that under this fiscal regime, total government liabilities evolve according to the law of motion

$$W_{t+1}^s = (1 + i_t) \left[W_t^s - P_t s_t - \frac{i_t}{1 + i_t} M_t^s \right]. \quad (2.25)$$

Our problem is now to solve for rational expectations equilibrium processes $\{P_t, M_t^s, W_t^s\}$ satisfying (2.16), (2.18), (2.22), (2.24), and (2.25), given exogenous processes $\{y_t, i_t, s_t\}$ and an initial quantity of nominal government liabilities.

The equilibrium conditions may be solved sequentially, as follows. We first note that (2.16) determines the equilibrium evolution of real balances, given the exogenous processes $\{y_t, i_t\}$. Substituting this solution for real balances into (2.24), we obtain

$$\frac{W_t^s}{P_t} = \sum_{T=t}^{\infty} \beta^{T-t} E_t \frac{\lambda(y_T, i_T)}{\lambda(y_t, i_t)} \left[s_T + \frac{i_T}{1 + i_T} L(y_T, i_T) \right], \quad (2.26)$$

where

$$\lambda(y, i) \equiv U_c(y, L(y, i)).$$

Note that all terms on the right-hand side are now functions of exogenous variables. Let us suppose that the fiscal expectations represented by the process $\{s_t\}$ are such that the right-hand side has a finite positive value.¹⁹ We then also observe that W_t^s is a *predetermined*

¹⁹If not, and if (as we assume) $W_t^s > 0$, then no equilibrium is possible. This would represent a monetary-

quantity in period t , under the fiscal regime specified here. Thus if $W_t^s > 0$, there is a unique equilibrium price level $P_t > 0$ that satisfies (2.26).

Once we have solved for P_t , (2.25) then implies a value for W_{t+1}^s , given by

$$W_{t+1}^s = (1 + i_t) \left[W_t^s - P_t s_t - \frac{i_t}{1 + i_t} P_t L(y_t, i_t) \right]. \quad (2.27)$$

We may then apply the same reasoning in period $t + 1$, solving (2.26) for P_{t+1} , and so on iteratively. We thus solve for unique equilibrium processes $\{P_t, W_t^s\}$, given an initial (positive) level of government liabilities and expectations regarding the exogenous processes. The equilibrium process for the price level then implies an endogenous evolution for the money supply, given by (2.16), and for any other asset prices that may be of interest, given by (2.17).

It might be thought problematic that the above construction of an equilibrium requires that W_{t+1}^s turn out to be positive in all periods. But in fact it suffices that the process $\{s_t\}$ satisfy bounds that imply that the right-hand side of (2.26) is positive at all dates. Under this assumption, one can show that the law of motion (2.27) always yields a positive value for W_{t+1}^s , given a positive value for W_t^s . This allows continuation of the construction forever. The constructed series must also satisfy (2.22) in order for it to represent an equilibrium. However, this simply requires certain bounds on the exogenous processes $\{y_t, i_t\}$; in particular, it suffices that $F(y_t, L(y_t, i_t))$ be a bounded process.

It may also be noted that no reference to equilibrium condition (2.18) has been made in this construction. This might lead to a suspicion that equilibrium is actually “overdetermined” under the kind of policy regime that has been postulated. But in fact the equilibrium just constructed necessarily satisfies (2.18). Note that if (2.26), with all time subscripts ad-

fiscal policy mix that is inconsistent; in equilibrium, one policy or the other would have to be expected to deviate from the proposed specification at some point. If one supposes that the the primary surplus process is unchangeable, this would mean that people would not be able to expect maintenance of the bill-rate peg forever. If the ‘inflation tax’ proceeds $iL(y, i)/(1 + i)$ are increasing in i , and expected primary deficits are too large to be consistent with the contemplated sequence $\{i_t\}$, an increase in the bill rate at some point might solve the problem. On the other hand, if projected primary deficits are too large, there might be *no* path of bill yields consistent with the $\{s_t\}$ process, which would then necessarily have to be adjusted. We do not take up such cases here, but instead consider the effects of fiscal news within the class of processes $\{s_t\}$ that are consistent with the postulated bill-rate peg.

vanced by one, is expected to determine the price level in period $t + 1$, it follows that in period t the conditional expectation should satisfy

$$\begin{aligned}
\beta E_t[\lambda(y_{t+1}, i_{t+1})P_{t+1}^{-1}] &= \frac{1}{W_{t+1}^s} \sum_{T=t+1}^{\infty} \beta^{T-t} E_t \lambda(y_T, i_T) \left[s_T + \frac{i_T}{1+i_T} L(y_T, i_T) \right] \\
&= \frac{1}{W_{t+1}^s} \left\{ \lambda(y_t, i_t) \frac{W_t^s}{P_t} - \lambda(y_t, i_t) \left[s_t + \frac{i_t}{1+i_t} L(y_t, i_t) \right] \right\} \\
&= \frac{\lambda(y_t, i_t)}{(1+i_t)P_t},
\end{aligned}$$

where the final line uses (2.27) to substitute for W_{t+1}^s . Thus (2.18) holds as well.

Note the effects of fiscal disturbances upon the price level in this equilibrium. News that reduces the conditional expectation at date t of current and/or future values of the primary surplus s_T , results (other things being equal) in a lower positive value for the right-hand side of (2.26). As a result, since W_t^s is predetermined, the equilibrium price level P_t must rise. Thus fiscal disturbances result in variations in the rate of inflation under such a regime. Furthermore, the nature of the effect is consistent with the observation that the outbreak of war in June 1950 (leading to expectations of lower government surpluses in the near future) resulted in an increase in the U.S. price level.

This effect of fiscal developments on inflation cannot really be explained by the fact that the money supply expands when the government budget deteriorates (or is expected to in the future). It is true that the quantity equation (2.16) is satisfied at all times; but the reason for the increase in the price level is supplied by (2.26), while (2.16) simply indicates how much the money supply must expand *given* that the price level rises. Furthermore, the fact that the price level may rise (and the money supply therefore expand) even *before* the reduced surpluses actually materialize, but simply because they are *expected*, makes it clear that a mechanical connection between the government budget and the monetary base is not at work.

The principle that most directly explains inflation determination under such a regime is instead the following: the price level adjusts as necessary to maintain intertemporal government budget balance. Such a *fiscal theory of the price level* makes the connection between

fiscal developments and price-level instability straightforward. The basic economic mechanism is the wealth effect of fiscal disturbances upon private expenditure. The anticipation of lower primary government surpluses makes households feel wealthier (able to afford a greater sum of private and government expenditure, given their expected after-tax income and given expected government purchases on their behalf), and thus leads them to demand goods and services in excess of those the economy can supply, except insofar as prices rise. A sufficient rise in prices can restore equilibrium by reducing the real value of the nominal assets held by households (which, in aggregate, are simply the nominal liabilities of the government). Equilibrium is restored when prices rise to the point that the real value of those nominal assets no longer exceeds the present value of expected future primary surpluses, since at this point the (private plus public) expenditure that households can afford is exactly equal in value to what the economy can produce.

Note that in this analysis, the inflationary effects of fiscal disturbances do not relate primarily to changes in expected seignorage revenues. The fiscal effect of the change in the real valuation of nominal government liabilities is also an important consequence of inflation; and this effect may well be the more important one for high-debt economies with sophisticated financial markets.

Indeed, the equilibrium just described remains well-defined in the limiting case of a “cash-less” economy. By this I mean an economy in which the transactions frictions responsible for the demand for cash balances are negligible.²⁰ In this limiting case, seignorage becomes negligible relative to the size of the government budget, and variations in real balances (in percentage terms) come to have a negligible effect on the marginal utility of income. This means that the marginal utility of income may be expressed simply as $\lambda(c_t + g_t)$, a decreasing function of total (private and public) purchases; that total nominal liabilities W_t correspond simply to the value of (interest-earning) public debt; and that the primary budget surplus need not be corrected to include interest savings on the monetary base in the evolution

²⁰See Woodford (1998a) for a more formal analysis.

equation for government liabilities. Thus in this limiting case, (2.26) and (2.27) reduce to

$$\frac{W_t^s}{P_t} = \sum_{T=t}^{\infty} \beta^{T-t} E_t \frac{\lambda(y_T)}{\lambda(y_t)} s_T \quad (2.28)$$

and

$$W_{t+1}^s = (1 + i_t) [W_t^s - P_t s_t] \quad (2.29)$$

respectively. This pair of equations can be solved recursively to obtain unique equilibrium sequences $\{P_t, W_t^s\}$, just as in the discussion above.

2.3 An Extension to Longer-Term Government Debt

A similar analysis is possible of price-support regimes with debt of longer duration, at the price of greater algebraic complexity. Here I consider a single, relatively simple case that illustrates the main new element introduced by longer-term debt: the fact that W_t^s is in general no longer completely predetermined, as it will depend upon the market value at t of government debt that has not yet matured. In this simple case, I shall suppose that all government debt consists of perpetuities with coupons that decay exponentially. Specifically, I suppose that a bond issued in period t pays ρ^j dollars $j + 1$ periods later, for each $j \geq 0$ and some decay factor $0 \leq \rho < \beta^{-1}$. The classic “consol” is a security of this kind, with $\rho = 1$. More generally, in an environment with stable prices, the *duration* of such a bond is $(1 - \beta\rho)^{-1}$. Thus our simple assumption allows us to analyze bonds of arbitrary duration. At the same time, we need consider the equilibrium price at each point in time of only one type of bond, because a bond of this type that has been issued k periods ago is equivalent to ρ^k new bonds. Let Q_t be the price in period t of a new bond. (Note that the bond’s *yield-to-maturity* is a monotonic function of this, given by $Q_t^{-1} - (1 - \rho)$.)

Now let us consider a price-support policy under which the central bank fixes the price of this bond each period. To simplify the analysis, let us suppose that $\{Q_t\}$ is an exogenously specified *deterministic* positive sequence.²¹ Then arbitrage considerations determine a unique

²¹This assumption still allows us to consider the effects of a one-time surprise change in monetary policy, after which households are assumed to have perfect foresight about the economy’s path. In the case of small enough random fluctuations in the bond-price targets, the effects of random variations in bond prices are approximately the same as in this perfect-foresight analysis, but the extension is not taken up here.

rational expectations equilibrium sequence for the short-term nominal interest rate i_t , given by

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

(I assume that the bond-price targets satisfy $Q_{t+1} > \rho^{-1}(Q_t - 1)$ at all times, so that the implied short-term interest-rate sequence satisfies $i_t > 0$.) The policy is thus equivalent to a Treasury-bill peg corresponding to this particular sequence, and we may solve for the equilibrium price level as above.

If the public debt consists solely of this single type of bond, the value of total government liabilities at the beginning of any period t is given by

$$W_t^s = M_{t-1}^s + B_{t-1}^s(1 + \rho Q_t),$$

where now B_t^s denotes the quantity of the geometrically decaying bonds outstanding at the end of period t . When $\rho > 0$, the dependence upon Q_t means that W_t^s is no longer a predetermined variable. Nonetheless, W_t^s depends only upon the predetermined variables M_{t-1}^s, B_{t-1}^s and the exogenous variable Q_t . Given the specification of monetary and fiscal policy from date t onward, and the predetermined values of M_{t-1}^s, B_{t-1}^s , there is a uniquely determined value for W_t^s . There is also a uniquely determined value for the right-hand side of (2.26), given the uniquely determined sequence $\{i_T\}$ just discussed. Thus (2.26) continues to uniquely determine the equilibrium price level P_t .

The money supply in period t is determined by money demand given this price level,

$$M_t^s = P_t L(y_t, i_t), \tag{2.30}$$

while the supply of bonds is then determined by the government's flow budget constraint,

$$B_t^s = Q_t^{-1}[M_{t-1}^s + B_{t-1}^s(1 + \rho Q_t) - P_t s_t - P_t L(y_t, i_t)]. \tag{2.31}$$

These equations then determine a value for W_{t+1}^s in the following period, given the exogenously specified value for Q_{t+1} . One can then use (2.26) to solve for P_{t+1} , and so on, iterating on the system of equations comprised by (2.26), (2.30), and (2.31). Once again, we assume

monetary/fiscal commitments such that the right-hand side of (2.26) is positive and finite at all times. Then if we start from initial conditions that imply a positive value for W_t^s at some initial date, the implied price level and the implied value of total government liabilities will also be positive at all later dates.

Thus the basic logic of price-level determination remains the same in this case. The main difference that longer-term debt makes is in the case of an unexpected *change* in the sequence of bond-price targets expected to be maintained from some date t onward. In the case that all debt is short-term, W_t^s is predetermined, and is thus unaffected by an unexpected change in monetary policy (current or future interest-rate expectations) at date t . A change in monetary policy then cannot affect the price level immediately, except insofar as it affects the present value of future budget surpluses (including the government's interest savings on the monetary base). This means that in the case of a high-debt economy, in which means for economizing on cash balances are also well-developed, the main effect of an increase in nominal interest rates by the central bank will be a faster rate of growth of nominal government liabilities, resulting in faster inflation. (This can be clearly seen in the case of the “cashless limit” discussed above.) Yet such a result makes it puzzling that in early 1951, the Fed wished to suspend its commitment to keep interest rates low, in order to contain the increase in prices underway at that time. (It would seem instead, under the present analysis, that an increase in nominal interest rates would only make the price level grow even faster.)

Allowing for longer-term government debt changes this conclusion. A decision to increase target bond yields lowers Q_t , and so lowers the value of W_t^s for any given predetermined values $M_{t-1}^s, B_{t-1}^s > 0$. In the absence of any change in the value of the right-hand side of (2.26), the increase in bond yields would therefore require a decline in the equilibrium price level P_t . In fact, the effects of interest-rate changes on the present value of future surpluses are likely to be small; in the “cashless limit”, the right-hand side of (2.28) is completely independent of monetary policy. Thus in the case of greatest interest, an increase in bond yields will be associated with deflation, initially, though it will also lead to faster subsequent growth of

nominal government liabilities, and consequently to a higher *eventual* price level. (It is this expectation of higher goods prices in the future that justifies the immediate decline in bond prices.)

The theory just expounded has several appealing features as a model of the U.S. bond price-support regime of the 1940s. First of all, it can explain why a regime that sought to fix nominal interest rates was consistent with relatively stable prices for so many years. Conventional theories of interest-rate pegs generally imply that such policies should lead to severe price instability. According to the familiar (Wicksellian) view summarized by Friedman (1968), an attempt to peg nominal interest rates should lead to either an inflationary or a deflationary spiral, requiring the peg to be abandoned before long. According to Sargent and Wallace (1975), instead, it should lead to indeterminacy of the rational expectations equilibrium price level, so that fluctuations in inflation may occur as a pure result of self-fulfilling expectations. The relative stability of prices in the 1940s is a puzzle from either point of view. In particular, it is striking that people continued to be willing to hold long-term U.S. Treasury securities at low nominal yields (below 2.5 percent per year) during the temporary high inflation (a 25 percent annual rate) of 1946-47; evidently there was little fear that this indicated that the price-support regime would generate chronic inflation, let alone an explosive Wicksellian “cumulative process”.

Friedman and Schwartz (1963, pp. 583-585) hypothesize that people did not expect inflation to continue because previous post-war periods (such as that following World War I) had been associated with deflation.²² But it is unclear why post-war periods should be expected to bring about deflation in the absence of a commitment to return to the gold standard at a pre-war parity, which there was no reason to expect following World War II. Eichengreen

²²However, they also discuss a mechanism closely related to the one analyzed here, when they discuss the role of the government’s budget surpluses. “Had the federal government not run a surplus, the public, with its accumulated liquid assets and pent-up demand, would have *tried* to spend more in the post-war period than it received,... [This] would have tended to raise prices and incomes and so would have reduced the level of liquid assets relative to income by this inflationary route.... As it was, the federal surplus enabled some reduction of liquid assets relative to income to be achieved without inflation” (p. 583). However, Friedman and Schwartz expound their idea in terms of effects of the government budget on “the market for loanable funds,” rather than a general-equilibrium analysis in terms of its effect upon private budget constraints, of the kind presented here.

and Garber (1991) instead propose that the policy regime of the early post-war period was actually an “implicit target zone” for the price level, with the price level maintained within the zone by an expectation of intervention should the boundaries ever be reached, even though little intervention was observed during these years. But such a hypothesis explains the behavior of the price level in terms of a purely hypothetical commitment to interventions that were not actually observed; it is hard to see why the public should have had confidence in such a presumed commitment. The explanation offered here, instead, depends only upon credibility of the commitment to interest-rate targeting (which commitment was being continuously demonstrated by the Fed’s actions), and beliefs about the exogenous evolution of primary budget surpluses (which again required only a simple extrapolation into the future of the policy that could already be observed).

The model can also explain the variations over time in the degree to which the regime generated inflation, at least broadly speaking. During World War II, the regime was inflationary, though much of the inflation was suppressed by a system of price controls, until their removal in 1946. This corresponded to a period of time in which large government deficits turned out to be necessary that would not initially have been expected. The transitory burst of inflation in 1946-47 represented delayed price adjustment once the wartime controls had been removed, rather than a demand-driven inflation. Once this adjustment had occurred, the regime was actually moderately deflationary in the early post-war period. The model predicts that pegging nominal interest rates at a low rate, with expectations of primary surpluses sufficient to make these interest rates consistent with equilibrium, should lead to steady mild deflation as the nominal liabilities of the government contract over time. Finally, inflation took off again suddenly in the second half of 1950, following the outbreak of war in Korea. The model explains why such a sudden change in expectations regarding the government budget should be inflationary. Furthermore, it can explain why the outbreak of war was able to cause inflation even *before* any large budget deficits materialized.²³ It is the

²³Note that the U.S. government budget continued to be in surplus during the second half of 1950 (Timberlake, 1993, p. 313).

present value of current *and expected future* surpluses that matters in equation (2.26); because of the crucial role of fiscal expectations in this theory, it is completely understandable that the outbreak of war should affect inflation before even it has significantly changed the government budget.

The model also offers an explanation for the abandonment of the price-support regime after March 1951. As just explained, the model implies that such a regime should lead to inflation when previously unexpected deficits come to be anticipated.²⁴ The Fed’s complaint that the regime had become an “engine of inflation” was justified, given the return to wartime fiscal policy. Furthermore, the model (in the version with long-term bonds) implies that an increase in bond yields should have been able to mitigate the degree to which prices needed to rise in the short run, following the revision of fiscal expectations. Hence the Fed’s interest in allowing bond yields to rise above the 2.5 percent ceiling, in order to contain inflation. The model implies that, in the absence of any change in fiscal expectations, the change in monetary policy actually implied greater *eventual* increases in the price level, though the suspension of the bond price-support policy allowed them to be delayed in time. Given the inflation that did in fact occur in the years subsequent to the “Accord”, it would be hard to call this an inaccurate prediction.²⁵

Finally, the model offers insight into why a policy regime of this kind would be appealing as an approach to war finance. First of all, the regime is one which loosens the constraint upon fiscal policy required for consistency with stable prices. Note that equilibrium condition (2.26) must hold in the case of *any* monetary and fiscal policies; the right-hand side is simply not always a function of purely exogenous variables. This implies that only a certain specific value for the expected present value of future primary government budget surpluses will be consistent with maintaining a price level $P_{t+j} = P_{t-1}$ for all $j \geq 0$. The bond price-

²⁴In the flexible-price model set out above, the price-level increase resulting from any single change in fiscal expectations occurs immediately, as soon as information changes. However, in a more realistic sticky-price extension of the model (expounded in Woodford, 1996), the price increase is predicted to be more gradual, and to be associated with high output during the period of adjustment.

²⁵Toma (1997, pp. 109-110) similarly interprets the Treasury-Fed “Accord” of March 1951 as a “default” on the government’s previous “commitment to long-run monetary constraint” under the bond price-support regime. See also Grossman (1990).

support regime, as modeled here, instead allows that present value to vary arbitrarily in response to fiscal shocks, within certain bounds. Such flexibility would obviously be quite valuable during wartime in particular. At the same time, the regime is one under which inflation variations are expected to be transitory; even when news of government budget shortfalls results in inflation, people can be confident (insofar as they expect equilibrium to be determined as described here) that inflation will quickly return to a stable (and quite low, possibly negative) long-run level. Such stable long-run inflation expectations would be valuable to a government needing to issue large quantities of long-term bonds exactly at a time when (because it has just been learned that the government's fiscal needs are more dire than previously anticipated) prices are currently rising. From this point of view, the Treasury's pressure upon the Fed to cooperate with such a regime during World War II would hardly be surprising.

3 Ricardian and Non-Ricardian Fiscal Policies

Before turning to the policy implications of this view of the effects of fiscal policy on inflation, it is appropriate to address some questions that may arise about the logic of the analysis just presented. One of the most obvious of these is, why should not *Ricardian equivalence* imply that fiscal disturbances have no effect upon aggregate demand, and hence no effect upon the price level?

The answer is that the usual argument for Ricardian equivalence *assumes* that changes in the government budget must involve no change in the *present value* of current and future budgets. (It is asserted, for example, that a current tax cut financed by government borrowing is necessarily accompanied by the expectation of tax increases at some later date or dates, of equal present value.) If this is so, then then equation (2.26) is satisfied by the *same* price level P_t as would have been the case in the absence of the fiscal disturbance. We would then indeed find that there should be no effect upon the price level of any such event. We have reached a different conclusion above because we have assumed that when war breaks out unexpectedly, this news *reduces* the present value of expected future budget surpluses.

We have thus considered a type of fiscal disturbance that Ricardian theory *assumes cannot occur*.

Let us call a fiscal policy commitment *Ricardian* if it implies that the present-value relation (2.24), or equivalently the transversality condition (2.21), necessarily holds for all possible goods-price and asset-price processes.²⁶ As an example of how this could be so, suppose that each period the primary surplus is set according to the rule

$$P_t s_t = \alpha W_t^s - \frac{i_t}{1 + i_t} M_t^s, \quad (3.1)$$

for some coefficient $0 < \alpha \leq 1$. This rule states that the primary budget surplus is chosen to pay off a certain positive fraction of existing government liabilities each period, but that the required surplus is adjusted to take account of the government's interest savings on the monetary base. Using the government's flow budget constraint,

$$M_t^s + E_t[R_{t,t+1}(W_{t+1}^s - M_t^s)] = W_t^s - P_t s_t, \quad (3.2)$$

we observe that (3.1) implies that

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

each period, and hence that

$$E_t[R_{t,T} W_T^s] = (1 - \alpha)^{T-t} W_t^s$$

for all $T > t$. But this guarantees that

$$\lim_{T \rightarrow \infty} E_t[R_{t,T} W_T^s] = 0,$$

²⁶This differs slightly from the definition of Ricardian policy originally proposed in Woodford (1995). There policy was defined to be Ricardian if it ensured that the value of the interest-earning public debt (as opposed to total government liabilities) satisfied a transversality condition. My reason for the original proposal was that I wanted to argue that the Ricardian postulate was implicit in standard quantity-theoretic analyses of price-level determination; the definition was therefore tailored to include a policy regime with an exogenous money supply and zero government debt at all times as an example of "Ricardian" policy. Such a regime is not Ricardian in the sense used here, since for price-level paths involving sufficient deflation, real balances would grow rapidly enough to violate the transversality condition (2.21); and this fact can be used to exclude deflationary paths that would otherwise satisfy all conditions for rational expectations equilibria (see, e.g., Woodford, 1999a, sec. 4.2). The definition of Ricardian policy used here, and in references such as Benhabib *et al.* (2000a), is conceptually preferable, as it defines the case in which the transversality condition ceases to play any role in equilibrium determination.

and hence that the transversality condition (2.21) holds, regardless of the paths of any of the endogenous variables. This condition plus the fact that (3.2) holds at all times can also be used to show that (2.24) necessarily holds.

In such a case, neither (2.21) nor (2.24) places any additional restrictions upon possible equilibrium paths for goods prices or asset prices. Rational expectations equilibrium is then defined simply by satisfaction of conditions (2.16), (2.18), and (2.22), along with the equation specifying monetary policy. None of the first three equations involves any fiscal variable (such as the government budget or the size of the public debt). Then if the monetary policy rule is *autonomous* in the sense defined above, the final equation is independent of all such variables as well, and the complete system of equations available to determine the equilibrium path of the price level is independent of all fiscal variables.

We thus obtain the *Ricardian Equivalence* proposition: if monetary policy is autonomous, the set of possible rational expectations equilibrium processes for goods and asset prices is *the same* for all alternative fiscal policy specifications within the Ricardian class. If monetary policy suffices to uniquely determine equilibrium in such a case, then a change in fiscal policy does not change the equilibrium path of prices. More typically, there will be a set of possible equilibrium price processes; but as the set is the same for each possible fiscal policy, one might suppose that the same equilibrium should be selected regardless of fiscal policy.²⁷

We have obtained a different result in the previous section because we have instead assumed a *non-Ricardian* fiscal policy specification. In the case of an exogenous real primary surplus process $\{s_t\}$, most paths for the price level and the nominal interest rate — even most of the paths that are consistent with the other requirements for rational expectations equilibrium — will not imply dynamics for total government liabilities that satisfy the transversality condition (2.21). Unlike what is assumed in (3.1), in the previous section we did not assume that the government budget would be automatically adjusted in response to changes in the level of total liabilities, so as to keep the latter quantity from growing expo-

²⁷In fact, I shall argue below that there may instead be good reasons for fiscal variables to affect the equilibrium selection in such a case. See section 3.2.

sively. The consequence is that only certain price-level paths will result in the transversality condition nonetheless being satisfied; these are those that satisfy condition (2.26). Hence the latter becomes a condition for equilibrium, making fiscal expectations relevant to price-level determination.

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

The explanation just offered raises questions of its own. It may be doubted whether it is in fact *possible* for fiscal policy to be anything other than Ricardian; if not, Ricardian equivalence should indeed hold (and the qualification about “Ricardian” fiscal policies may be omitted).

A common objection to the logical possibility of a non-Ricardian fiscal policy is to assert that condition (2.24) is nothing but the *intertemporal budget constraint* of the government; it is argued that government policy *must* be expected to satisfy this constraint, regardless of what prices the government faces, just as in the case of private households and firms. It would then follow that fiscal policy must necessarily be Ricardian.

It is true that general equilibrium models always assume that private households and firms optimize subject to a set of budget constraints that *imply* an intertemporal budget constraint, 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 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.

Indeed, it is not even necessary, at the level of general principle, for an intertemporal budget constraint of the form (2.24) to be satisfied *in equilibrium*. The famous overlapping generations model of Diamond (1965) describes a situation in which (because the equilibrium real rate of return does not exceed the economy's growth rate) it is possible for a government to finance transfers to an initial old generation by issuing debt that it then "rolls over" forever, without ever raising taxes. Of course, in the setting assumed above, condition (2.24) is a requirement for *equilibrium*, and the Diamond result that it is possible to violate this condition in equilibrium depends upon a number of rather special assumptions (even once one has granted that people are finite-lived), as explained in Santos and Woodford (1997).²⁸ But this is a consequence of optimal wealth accumulation by households, not of any constraint upon government borrowing programs other than the requirement that in equilibrium someone has to choose to *hold* the debt that the government issues.

Even if we wish to analyze the behavior 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 the theory of 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

²⁸Note that the possibility of rolling over government debt forever implies the possibility of an equilibrium involving an asset pricing "bubble"; the same people who hold the government debt in the debt roll-over example can hold the "bubble asset" instead. Thus the Santos-Woodford results on the fragility of examples with "bubbles" also apply to the possibility of rational expectations equilibria in which (2.24) is violated.

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.²⁹

Thus far I have addressed only the question of whether a commitment to satisfy an intertemporal government budget constraint is a *logical* necessity, as suggested by authors such as Buiter (1998, 1999). A subtler question is whether it makes sense to suppose that actual market institutions do not actually impose a constraint of this kind upon governments (whether logically necessary or not), given that we believe that they impose such borrowing limits upon households and firms. The best answer to this question, I believe, is to note that a government that issues debt denominated in its own currency is in a different situation than from that of private borrowers, in that its debt is a promise only to deliver *more of its own liabilities*. (A Treasury bond is simply a promise to pay dollars at various future dates, but these dollars are simply additional government liabilities, that happen to be non-interest-earning.) There is thus no possible doubt about the government's technical ability to deliver what it has promised; this is not an implausible reason for financial markets to treat government debt issues in a different way than the issuance of private debt obligations.

Furthermore, no one would doubt the ability of a government to issue an arbitrary amount of currency, without any commitment to retiring it from circulation (e.g., by running budget surpluses) at some later date. Market participants do not consider whether newly issued government liabilities of this kind exceed some bound on what it is considered prudent for

²⁹Woodford (1998c, section 5) gives an example of a case in which a non-Ricardian policy regime – one quite similar to our description above of a bond price-support regime, in fact – provides a simple way of implementing the Ramsey-optimal allocation of resources. (See also Sims (1999) and Christiano and Fitzgerald, 2000.) I do not wish to dwell upon this case here, as I do not wish to suggest that such a regime is likely to be a desirable policy commitment in general. But the example illustrates the point that the mere wish to hypothesize that government policy is optimal, from the point of view of some coherent objective that the government happens to pursue, is not in itself a reason to exclude the possibility of non-Ricardian policy.

the government to issue before deciding whether to accept them as payment for real goods and services; instead, each agent makes an individual decision about the terms on which to accept such government paper, that depend upon the expected rate of return on the asset in equilibrium. An issuance of further monetary liabilities by the government, without any increase in the real money balances that the private sector wishes to hold, requires an increase in the price level (reduction in the exchange value of the government paper) in order for the market to clear; but this is a condition for market equilibrium given the government's policy, and not a precondition that must happen to hold for other reasons in order for the government to be able to create additional money. All this is a familiar way of thinking about monetary financing of the government budget. But what is fundamentally different about the issuance of interest-earning debt, when this is simply a promise of future delivery of money?

A useful analogy is suggested by Cochrane (2000) and Sims (1999). Consider the equilibrium valuation of the stock of a company that pays no dividends, and instead distributes its earnings to its shareholders entirely through share repurchases. (The example may seem fanciful, but in fact share repurchases have become a more important source of distributions to shareholders in the case of some U.S. stocks, such as Microsoft, and the tax code favors this development.) The correct (beginning-of-period) equilibrium share price q_t for such a stock would generally be agreed to be given by the present-value relation

$$q_t S_t = \sum_{T=t}^{\infty} \beta^{T-t} E_t \frac{\lambda(y_T)}{\lambda(y_t)} e_T, \quad (3.3)$$

where S_t is the number of shares outstanding at the beginning of period t , e_t is the total earnings of the company used to finance share repurchases in period t , and $\lambda(y_t)$ is again the marginal utility of (real) income in period t . (I here assume the “cashless limit”, as is standard in financial economics.)

The argument for this valuation equation is simple. If the earnings stream $\{e_t\}$ were instead paid out in the form of dividends, the valuation formula (3.3) would follow from standard theory. But suppose instead that each period, the stock were to “split” at a rate

given by

$$\sigma_t = \frac{e_t}{q_t S_t - e_t}, \quad (3.4)$$

meaning that during period t , each owner of a share of the stock receives a distribution of σ_t additional units, followed by a repurchase of $(1 + \sigma_t)e_t/q_t$ shares of the outstanding stock. Under this alternative policy, the total payout by the company during period t is again equal to e_t (because the price per share after the split is $q_t/(1 + \sigma_t)$), and the value of the distribution per share is again e_t/S_t . The same prices and portfolio allocations then continue to describe an equilibrium; it should not matter whether the distribution is called a distribution of stock followed by a repurchase of exactly the number of new shares just issued, or a cash dividend.

On the other hand, the fact that the stock splits at exactly the rate (3.4) should be irrelevant to its valuation. Whatever the process $\{\sigma_T\}$ describing the expected rate of splitting for dates $T \geq t$, the equilibrium evolution of the total value of the company's stock $q_t S_t$ should be the same, as long as the process $\{e_T\}$ describing the total resources used to finance repurchases remains the same. Thus (3.3) should continue to apply, regardless of the splitting policy. Note that for any given process $\{e_T\}$ specifying the funds available for repurchases, and any given process $\{\sigma_T\}$ describing the rate of splitting, the evolution of the number of outstanding shares $\{S_T\}$ is given by the accounting identity

$$S_{t+1} = (1 + \sigma_t)[S_t - e_t/q_t]. \quad (3.5)$$

Equations (3.3) and (3.5) then jointly describe the evolution of the endogenous variables $\{q_t, S_t\}$ under a rational expectations equilibrium. Note that the equilibrium valuation q_t implied by (3.3) is necessarily such that (3.5) implies a positive number of outstanding shares at the beginning of the following period, so that these two equations can be solved recursively forever, yielding a positive equilibrium share price at all dates.

One may now observe a formal analogy between equations (3.3) and (3.5) for the valuation of the zero-dividend stock and equations (2.28) and (2.29) for the equilibrium valuation of nominal government liabilities (also in the “cashless limit”). To the variable S_t in the stock example there corresponds W_t^s (the number of dollar claims on the government outstanding

at the beginning of period t); to q_t there corresponds $1/P_t$ (the exchange value of each dollar's worth of public debt); to e_t there corresponds s_t (the stream of "earnings" used to retire public debt); and to σ_t there corresponds i_t (the rate at which additional dollar claims are distributed to the holders of existing claims).

The advantage of considering this analogy is that it is clear in the stock case that (3.3) is an *equilibrium condition* that determines the share price, given earnings expectations (that may well be causally independent of the evolution of the company's stock value), and not a *constraint* upon possible corporate policies. There is no requirement, enforced by the financial markets, that the company generate earnings that validate whatever market valuation of its stock may happen to exist. Indeed, if the company's earnings were to be determined by such a requirement, its equilibrium share price would come to be *indeterminate*, just as the equilibrium price level is indeterminate under a bond-price support regime, if the government budget is determined by a Ricardian rule such as (3.1).

The analogy is also deeper than a mere similarity of algebraic form. The economic mechanism that ensures that (3.3) must hold in equilibrium is in fact the requirement that households must exhaust their intertemporal budget constraints if they are behaving optimally; a stock valuation $q_t S_t$ in excess of the present value of future corporate earnings would imply that households should believe themselves wealthy enough to purchase a stream of goods with greater value than the economy's product (the source of corporate earnings), which (if households exhaust their budget constraints) will be inconsistent with goods market clearing.³⁰

Finally, the stock analogy provides an answer to a common question about the fiscal theory of the price level: What is special about the government, that *its* budget should be able to determine the equilibrium price level (under policy regimes like the bond price-support regime analyzed above), and not that of any other person or organization? The

³⁰Above, I have instead presented a heuristic argument for (3.3), starting from the standard present-value theory in the case that all distributions are cash dividends. But that latter theory relies upon the requirement that households exhaust their intertemporal budget constraints in order to exclude the possibility of an equilibrium pricing "bubble"; see, e.g., Santos and Woodford (1997).

answer is not simply that national governments routinely issue liabilities that entitle the holders only to the receipt of further similar liabilities in the future; as we have seen, a private organization such as Microsoft could do this as well, in principle. (It would call its liabilities “stock” rather than “debt” in such a case.) The other crucial special feature of a national government is that prices are commonly quoted in units of *its* liabilities, *i.e.*, in terms of the national currency. If it happened that prices of goods and services were routinely quoted in units of Microsoft stock, say, then it would indeed be Microsoft’s budget that would determine the price level, and not that of the federal government.

3.2 Consequences of a Government Borrowing Limit

Finally, even if one supposes that markets *do* impose a limit on how much a government can borrow, it is not clear that this invalidates the analysis given above of the way in which fiscal developments determine the equilibrium price level under a bond price-support regime. Suppose that there is a finite level of real public debt (the determination of which we shall not model here) beyond which new debt issues will simply not be purchased. This would mean that it is not possible for a government to refuse to adjust its budget when its debts grow too large; thus a purely exogenous primary surplus process, as assumed in section 2, would be precluded.

For the sake of concreteness, suppose that there is an upper bound on the possible end-of-period value of outstanding government liabilities, so that government borrowing must remain within the bound

$$\frac{M_t^s + Q_t B_t^s}{P_t} \leq \bar{d}$$

at all times, for some finite positive bound \bar{d} . (For simplicity, I shall assume in the discussion to follow that government debt consists entirely of single type of bond with geometric coupons, the price of which is Q_t .) This implies a lower bound $s_t \geq w_t - \bar{d}$ upon possible levels of the real primary surplus, where $w_t \equiv W_t^s/P_t$ is the real value of beginning-of-period government liabilities. We may similarly imagine that there should be a lower bound on the value of end-of-period liabilities as well (not so much because the private sector will

not allow unlimited government lending, but because we may suppose that governments will never actually be so generous); for simplicity, let us suppose that this is zero. This would imply an upper bound upon feasible primary surpluses as well, $s_t \leq w_t$, the value that would leave the government with no net liabilities at the end of the period.³¹ Then the fact that total government liabilities must satisfy the bounds

$$0 \leq \frac{M_t^s + Q_t B_t^s}{P_t} \leq \bar{d} \quad (3.6)$$

implies that the primary surplus process $\{s_t\}$ would have at all times to satisfy the bounds

$$w_t - \bar{d} \leq s_t \leq w_t. \quad (3.7)$$

Condition (3.6) implies that in any equilibrium

$$\begin{aligned} -E_t \beta^T U_m(y_T, m_T) m_T &= -E_t \beta^T \lambda(y_T, i_T) \frac{i_T}{1 + i_T} \frac{M_T^s}{P_T} \\ &\leq E_t \beta^T \lambda(y_T, i_T) \left[\frac{1}{1 + i_T} \frac{M_T^s}{P_T} + \frac{Q_T B_T^s}{P_T} \right] \\ &\leq E_t \beta^T \lambda(y_T, i_T) \frac{M_T^s + Q_T B_T^s}{P_T} \\ &\leq \beta_T \lambda(y_T, i_T) \bar{d}. \end{aligned}$$

Furthermore, the third term in this series is equal to

$$E_t \beta^T \lambda(y_{T+1}, i_{T+1}) \frac{W_{T+1}^s}{P_{T+1}}, \quad (3.8)$$

so that expression (3.8) must be bounded above and below by the initial and final terms in the previous series. But equilibrium condition (2.22) implies that the initial term must converge to zero as T is made unboundedly large; and for all interest-rate paths $\{i_T\}$ satisfying bounds sufficient to imply that $\{\lambda(y_T, i_T)\}$ is uniformly bounded,³² the final term must converge to zero as well. Thus (3.8) must converge to zero as T becomes large as well, and the

³¹As noted earlier, this bound would already imply some government lending, but the government would discount private obligations only in the amount that the central bank could hold as backing for the monetary base.

³²This assumption is certainly not problematic in the case of a bond price-support regime which implies bounds on interest rates that are independent of the evolution of goods prices.

transversality condition (2.21) is necessarily satisfied. It follows that any fiscal policy that satisfies the bounds (3.7) at all times is essentially Ricardian;³³ and condition (2.24) places no restrictions upon possible equilibrium paths of the price level.

Nonetheless, fiscal disturbances might well affect the price level. To see why, let us consider a modified version of our previous analysis of the bond price-support regime. Suppose that the government’s “desired” real primary surplus evolves according to some exogenous stochastic process $\{\bar{s}_t\}$ as assumed earlier, and that the actual budget surplus equals this, except when one of the bounds in (3.7) would be violated; in the latter case, the real primary surplus is equal to the bound. Thus under this fiscal regime,

$$s_t = s(w_t, \bar{s}_t) \equiv \begin{cases} w_t & \text{if } w_t < \bar{s}_t \\ \bar{s}_t & \text{if } \bar{s}_t \leq w_t \leq \bar{s}_t + \bar{d} \\ w_t - \bar{d} & \text{if } w_t > \bar{s}_t + \bar{d} \end{cases}$$

Otherwise, policy is as assumed earlier: there is a single type of interest-earning government debt (with geometric coupons), and monetary policy is specified by an exogenous bond-price sequence $\{Q_t\}$.

Note that as long as the fluctuations in $\{\bar{s}_t\}$ are small enough (or the bounds (3.7) are loose enough), the equilibrium presented earlier is *still* a rational expectations equilibrium under the modified specification of fiscal policy. This is because the equilibrium described earlier does *not* involve explosive growth of the real public debt. If the bounds (3.7) would not have been violated in equilibrium in any event, stipulating that fiscal policy must respect those bounds does nothing to exclude an equilibrium of that kind.

Thus one still can have an equilibrium in which fiscal disturbances affect the price level; this is simply no longer the *only* equilibrium. However, it continues to be a *locally* unique equilibrium, in the following sense: it is the only equilibrium in which the state variable $\{(M_t^s + Q_t B_t^s)/P_t\}$ remains forever in the interior of the interval (3.6). Thus there is no other equilibrium “near” this one in the sense of involving nearby values for all endogenous

³³The qualification is that the transversality condition has not been shown to hold for *all* possible price-level and interest-rate paths, but only those that satisfy certain bounds on interest rates and the equilibrium condition (2.22). But this near-Ricardian property suffices to imply that the transversality condition, or alternatively condition (2.24), places no additional restrictions upon the possible equilibrium paths of the price level, given a monetary policy that maintains interest rates within the assumed bounds.

variables (including this one) at all times. This concept of local uniqueness or determinacy of equilibrium suffices, for example, for the usual sorts of “comparative statics” analyses of the effects of perturbations of the model (see, *e.g.*, Woodford, 1998a, 1999a).

If we are simply interested in the existence of a determinate equilibrium in which fiscal disturbances affect the price level, then the *global* specification of the fiscal policy rule does not matter: all that matters is how the government’s budget would be different in the case of price-level and asset-price paths that are close to the equilibrium paths. It thus only matters that fiscal policy be *locally non-Ricardian*:³⁴ that the dynamics of the public debt be *locally* explosive, for most price-level paths near the equilibrium path. The existence of debt limits such as (3.6), that eventually constrain the growth of the public debt in the case of paths far from the equilibrium in question, do nothing to interfere with this.

Despite this conclusion, under fiscal policy of the type just described, Ricardian Equivalence holds, when properly understood. The *set* of possible state-contingent equilibrium paths is the same regardless of the evolution of the desired primary surplus process $\{\bar{s}_t\}$. But under this policy regime, the set of equilibrium price processes is quite large; among the possibilities is a solution in which the price level happens to fluctuate at the same time as unexpected changes in the desired primary surplus.

In order to illustrate the multiplicity of possible equilibria, it is useful to further specialize our example, and consider the case in which $\bar{s}_t = \bar{s} > 0$ forever, $Q_t = \bar{Q} < (1 - \rho)^{-1}$ forever, and $y_t = \bar{y} > 0$ forever. Let $\bar{i} > 0$ be the constant nominal interest rate implied by the bond-price target, and $\bar{m} \equiv L(\bar{y}, \bar{i})$ be the implied stationary equilibrium level of real money balances. We assume that

$$\bar{d} > \frac{1}{1 - \beta} \left[\beta \bar{s} + \frac{\bar{i}}{1 + \bar{i}} \bar{m} \right] > 0, \quad (3.9)$$

so that an equilibrium of the kind described earlier exists, and remains forever within the interior of the bounds (3.7). To simplify, let us consider simply the set of perfect foresight

³⁴This is what Leeper (1991) calls “active” fiscal policy; his definition is for a specific parametric family of fiscal policy rules, but his more general intent seems to be the one identified here. Note that his analysis of equilibrium is purely local, in that he relies upon linear approximations to the equilibrium conditions, and considers only non-explosive solutions. See Woodford (1998a) for further discussion of “locally Ricardian” and “locally non-Ricardian” policies.

(deterministic) equilibria (p.f.e.) consistent with such a regime.

Given an initial condition $W_0^s \equiv M_{-1}^s + \bar{Q}B_{-1}^s > 0$, any path for $\{w_t\}$ satisfying the difference equation

$$w_{t+1} = \beta^{-1} \left[w_t - s(w_t, \bar{s}) - \bar{m} \left(\frac{\bar{i}}{1 + \bar{i}} \right) \right] \quad (3.10)$$

for all $t \geq 0$, and the transversality condition

$$\lim_{t \rightarrow \infty} \beta^t w_t = 0, \quad (3.11)$$

represents a p.f.e. The equilibrium path of the price level corresponding to any such solution is given by

$$P_t = \frac{W_0^s}{w_0} [\beta(1 + \bar{i})]^t.$$

A graph of the right-hand side of (3.10) is shown in Figure 2. Under assumptions (3.9), there are three possible steady-state solutions to (3.10), given by

$$\begin{aligned} \underline{w} &\equiv -\frac{1}{\beta} \frac{\bar{i}}{1 + \bar{i}} \bar{m} < 0, \\ w^* &\equiv \frac{1}{1 - \beta} \left[\bar{s} + \left(\frac{\bar{i}}{1 + \bar{i}} \right) \bar{m} \right] > 0, \\ \bar{w} &\equiv \frac{1}{\beta} \left[\bar{d} - \left(\frac{\bar{i}}{1 + \bar{i}} \right) \bar{m} \right] > w^*. \end{aligned}$$

In addition to these three solutions with a constant level of real government liabilities, there exists a continuum of non-stationary solutions to the difference equation. In particular, for any choice of $w_0 > 0$, the sequence can be continued forever. (An example of a non-stationary solution with $w^* < w_0 < \bar{w}$ is shown in the figure.) Because the implied sequence $\{w_t\}$ is necessarily bounded, the transversality condition (3.11) is necessarily satisfied, and as long as $w_0 > 0$, the implied price sequence is forever positive. Thus this entire continuum of solutions represents alternative possible p.f.e. under such a regime.

One of these solutions, the one with $w_t = w^*$ forever, is the fiscalist equilibrium discussed earlier. Previously, when we assumed that $s_t = \bar{s}$ at all times, this was the only possible equilibrium; in that case, the corresponding graph would continue the steep center segment off indefinitely in both directions, and all solutions to the difference equation starting from

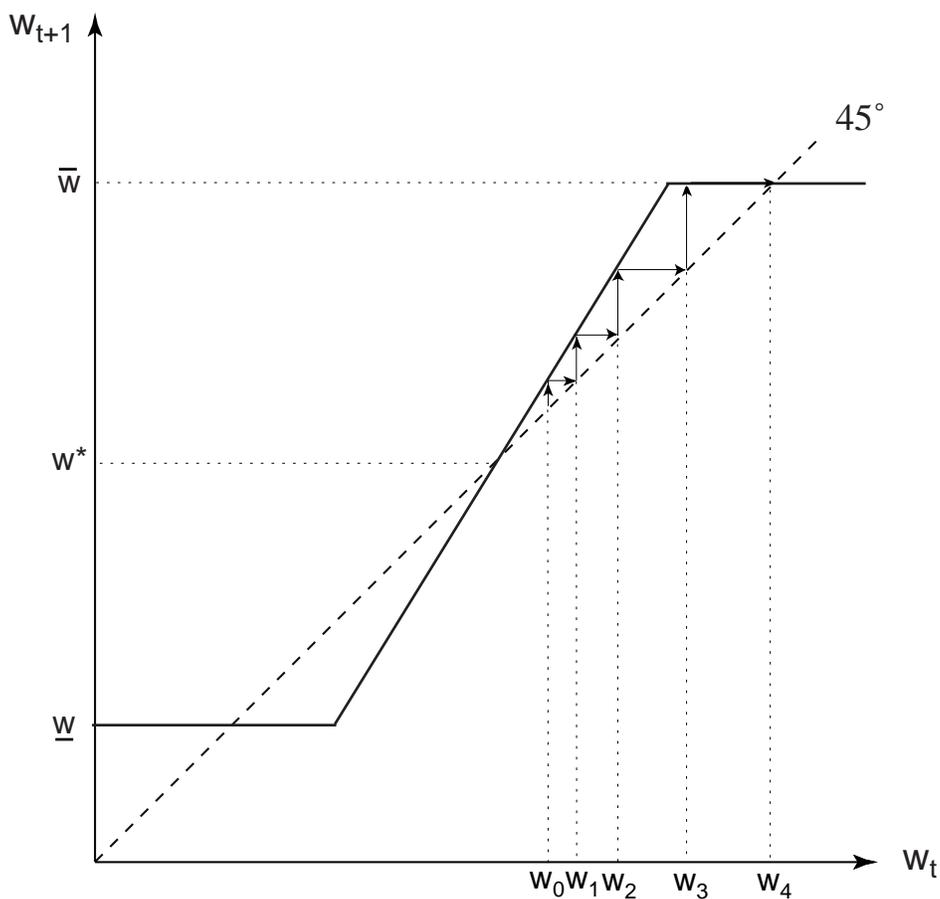


Figure 2: Perfect foresight debt dynamics.

$w_0 \neq w^*$ would be explosive, and would violate (3.11). With the assumed bounds on government liabilities, this is no longer true. For example, another equilibrium is the one shown in the figure, in which the price level is initially (and forever after) lower than in the fiscalist equilibrium. This lower price level is sustained as an equilibrium by people's (correct) expectations that the exploding public debt will eventually lead to a fiscal consolidation, following which primary surpluses are increased. Anticipation of this leads to feel less wealthy, so that lower prices are required for goods markets to clear.

But the fiscalist equilibrium is still the *only* equilibrium in which neither bound in (3.6) is ever binding; thus this equilibrium is locally isolated, as mentioned above. One may also observe that none of the other p.f.e. are locally unique; corresponding to any equilibrium

like the one with an exploding public debt shown in Figure 2, there exist an infinite number of other equilibria arbitrarily close to it (in the sense that the price level and other variables are nearly the same, but not exactly the same, at all times as in this equilibrium). Slightly different expectations about the size and timing of the eventual fiscal consolidation are equally consistent with equilibrium.

Given the existence of a multiplicity of possible self-fulfilling expectations, an obvious question is whether the fiscalist equilibrium remains a plausible *equilibrium selection*, under a regime of the kind just described. This is presumably what McCallum (1998) means to challenge, in arguing that the fiscalist equilibrium is a “bubble equilibrium”. However, what constitutes a “bubble equilibrium” is often in the eye of the beholder; one might at least as easily say that the equilibrium shown in Figure 2 is a “bubble equilibrium”, as the higher value of the public debt is sustained by self-fulfilling expectations of a future fiscal consolidation. Here I present an argument for why expectations might naturally coordinate upon the fiscalist equilibrium.³⁵

Essentially, I would argue that the fiscalist equilibrium is an especially plausible focal point for households’ expectations, because it involves *simpler* fiscal expectations than the other possible equilibria. More formally, one may note that these particular expectations are ones that households could converge upon through an Evans-Ramey (1998) process of “expectation calculation”. Evans and Ramey define an intuitively plausible form of iterative refinement of expectations, in which people make use of their knowledge of a true model of the economy to decide what to expect should happen in equilibrium. The process is one which converges — *if it converges* — to a rational expectations equilibrium (r.e.e.); Evans and Ramey are instead interested in the kind of approximate r.e.e. that may result from iterating only a finite number of times, owing to “calculation costs”. One might alternatively use the same analysis to consider the stability of alternative r.e.e. under the calculation dynamics,

³⁵It is worth noting that in the present example, there is no “monetarist equilibrium” (the selection principle that McCallum would instead prefer), because of the endogeneity of the money supply. Rational-expectations monetarist analyses generally argue that the price level should be indeterminate under a monetary policy of the kind considered here.

and use this judge whether a given equilibrium is likely to be reached in practice.

Such an analysis begins with a mapping of expectations into equilibrium outcomes. To simplify, I shall suppose that there is no uncertainty about the deterministic paths of real and nominal interest rates, as these are the same in *each* of the continuum of perfect foresight equilibria just described; I shall only consider the coordination of expectations upon one expected path or another for the primary budget surplus $\{s_t\}$. In the model just considered, a household's optimal plan for the sequences $\{c_T + g_T, m_T\}$ at dates $T \geq t$ depends solely upon its estimate of its "total wealth" $W_t/P_t + H_t$, where "human wealth" is defined as

$$H_t \equiv \sum_{T=t}^{\infty} \beta^{T-t} [y - s_T].$$

(Here we have included government purchases as part of the household's "income" net of taxes, as they substitute for private expenditures.) Specifically, in the context of a constant real rate of return on (non-monetary) savings equal to $\beta^{-1} - 1$, and a constant nominal interest rate \bar{i} , the optimal plan involves a constant level of total (private plus public) purchases, $c_T + g_T = y^d$, and a constant level of real money balances, $m_T = L(y^d, \bar{i})$, for each $T \geq t$, where y^d is the highest level of total purchases consistent with the household's intertemporal budget constraint, *i.e.*, the solution to

$$\frac{1}{1 - \beta} \left[y^d + \frac{\bar{i}}{1 + \bar{i}} L(y^d, \bar{i}) \right] = \frac{W_t}{P_t} + H_t. \quad (3.12)$$

In the case of arbitrary fiscal expectations, I shall assume that the representative household chooses consumption $c_t = y_t^d - g_t$ and money balances $M_t = P_t L(y_t^d, \bar{i})$, where the values of g_t and P_t are observed by the household at the time that it decides, and y_t^d is the solution to (3.12), given the observed values of W_t and P_t , and the household's subjective estimate H_t^e of its human wealth H_t .

If each household has a common (though not necessarily rational) expectation H_t^e , then goods market clearing requires that $y_t^d = y$. This occurs if and only if the price level satisfies

$$\frac{W_t^s}{P_t} + H_t^e = x \equiv \frac{1}{1 - \beta} \left[y + \frac{\bar{i}}{1 + \bar{i}} L(y, \bar{i}) \right]. \quad (3.13)$$

Corresponding to any sequence³⁶ of expectations $\{H_t^e\}$, the corresponding sequence of *temporary competitive equilibrium* (t.c.e.) paths for the price level is given by (3.13), where W_t^s evolves according to

$$W_{t+1}^s = P_t[(1 + \bar{v})(x - H_t^e - s_t) - \bar{v}L(y, \bar{v})], \quad (3.14)$$

and the primary budget surplus each period is given by

$$s_t = s(W_t^s/P_t, \bar{s}). \quad (3.15)$$

In this way, an arbitrary evolution over time of beliefs about future government budgets (summarized by the evolution of $\{H_t^e\}$) gives rise to a sequence of actual government budgets (the t.c.e. sequence $\{s_t\}$ given by (3.15)).

We now consider what expectations a household might have which understands the above model, and hence the mapping just described. Evans and Ramey propose that a household should begin by conjecturing a path for the economy (for example, the t.c.e. dynamics generated by some simple expectational hypothesis such as “adaptive expectations”), and then refine this conjecture by iterating on the mapping just derived. That is, they propose that a household should form *its own* forecast of the economy’s evolution by assuming that the beliefs of *others* will evolve in the conjectured way, and then calculating the t.c.e. dynamics that should actually occur given that others have beliefs of the simpler sort. (The process might then be iterated again, if the household instead assumes that other households will form their beliefs by iterating once, and so on.)

Any of the sequences $\{s_t\}$ associated with one of the continuum of p.f.e. identified earlier is a fixed point of this mapping; thus the proposed method of mapping expectations into t.c.e. outcomes does not exclude any of these possibilities by itself. And the beliefs obtained (even if one imagines iteration an infinite number of times) obviously depend upon what the initial conjecture is. But we may still regard beliefs as more likely to be converged upon

³⁶As usual (see, e.g., Grandmont, 1983), certain bounds upon expectations are required in order for a temporary equilibrium to exist. In the present context, equations (3.14) – (3.15) below imply uniquely defined temporary equilibrium sequences with $P_t > 0$ and $W_{t+1}^s > 0$ each period, starting from any positive initial level of nominal government liabilities, as long as expectations satisfy the bound $H_t^e < \bar{H}$ each period, where \bar{H} is defined in (3.17) below.

if they have a larger “basin of attraction” under the expectation-calculation dynamics (*i.e.*, iteration of the above map). It is thus noteworthy that the fiscalist equilibrium (corresponding to the expectation that $s_T = \bar{s}$ for all $T \geq t$) is the *only* p.f.e. with the property that expectations converge to it under the calculation dynamics, from any near enough initial beliefs. Specifically, suppose that one initially conjectures an evolution of fiscal beliefs such that the sequence $\{H_T^e\}$ is expected to satisfy the bounds

$$\underline{H} < H_T^e < \bar{H} \quad (3.16)$$

for all $T \geq t$, where

$$\begin{aligned} \underline{H} &\equiv x - \bar{s} - \bar{d}, \\ \bar{H} &\equiv x - \bar{s} - \frac{\bar{i}}{1 + \bar{i}} L(y, \bar{i}). \end{aligned} \quad (3.17)$$

Then (3.13) implies that each period, the t.c.e. price level will satisfy

$$\bar{s} < \frac{W_T^s}{P_T} < \bar{s} + \bar{d},$$

so the neither bound on government liabilities ever binds, and $s_T = \bar{s}$ each period. One thus obtains convergence to the beliefs associated with the fiscalist equilibrium, after even a single iteration of the expectation-calculation algorithm, starting from any initial conjecture satisfying the bounds (3.16).³⁷

Furthermore, an initial conjecture satisfying (3.16) would not be implausible. For example, suppose a household generates its initial conjecture by assuming that the beliefs of others will evolve according to an “adaptive expectations” formula. Since H_t^e is an estimate of $(1 - \beta)^{-1}$ times a certain (discounted) long-run average value of $y - s_T$, one might assume that people will adjust their estimate in response to the discrepancy between their current estimate and the most recently observed value of the variable in question. This would suggest

³⁷On the other hand, no other p.f.e. has the property that its basin of attraction includes any neighborhood of the equilibrium beliefs themselves. This is because no other p.f.e. is locally isolated, and every p.f.e. is a fixed point of the expectation-calculation mapping.

a rule of the form

$$\begin{aligned} H_{T+1}^e &= \lambda H_T^e + (1 - \lambda)(1 - \beta)^{-1}(y - s_T) \\ &= \lambda H_T^e + (1 - \lambda)(1 - \beta)^{-1}(y - s(x - H_T^e, \bar{s})). \end{aligned}$$

Combining this law of motion for expectations with (3.13) – (3.15), one generates a t.c.e. in which expectations satisfy the bounds (3.16) forever, as long as one conjectures that expectations will initially start from a value of H_t^e satisfying the bounds. (The same would be true for a large number of other simple adaptive schemes.)

Thus it is easy to describe reasoning that would lead households who understand the model to converge upon expectations that would bring about the fiscalist equilibrium, rather than any of the others. But if one accepts that this should be equally true following a fiscal disturbance (say, a one-time permanent change in the value of \bar{s} , correctly understood by the households who form their beliefs according to the above algorithm), then such a disturbance should affect the price level in the way described by the fiscal theory, and contrary to the doctrine of Ricardian Equivalence.

3.3 Empirical Evidence on the Character of Fiscal Policy

Thus far our primary concern has been with the logical possibility of a non-Ricardian fiscal regime. It is worth asking as well whether actual fiscal policies seem to be of this kind. This has been challenged in a number of studies, though on the whole there has been little empirical analysis relative to the amount of recent theoretical interest in regimes of this kind.³⁸ It will take us too far afield to address the issue in any detail here; but a few comments on the relevance of the empirical literature to our discussion may nonetheless be appropriate.

Several studies have sought to show that fiscal policy is Ricardian, at least in particular places and times, such as the U.S. in the twentieth century. For example, Bohn (1998a) regresses the primary U.S. government budget surplus (as a share of GDP) on privately held

³⁸Two noteworthy early attempts were Shim (1984) and Leeper (1989).

U.S. public debt (again as a share of GDP), along with other variables that are regarded as plausible arguments of a fiscal policy rule, and finds a significantly positive coefficient (with a point estimate on the order of three to five percent) for each of the sample periods that he considers. Bohn interprets his results as estimates of the coefficients of a fiscal policy rule, and in particular he interprets the regression coefficient on the debt/GDP ratio as indicating the degree of feedback from the size of the public debt to the size of the primary surplus — *i.e.*, as the coefficient α in a feedback rule of the form (3.1). If this is correct, then our reasoning above would imply that fiscal policy over this period was Ricardian, as the transversality condition would hold for all inflation and asset-price processes.³⁹

However, such a regression coefficient need not have a structural interpretation of the proposed sort. In the case of an exogenous primary surplus process — a simple example of a non-Ricardian regime — the existence of an equilibrium present-value relation between the value of the public debt and expected future primary surpluses would imply that variations in the value of the public debt relative to GDP would tend to forecast subsequent variations in primary surpluses relative to GDP. The reason is the same as the reason that, according to the present-value theory of stock prices, the price-earnings ratio of a stock should forecast future earnings growth; yet no one would interpret econometric support for the latter prediction as a demonstration that high p/e ratios *cause* companies' earnings to grow faster. Similar alternative interpretations are possible in the case of the more sophisticated “tests” for Ricardian as opposed to non-Ricardian policy presented by Canzoneri *et al.* (1999).⁴⁰ Indeed, as Cochrane (1998) and Woodford (1998b) demonstrate, it is possible to propose non-Ricardian policy regimes, under which the inflation process evolves primarily in response to fiscal disturbances, which match quite well the joint stochastic processes of inflation, interest rates, the public debt, and the primary budget surplus for the U.S. since 1960. Thus there are no aspects of the co-movements of those series that are incompatible

³⁹Bohn (1998b) suggests exactly this interpretation of the results reported in Bohn (1998a). Note that the analysis above does not apply precisely to the rule estimated by Bohn, because his estimated rule does not have a term responding to variations in the interest saved on the monetary base; but it is unlikely that this matters much for the validity of his conclusion.

⁴⁰See Cochrane (1998, 1999) and Woodford (1998b) for detailed discussion.

with Ricardian regimes (and fiscal determination of the price level) as such.

A general difficulty with econometric tests of whether policy is Ricardian is that in the model expounded above, the present-value relation (2.24) must hold *in equilibrium*, whether policy is Ricardian or not. Thus the empirical question is not whether or not such a relation appears to hold in practice; it is whether the fiscal policy is such that it *would* also have held in the case of other price paths that have not actually occurred, and perhaps could not ever occur. This is inherently a difficult question to try to answer, and it plainly cannot be answered in the absence of assumptions about the structural form of the policy rules in place. (This does not, however, make it any less meaningful an empirical question than the other counterfactual questions that econometricians habitually address, when estimating elasticities of demand and the like.) Furthermore, simple structural specifications like the one proposed by Bohn are not too persuasive in this context, owing to the fact that the process that determines the size of government budgets clearly involves considerable lags. It is thus quite plausible that market participants will often have additional important information about likely future budgets, beyond that contained in a small number of variables like those included in Bohn's regression; but then the possibility that a regressor such as the current debt/GDP ratio responds to such information must be taken seriously.

Bohn (1998b) suggests that his proposed structural interpretation of his regression coefficient is more sensible than the alternative suggested by Cochrane (1998), because it is based on "a coherent model of government behavior," namely a model of optimal tax-smoothing. But while the theoretical model to which Bohn refers may justify the inclusion of certain regressors in his fiscal rule, it does not provide any theoretical justification for the assumption that no *other* information can help to forecast future budgets, and it is this exclusion restriction that is crucial to Bohn's proposed identification. Nor is it really true that the model of optimal tax smoothing provides theoretical justification for assuming a fiscal rule of Bohn's form (in particular, one in which the primary budget surplus is a function of the size of the public debt). The model of optimal tax-smoothing justifies a particular pattern of state-contingent government budgets, but there is no *unique* form of feedback rule for the

government budget that implements the desired equilibrium. (Once again, different specifications of government policy out of equilibrium may be equally consistent with a given equilibrium.) For example, Woodford (1998c) shows how an optimal tax-smoothing policy can be implemented by a regime that combines a non-Ricardian fiscal policy (specifically, one in which the real primary budget surplus is exogenous) with an interest-rate peg for monetary policy — exactly the type of regime analyzed in section 1.

An alternative possible source of information about the likely form of the fiscal policy rule can be obtained from estimates of the monetary policy rule, combined with deductions about the kind of equilibrium behavior that should result from alternative monetary/fiscal policy rule combinations. For example, John Taylor (1993) argues that U.S. monetary policy since at least the late 1980s has been characterized by an interest-rate feedback rule according to which increases in inflation cause increases in the federal funds rate of an even larger magnitude, and a large subsequent empirical literature has reached similar conclusions. However, this sort of policy rule (which Leeper, 1991, calls “active monetary policy”), would imply explosive debt dynamics in the presence of an exogenous real primary surplus process, or other similar locally non-Ricardian fiscal rule.⁴¹ (We discuss this further in the next section, in connection with Loyo’s (1999) analysis of Brazil’s policy mix in the early 1980s.) The fact that a Brazilian-style debt explosion and hyperinflation did *not* occur in the U.S. following the shift to a monetary policy similar to the “Taylor rule” implies that U.S. fiscal policy has been locally Ricardian, at least since the late 1980s.⁴² This also conforms with what we know about the emphasis upon the goal of budget balance in discussions of U.S. fiscal policy

⁴¹Leeper (1991) and Loyo (1999) show this in the case of flexible-price models. However, the analysis in Woodford (1996) of determinacy of equilibrium in a model with sticky prices (Calvo-style staggered pricing) shows that the same classification of policy regimes consistent with unique non-explosive debt dynamics continues to apply in that context. The only difference is that the demarcation between “active” and “passive” monetary policy rules must be modified to take account of the effects of feedback from the level of output to the central bank’s interest-rate instrument, as in the discussion of the “Taylor principle” in Woodford (2000).

⁴²Of course, such a judgment depends upon believing the identifying assumptions that are made in estimates of Fed reaction functions; but these are arguably grounded to a greater extent in knowledge of the factors actually considered in Fed decisionmaking than is the case with attempts to estimate a fiscal policy rule.

since the late 1980s.

On the other hand, Taylor (1999) argues that Fed policy in the 1960s and 1970s involved an interest-rate response to inflation increases that was substantially weaker, and in particular failed to raise nominal interest rates by as much as the increase in inflation. Such a policy (which Leeper, 1991, calls “passive monetary policy”) would *not* imply explosive debt dynamics when combined with a locally Ricardian fiscal policy; indeed, it is only in the case of such a fiscal policy that the policy regime would imply determinate equilibrium paths for nominal variables, including the path of the public debt.⁴³ Clarida *et al.* (2000) similarly find that their estimated Fed policy rule for the period 1960-1979 would imply an indeterminate equilibrium, under their (implicit) hypothesis of Ricardian fiscal policy; but once again (and for similar reasons) their estimated policy would be consistent with a unique non-explosive equilibrium under a hypothesis of locally non-Ricardian fiscal policy. The empirical relevance of the hypothesis of “passive” monetary policy on the part of the Fed is even clearer for the 1940s, as discussed above. Once again, this would at least make it possible to reconcile an apparently stable inflation process with a hypothesis of non-Ricardian fiscal policy; and indeed, we have argued that this hypothesis provides an appealing explanation of several aspects of inflation variation during that period.

It is important to recognize that the analysis presented above of equilibrium determination under the bond-price support regime is not offered as a *universal* theory of inflation determination. While the equilibrium relation (2.24) should always hold, regardless of the character of the monetary/fiscal policy regime, it may or may not be useful to view this condition as the key to price-level determination, and fiscal disturbances may or may not have an important effect upon inflation — these latter propositions will depend upon the nature of the policy regime. However, the fact that non-Ricardian policy regimes are among the *possible* kinds of systematic fiscal policies is important, even if one does not think that

⁴³In the case of a model with nominal rigidities, indeterminacy of the paths of nominal variabilities would imply indeterminacy of the equilibrium paths of real variables as well. The determinacy of equilibrium under a policy rule of the kind that Taylor estimates for the 1960s and 1970s, when combined with a locally non-Ricardian fiscal policy, is shown by Leeper (1991) for a flexible-price model and by Woodford (1996) for a sticky-price variant of that model.

U.S. fiscal policy (for example) is currently of that kind, for reasons to be taken up next.

4 Implications for Inflation Control

I now turn to the implications for the design of public policy of a recognition that non-Ricardian fiscal regimes are possible (though not, of course, a necessity). Consideration of this possibility has consequences of several sorts. In taking them up, I shall assume that a key goal of policy is the maintenance of as stable a general price level as possible; the question whether, or to what extent, this should be a goal is left for another occasion.⁴⁴

First of all, in the case that the government's budgetary policy is expected to be non-Ricardian — for reasons that a policymaker choosing a monetary policy rule is not in a position to change — this fact affects which monetary policy rules should be expected to be consistent with the greatest degree of price stability. Rules that would be quite desirable in the context of a (locally) Ricardian fiscal policy, such as a “Taylor rule”, may instead have disastrous consequences for price stability when combined with an alternative fiscal policy.

But this very fact implies that the choice of fiscal policy is *also* relevant to an economy's chances of achieving price stability, and so our second category of policy implications considers the choice of a fiscal policy rule that would be consistent with price stability. Here the essential point is that fiscal policy should be locally Ricardian, so that fiscal expectations do not frustrate the central bank's use of a suitably “active” monetary policy to stabilize the price level.

Finally, the contribution that a suitable fiscal policy commitment can make to price stability is not simply a matter of failing to interfere with a desirable equilibrium that would otherwise be consistent with the central bank's monetary policy rule. A globally non-Ricardian (though locally Ricardian) fiscal commitment may be useful in order to *exclude undesirable equilibria*, ones involving less stable prices, that would otherwise be consistent

⁴⁴One reason for doing so is that the simple theoretical framework used above is one in which there are no frictions of the sort that imply that any economic distortions should result from unexpected variation in the equilibrium price level; in reality, such frictions are important. See Woodford (1999b) for discussion of the welfare consequences of inflation variability in some simple models with sticky prices.

with the monetary policy regime. I take up each of these categories of implications in sequence.

4.1 Monetary Policy Choice when Fiscal Policy is Non-Ricardian

If fiscal policy is expected to be non-Ricardian, these fiscal expectations constrain the set of possible equilibrium outcomes that monetary policy can achieve. This constraint may furthermore have important consequences for the ranking of alternative monetary policies. In the presence of non-Ricardian fiscal expectations, the choice of a monetary policy that is intended to be anti-inflationary may lead (at least eventually) to even *more* inflation. Indeed, it could even result in a hyperinflation, as Loyo (1999) argues occurred in Brazil in the 1980s.

Consider, for example, the consequences of a central bank commitment to set a short-term nominal interest rate instrument according to a “Taylor rule”⁴⁵

$$i_t = \phi(\Pi_t), \tag{4.1}$$

where $\Pi_t \equiv P_t/P_{t-1}$ is the gross rate of inflation, and $\phi(\Pi)$ is an increasing, non-negative function, consistent with an implicit target rate of inflation $\Pi^* > \beta$, *i.e.*, such that

$$1 + \phi(\Pi^*) = \beta^{-1}\Pi^*. \tag{4.2}$$

I shall assume that there is a unique $\Pi^* > \beta$ satisfying (4.2).

Let us again consider a deterministic environment for simplicity, and suppose that output is constant and equal to $y > 0$ each period. Given a commitment to the monetary policy rule (4.1), perfect foresight equilibrium requires that the inflation sequence $\{\Pi_t\}$ satisfy the nonlinear difference equation

$$\frac{\Pi_{t+1}}{\lambda(\phi(\Pi_{t+1}), y)} = \frac{\beta(1 + \phi(\Pi_t))}{\lambda(\phi(\Pi_t), y)}, \tag{4.3}$$

⁴⁵The rule discussed in Taylor (1993) also involves feedback from deviations of real output from trend and/or potential. But in the present flexible-price model, there are no deviations of output from potential, and any deviations from trend are exogenous, so that such feedback would represent at most an exogenous shift term in (4.1), with consequences identical to those of time variation in the inflation target. Such an extension would not change our conclusions about the stability of inflation dynamics under the policy rule.

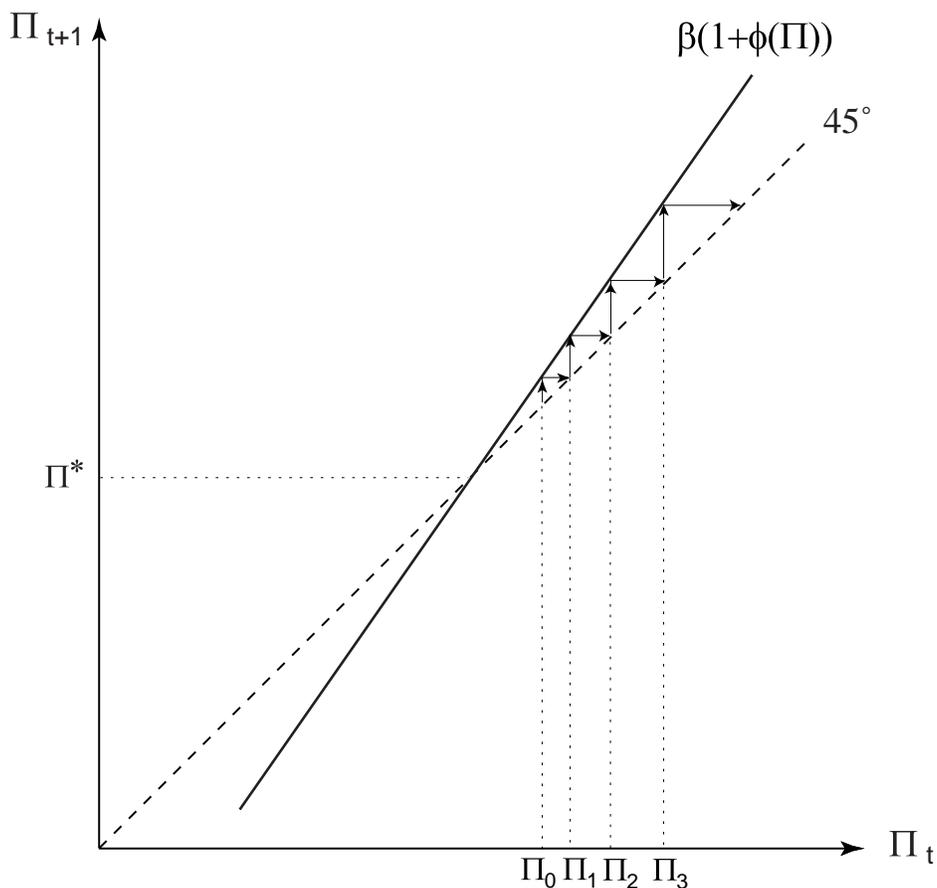


Figure 3: An inflationary spiral under a Taylor rule.

obtained by using (4.1) to substitute for i_t in (2.18). In the “cashless limit,” or the case of additively separable preferences, (4.3) reduces to

$$\Pi_{t+1} = \beta(1 + \phi(\Pi_t)). \quad (4.4)$$

Our analysis of the qualitative properties of this difference equation is simplified if (following Loyo) we restrict attention to the latter special case.

If, in accordance with Taylor’s (1993) characterization of U.S. policy since the late 1980s, we assume that $\epsilon_\phi(\Pi^*) > 1$, where $\epsilon_\phi(\Pi)$ is the elasticity of $1 + \phi$ with respect to Π , then the graph of the right-hand side of (4.4) cuts the diagonal from below, as shown in Figure 3. As the figure shows, in this case Π^* is an “unstable” steady state under the dynamics implied by (4.4). (The figure illustrates a solution starting from an initial inflation rate $\Pi_0 > \Pi^*$: in this

case, inflation must grow without bound over time. If instead one were to assume $\Pi_0 < \Pi^*$, inflation would have to be forever declining, eventually leading to permanent deflation.) This means that the only solution to (4.4) in which Π_t remains within a neighborhood of Π^* forever is the one in which $\Pi_t = \Pi^*$ for all t . Thus the target steady state is not only *consistent* with policy rule (4.1), but, if (4.4) is the only restriction upon equilibrium inflation, the rule also makes it a determinate (locally unique) equilibrium.⁴⁶ One might then be optimistic that people would in fact succeed in coordinating their expectations upon that equilibrium, so that the “Taylor rule” would succeed in stabilizing inflation at the desired rate.⁴⁷

But is this in fact the only requirement for a perfect foresight equilibrium? The answer depends upon the character of fiscal policy. If fiscal policy is “locally Ricardian,” in the sense introduced above — the fiscal rule implies that real government liabilities will necessarily remain within a bounded interval, in the case of any path for inflation that remains forever near enough to the target inflation rate Π^* — then (4.4) is the only restriction upon inflation paths that remain forever near the target inflation rate. The conclusion in that case would be (i) that the target steady state is indeed a perfect foresight equilibrium, and (ii) that it is indeed determinate, as there will be no other nearby solutions. Thus in such a case the “Taylor rule” would be an appealing approach to inflation stabilization.

But suppose instead that fiscal expectations can be described by an exogenous sequence $\{s_t\}$. Then we can show, as in our analysis above of the bond price-support regime, that there is only a single initial value for Π_0 that is consistent with these fiscal expectations. This is most easily seen in the case of short-term (one-period) nominal government debt.⁴⁸ Then W_0^s is given as an initial condition, while the right-hand side of (2.28) depends only upon the exogenous sequence of surplus expectations; so there is clearly a unique value of P_0 that satisfies (2.28), and correspondingly a unique possible equilibrium inflation rate Π_0 ,

⁴⁶Here it is important to note that Π_t is not a predetermined state variable, so that history provides no initial condition for the difference equation (4.4). Instead, the variable is free to “jump” so as to be consistent with the expected future evolution of inflation.

⁴⁷This is the sort of analysis of inflation determination under such a rule proposed, for example, in Woodford (1999a). See section 4 of that manuscript for discussion of other possible equilibria.

⁴⁸See Woodford (1998c) for an extension of the analysis to the case of longer-term government debt.

given an initial condition for P_{-1} . This initial condition then picks out a unique solution from among the continuum of solutions to the difference equation (4.4), and this will be the unique p.f.e. inflation sequence consistent with the fiscal expectations in question. Alternatively, the evolution of inflation is determined by recursive solution of the pair of equations (2.28) and (2.29), with i_t in the latter equation being substituted out using (4.1); as shown earlier, this generates an inflation sequence that also satisfies (2.18) and hence (4.4). The latter calculation better represents the causal logic by which a particular sequence of inflation rates is generated in equilibrium; but simple reference to (4.4) is an easier way to quickly determine what the equilibrium inflation dynamics are like.

The unique value of Π_0 that solves (2.28) will, in general, not happen to equal Π^* . If, for example, the expected future budget surpluses are too small, so that $\Pi_0 > \Pi^*$, then the only possible p.f.e. is one in which the inflation rate grows without bound over time, as shown in Figure 3. This equilibrium is characterized by an inflationary spiral, in which progressively higher rates of inflation lead to higher nominal interest rates, hence higher rates of growth of nominal government liabilities, which in turn lead to still higher rates of inflation. Alternatively, if the expected future budget surpluses are too large, this sort of policy regime will instead lead to a deflationary spiral, in which the logic is the same but in the opposite direction. Thus this particular type of policy combination almost inevitably leads to equilibrium inflation far from the target rate.

Our analyze of this problem has assumed a globally non-Ricardian policy; but even if we instead were to assume that the primary surplus is equal to the exogenously evolving “desired” surplus only when it does not violate the bounds (3.7), much the same problem arises. Just as before, the imposition of these bounds does nothing to change the character of the fiscalist equilibrium (which here involves an inflationary or deflationary spiral); as long as the fluctuations in $\{\bar{s}_t\}$ are small enough, w_t never violates the bounds in this equilibrium, and so the same equilibrium continues to be possible. It is true that the bounds on the evolution of real government liabilities make possible other equilibria as well; in particular, in the present case there will now be a possible equilibrium in which $\Pi_t = \Pi^*$ forever. (In the

case where the expected sequence of “desired” primary surpluses is too small, this equilibrium is associated with explosive growth in real government liabilities, as shown in Figure 2, and the expectation that at a certain future date a fiscal retrenchment will bring about actual surpluses higher than the “desired” surpluses.) But the arguments given in section 2.2 above for selection of the fiscalist equilibrium would continue to apply in this case. In particular, it is still true that for any conjectured fiscal expectations close enough to those consistent with the fiscalist equilibrium, a single iteration of the expectation-calculation mapping defined above would lead to the expectations that bring about the fiscalist equilibrium. It thus remains plausible that people could coordinate upon an equilibrium with unstable inflation under such a policy configuration.

On the other hand, if the central bank were to commit itself to a policy rule like (4.1), but with $\epsilon_\phi(\Pi^*) < 1$,⁴⁹ then the graph of the right-hand side of (4.4) cuts the diagonal from above, so that the dynamics converge to Π^* regardless of the initial condition Π_0 . In this case, in the presence of an exogenous primary surplus process, one has a uniquely determined p.f.e., in which Π_0 will in general not exactly equal Π^* , but the sequence $\{\Pi_t\}$ will converge asymptotically to π^* in any event. Thus there will be a substantial range of fiscal expectations that are all consistent with an equilibrium inflation rate that remains forever near the target rate. (In the case of a stochastic version of this model, the equilibrium inflation rate will vary in response to random shocks, but with bounded shocks it will fluctuate forever within an interval around the target inflation rate.) This alternative type of monetary policy rule would accordingly be more conducive to price stability, in the context of a non-Ricardian fiscal policy of the kind assumed.⁵⁰

We thus observe that a monetary policy rule that would conventionally be thought to be

⁴⁹This is what Leeper (1991) calls “passive” monetary policy, by contrast with the “active” case when the inequality is reversed.

⁵⁰Leeper (1991) obtains a similar conclusion in the context of a purely local analysis. He finds that there is a determinate r.e.e., involving stationary fluctuations in the inflation rate, when an “active” monetary policy is combined with a “passive” (locally Ricardian) fiscal policy, or alternatively when a “passive” monetary policy is combined with an “active” (locally non-Ricardian) fiscal policy. He regards the combination of an “active” monetary policy and an “active” fiscal policy as mutually incompatible, as in this case there will generally be no non-explosive equilibrium at all. But as we have seen, this need not mean that there is actually no equilibrium possible; instead, the equilibrium may necessarily involve an inflationary or deflationary spiral.

anti-inflationary, such as a Taylor rule with an aggressive response to deviations of inflation from the target rate, may instead lead to an inflationary spiral when combined with an unsuitable fiscal policy. This is exactly what Loyo (1999) argues occurred in Brazil in the early 1980s. As shown in Figure 4(a), the Brazilian inflation rate remained quite stable (though non-trivial, two to three percent per month) throughout the late 1970s, but grew to progressively higher levels in the early 1980s, degenerating into hyperinflation by 1985.⁵¹ Loyo attributes this to a shift toward a more anti-inflationary interest-rate policy beginning in 1980. He shows that nominal interest rates on Treasury obligations were quite steady in the 1970s, despite fluctuations in inflation, while they rose more than one-for-one with increases in inflation in the early 1980s, and thus proposes that the shift was from a policy rule with $\epsilon_\phi < 1$ to one with $\epsilon_\phi > 1$. If we suppose that fiscal expectations remained non-Ricardian both before and after the monetary policy change, then the above model implies that equilibrium inflation could well have been stable before 1980 (as it was), while the change in the monetary policy could result in an inflationary spiral of the kind shown in Figure 3.

Loyo also notes that real seignorage revenues (shown in Figure 4b) did not increase notably during the inflationary spiral, so that the increased inflation cannot plausibly be attributed to increased revenue needs that resulted in an increase in the central bank's seignorage target. The inflationary spiral was associated with explosive growth of nominal government liabilities, resulting from increased conventional deficits (plotted in real terms in Figure 4b). As the figure shows, the increased deficits were largely due to rapid growth in the interest payments required on the public debt, which exploded as a result of the change in interest-rate policy.

Why, then, did the shift in the U.S. to a policy similar to the "Taylor rule" in the 1980s not lead to a similar inflationary spiral?⁵² A possible answer is that in the U.S. this kind

⁵¹The data plotted in Figure 4 are kindly supplied by Eduardo Loyo.

⁵²As noted earlier, Taylor (1999) argues that U.S. policy in the 1960s and 1970s could be described a similar interest-rate feedback, but with an inflation elasticity $\epsilon_\phi < 1$, whereas policy since the late 1980s at least can be described by a rule with $\epsilon_\phi > 1$.

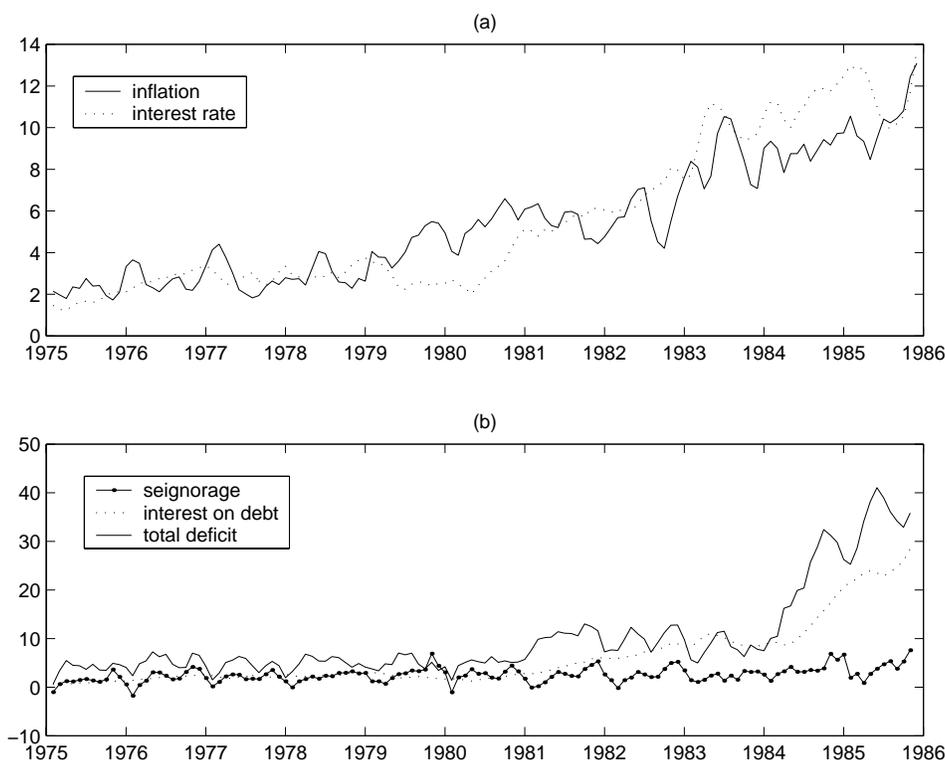


Figure 4: Onset of hyperinflation in Brazil. (a) Inflation rate and short-term nominal interest rate, in percent per month. (b) Real value of seignorage revenues, interest payments on public debt, and deficit inclusive of interest payments. Source: Loyo (1999).

of monetary policy was accompanied by a different type of fiscal expectations. From the mid-1980s onward, concern with the size of the public debt led to calls for constraints upon the government budget, such as those incorporated in the Gramm-Rudman-Hollings Act of 1985, which would automatically adjust annual budgets so as to prevent further growth in the debt. And at least since the 1990 budget, this concern (implying feedback from the size of the public debt to the size of the primary surplus) has been a major determinant of the evolution of the U.S. federal budget. If these developments were correctly anticipated, then people would indeed have expected fiscal policy to be Ricardian, allowing expectations to coordinate upon the desirable equilibrium in which inflation fluctuates around its target level.

Note that the success of the American experiment need not imply that people under-

stood that fiscal policy would be Ricardian from the beginning of vigorously anti-inflationary interest-rate policy under Paul Volcker.⁵³ Even in the context of unchanged expectations regarding the future path of real primary budget surpluses, a shift toward a lower target inflation rate and a value of $\epsilon_\phi > 1$ need not result in an immediate increase in inflation. Instead, in an economy with long-term, non-indexed government debt, nominal interest rate increases can lower the (nominal) market value of existing government bonds, and thus lead initially to a *lower* path for W_t^s than would otherwise have been followed, and correspondingly a lower path for the price level. The inflationary spiral thus would not have had to manifest itself immediately in the American context (though it would have been expected to in Brazil, owing to the much shorter maturity of the Brazilian public debt). It is thus possible that the expectation of a Ricardian fiscal policy developed only later, but still in time to head off inflationary debt dynamics in the U.S.

The successful disinflation in the U.S. during the 1980s, and the successful maintenance of low inflation since, indicates that commitment to an interest-rate policy similar to the “Taylor rule” can indeed be an appropriate way of stabilizing inflation around a low level. But the contrary example of Brazil suggests that countries plagued by high inflation and seeking to emulate the U.S. recipe should not assume that mere adoption of a Taylor rule will be sufficient; instead, it is important also to emulate the constraints upon fiscal policy characteristic of the U.S. during this period.

4.2 Constraining Fiscal Expectations

Above we have commented upon the choice of a monetary policy rule so as to minimize the undesirable instability of the price level, in the presence of a non-Ricardian fiscal policy that is taken as given. But it is clear that such an adaptation to the inevitability of exogenous fluctuations in primary budget surpluses is hardly the optimal arrangement, at least from the point of view of price stability.⁵⁴ For example, in general, a given exogenous process

⁵³Articles such as Sargent and Wallace (1981) indicate that the existence of a fiscal commitment of this kind was not clear during the early Volcker years.

for the primary budget surplus will be inconsistent with complete stabilization of the price level, regardless of the monetary policy that is chosen (Woodford, 1996, 1998c). On the other hand, complete stabilization of the price level, even in the face of real disturbances, may well be possible in principle — say, using a Taylor rule with a time-varying intercept that shifts appropriately in response to the real disturbances (Woodford, 1999a) — as long as fiscal expectations are consistent with that equilibrium. Thus the best approach to the achievement of price stability will involve the choice of an appropriate rule for fiscal policy, in addition to the choice of a desirable monetary policy rule.

What kind of fiscal policy would best serve this end? The simplest answer would be, any policy that is consistent with stable prices. But this does not go far enough. An exogenous process for the primary budget surplus, for example, could happen to be consistent with a target path for the price level. Thus one might suggest that the inflationary spiral shown in Figure 3 will not occur, and instead one will have inflation equal to the target rate forever, as long as the expected sequence of primary surpluses makes $\Pi_0 = \Pi^*$ the solution to (2.28). But this would depend upon getting the size of the expected surpluses exactly right, which is simply incredible (in the case that the surpluses are set simply as a function of the estimated exogenous state of the world, and not with feedback from endogenous developments, such as the actual evolution of prices).

A more plausible proposal might seem to be a regime like the bond price-support regime described in section 2, in which however the exogenous surplus process is chosen to be one that is calculated to be consistent with stable prices. (One would be committed, for example, not to reduce primary surpluses in response to an event such as the outbreak of war in Korea.) This is a more practical proposal, in that control errors in the government's attempts to target the primary surplus would not lead to any explosive deviation from the desired equilibrium. Still, this type of regime is not one in which inflation is likely to be too stable in practice. It makes the equilibrium price level a function not merely of fiscal

⁵⁴Whether it is possible or desirable for primary surpluses to follow an alternative path depends, of course, upon what sources of revenue are available and how pressing the government's need for funds may be. These issues are beyond the scope of the analysis here.

expectations in the near term, but of expectations about government budgets far in the future (since it is the present value of all future surpluses that enters (2.24)). Expectations about the distant future may be especially difficult for the government to “manage” through policy announcements. Furthermore, the nature of the legislative process in a democracy makes it unlikely that government budgets can be subjected to the same degree of discipline as monetary policy actions. A nontrivial degree of random variation in the equilibrium price level would be inevitable under the price-support regime, both as a result of random disturbances to fiscal policy that could not be prevented, and as a result of inability to adjust fiscal policy with sufficient precision to offset the consequences of other real disturbances (such as fluctuations in the equilibrium real rate of interest).

Controlling inflation through an interest-rate rule such as the Taylor rule represents a more practical alternative, both because it is more politically realistic to imagine monetary policy being subordinated wholly to this task, and because it is technically more feasible to “fine-tune” monetary policy actions as necessary to maintain consistency with stable prices. Finally, under a Taylor rule (together with a locally Ricardian fiscal policy), expectations regarding future monetary policy do affect equilibrium inflation, but these expectations are discounted more rapidly (as one considers dates farther in the future) in this case than under the bond price-support regime — much more rapidly, in the case of sufficiently aggressive response to current inflation (Woodford, 1999a). It would make sense, then, to choose a fiscal rule that is compatible with this kind of approach to control of inflation. What this requires is choosing a fiscal rule that is consistent not simply with *one particular* target path for inflation, but with *all* paths involving sufficiently moderate deviations of the inflation rate from its desired path; one would then rely upon an “active” monetary policy to determine which of these paths would actually be the equilibrium path. This means choosing a *locally Ricardian* fiscal policy. (Whether it should also be *globally* Ricardian is another matter; in the next section, I shall argue that it is better that it not be.) Because the property of being locally Ricardian requires only that the path of the public debt satisfy certain *bounds*, this is a goal that remains practical even in a world where the government budget will inevitably

be subject to only imperfect control.

What kind of constraint upon fiscal policy does this mean? A mere commitment to “satisfy the transversality condition” is plainly unsuitable; this would place no constraints upon observable behavior over any finite time period, so that it is hard to see how the public should be convinced of the truth of such a commitment, in the absence of a commitment to some more specific constraint that happens to *imply* satisfaction of the transversality condition. One such possibility, discussed above, is a commitment to keep real government liabilities within bounds such as (3.6). This is exactly the spirit of the requirement of the Maastricht treaty (and of the subsequent “Stability Pact” binding the members of the European Monetary Union) constraining each nation’s public debt to (eventually) remain no greater than 60 percent of a year’s GDP.⁵⁵

However, while a commitment to such a constraint would suffice to ensure satisfaction of the transversality condition (under mild conditions, as discussed above), and so render policy Ricardian, it may not suffice to eliminate the problem illustrated by the Brazilian case.⁵⁶ For as we have shown in section 2.3 above, fiscal policy might remain *locally non-Ricardian* even while respecting the bounds (3.6). In such a case, there would remain a determinate (locally isolated) equilibrium in which fiscal expectations would determine the price level, and people might well coordinate their expectations upon this particular equilibrium. In the case that monetary policy is described by a Taylor rule with $\epsilon_\phi > 1$, this fiscalist equilibrium almost inevitably involves an inflationary or deflationary spiral. Of course, the commitment to the bounds would also make possible other equilibria (just as in our previous discussion, when it was hypothesized that such bounds would be *inevitably* satisfied); these equilibria would include one in which inflation is always equal to the target rate. But because of the complicated nature of the fiscal expectations required to support that “good” equilibrium, one may not wish to rely upon people to coordinate upon it rather than one of the others.

⁵⁵Above we have considered a ceiling on the real value of government liabilities, but in a model in which output does not grow over time. Similar conclusions can easily be obtained in a model with growth in the case of debt limit that grows in proportion to real GDP.

⁵⁶Here I take a different view of the consequences of such a constraint than that presented in Woodford (1996).

In the case of a *locally* Ricardian fiscal policy, instead, there will be no unique inflation path with the property that the real value of government liabilities remains within narrow bounds, to provide a natural focal point for expectations. (This will instead be equally true of *all* of the solutions to (4.4).) It then may be plausible for expectations to coordinate upon the locally unique equilibrium in which inflation and interest rates never deviate too far from the values Π^* and $\phi(\Pi^*)$ respectively, which is the one in which the Taylor rule successfully stabilizes inflation.⁵⁷

One simple example of a locally Ricardian regime would be to make the primary budget surplus a linear function of accumulated real government liabilities,

$$s_t = \bar{s} + \alpha(w_t - \bar{w}) \quad (4.5)$$

where $1 - \beta < \alpha \leq 1$, and $\bar{w} > 0$ is some “target” level for real government liabilities. (This is closely related to Leeper’s (1991) definition of “passive fiscal policy”.) Substituting (4.5) into (2.31) yields a law of motion for real public debt of the form

$$b_t = \mathcal{B}(b_{t-1}, \Pi_t, Q_{t-1}, Q_t, m_{t-1}, m_t), \quad (4.6)$$

where $b_t \equiv Q_t B_t^s / P_t$. Evaluated near a stationary equilibrium with constant values of Π_t , Q_t , and i_t , the derivative of this function with respect to its first argument is

$$\frac{\partial \mathcal{B}}{\partial b} = \beta^{-1}(1 - \alpha),$$

which is non-negative and strictly less than one. Thus the dynamics of the real public debt are stable (in the absence of perturbations to the other arguments of \mathcal{B}). It follows that for any small enough fluctuations in $\{\Pi_t, Q_t, i_t\}$ around the constant values just assumed (which in turn imply small fluctuations in $\{m_t\}$ around a constant value, given small enough fluctuations in $\{y_t\}$), the path of $\{b_t\}$ will be restricted to a bounded interval as long as it starts from an initial condition within that interval. This in turn implies bounded fluctuations in w_t as well; thus such a policy is locally Ricardian.

⁵⁷Whether there continue to actually be other equilibria depends the specification of policy far away from the target inflation rate; see the next section.

An alternative possibility would be real *conventional* deficit targeting. Under such a rule, the conventional (*i.e.*, inclusive of interest on the public debt) budget deficit,⁵⁸

$$\Delta_t \equiv (1 + \rho Q_t - Q_{t-1})B_{t-1}^s + P_t g_t - T_t,$$

is set each period according to a rule of the form

$$\Delta_t/P_t = \bar{\delta}, \tag{4.7}$$

where $\bar{\delta}$ is a constant target level. Equivalently, we may assume a constant target value for the deficit as a share of GDP; such a rule is in the spirit of the limits on government budgets imposed by the Maastricht treaty and the “Stability Pact”. Note that in the special case that $\bar{\delta} = 0$, this reduces to a *balanced-budget rule*.⁵⁹

In a steady state with a constant rate of inflation Π^* , and under the assumption that the official interest rate is chosen to equal the steady-state interest rate associated with the inflation target, $\bar{r} = \beta^{-1}\Pi^* - 1$, deficit target (4.7) is associated with a steady-state level of (end-of-period) real government liabilities equal to

$$\bar{m} + \bar{b} = \frac{\Pi^*}{\Pi^* - 1} \bar{\delta}.$$

Let us assume that $\Pi^* > 0$, and that $\bar{\delta} \geq 0$, so that end-of-period government liabilities are non-negative in the steady state. (In practice, the value of $\bar{\delta}$ would need to be set at a level that is high enough to be consistent with a steady state in which the government is not a net creditor, but low enough to be consistent with a steady state in which the tax collections required by the rule are not too burdensome. The exact level of $\bar{\delta}$ does not matter, however,

⁵⁸Here we measure “interest” on the public debt by the realized nominal one-period holding return, rather than by the part of payouts to bondholders that is officially designated “interest” as opposed to repayment of principal; the latter quantity has no economic significance. However, our conclusion as to the locally Ricardian character of such a policy does not depend upon this particular definition of the deficit. The main convenience of this definition is that it establishes a simple equivalence between deficit targeting and targeting the path of nominal government liabilities; these would otherwise be closely related, but slightly distinct types of fiscal commitment.

⁵⁹Schmitt-Grohé and Uribe (2000) analyze the consequences of a fiscal rule of this kind in a slightly different model, and under the assumption that $\rho = 0$.

for our argument here.) Fiscal rule (4.7) again implies public debt dynamics of the form (4.6), but now the derivative is

$$\frac{\partial \mathcal{B}}{\partial b} = \Pi^{*-1} < 1.$$

Hence (as long as the target inflation rate is positive) the debt dynamics are again stable, and policy is locally Ricardian. Thus adoption of deficit targets of this kind in conjunction with a Taylor rule for monetary policy would create a regime consistent with stable, low inflation, and in which there would be no reason to expect to coordinate upon an equilibrium other than the one in which this outcome is achieved.

4.3 Fiscal Commitments to Exclude a Deflationary Trap

Thus far we have considered only the problem of choosing a fiscal commitment that will *not interfere* with the central bank's efforts to stabilize inflation through interest-rate policy. We have argued that this can best be achieved through a fiscal commitment that ensures that the dynamics of the public debt will be stable, in the case of *any* moderate fluctuations in inflation, interest rates, and bond prices, so that fiscal policy will be equally consistent with any of these paths. But a fiscal rule can also serve the goal of price stability by *excluding unwanted equilibria* that would otherwise be consistent with the monetary policy rule. Thus there may be advantages to commitment to a rule that is not *globally* Ricardian: fiscal expectations of that kind may prevent unwanted price-level instability due to self-fulfilling expectations.

We have pointed out above that commitment to the Taylor rule in itself does not exclude any of the possible solutions to the difference equation (4.4) from being possible perfect foresight equilibria. (And the complete set of rational expectations equilibria would include a large set of stochastic equilibria as well.) We have suggested that the locally unique equilibrium with inflation forever near the target rate might be a logical one for people to coordinate upon; but a policy regime that could actually exclude the other paths as genuine equilibria (*i.e.*, as outcomes that could be expected by people with a correct understanding of the policy rule and of the principles of price-level determination) would allow greater

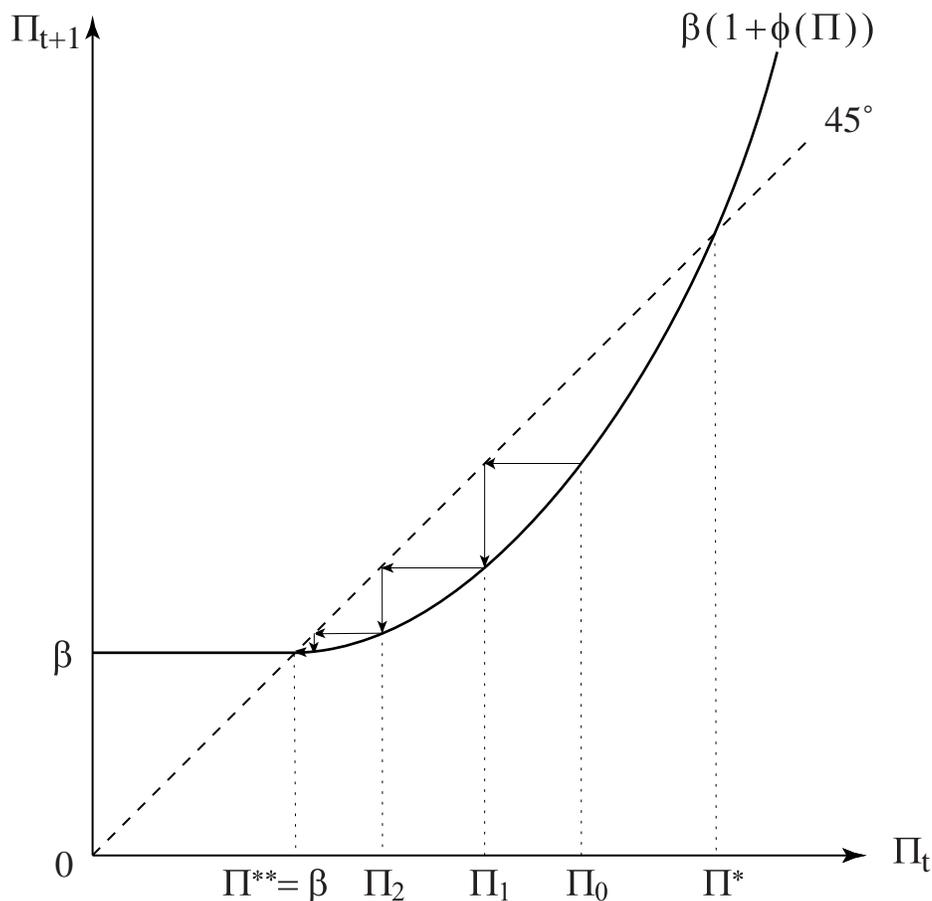


Figure 5: A self-fulfilling deflation under a Taylor rule.

confidence that the desired equilibrium should actually be reached. It is particularly difficult for the central bank to achieve this by itself in the case of the possibility of a *deflationary spiral* of the kind shown in Figure 5. (This is another solution to the same difference equation as in Figure 3, but now assuming an initial inflation rate $\Pi_0 < \Pi^*$.)

Inflationary spirals of the kind shown in Figure 3 might be excluded, or at least rendered less likely for people to coordinate upon, through a commitment to raise interest rates sharply in the case of high rates of inflation; this would mean that any inflation rate higher than the target rate could be sustained only by expectations of future inflation that are quite

extreme, if not impossible.⁶⁰ But similarly aggressive responses to deflation are not possible, insofar as the zero lower bound on nominal interest rates limits the extent to which interest rates can be reduced. As Benhabib *et al.* (2000b) point out, this implies that there must exist a second, lower steady-state equilibrium inflation rate in the case of a Taylor rule with $\epsilon_\phi(\Pi^*) > 1$, at or above the gross inflation rate of β , which corresponds to deflation at the rate of time preference. (Under our assumptions, this second steady state Π^{**} involves deflation at exactly that rate, and a nominal interest rate of zero.) There necessarily exists a continuum of solutions to (4.3) converging to Π^{**} , and the deflationary expectations required to support these solutions are not too extreme, either. Benhabib *et al.* suggest that the possibility of such self-fulfilling deflationary traps is an important weakness of the Taylor rule as a prescription for monetary policy.

However, whether these solutions represent genuine perfect foresight equilibria or not depends upon the nature of fiscal policy. Benhabib *et al.* assume a (globally) Ricardian fiscal policy, so that all solutions to (4.3) represent perfect foresight equilibria. But as Woodford (1999a, sec. 4.2) points out, under alternative fiscal policy commitments, this is no longer true.⁶¹ In particular, it is possible for fiscal policy to be locally Ricardian (so that the transversality condition is satisfied in the case of all inflation paths that remain forever within an interval of inflation rates around the target rate), and still imply that the transversality condition is violated in the case of any deflationary path of the kind shown in Figure 5. To achieve the latter end, it suffices that fiscal policy place a floor on the asymptotic growth of nominal government liabilities, which implies that their real value will grow too rapidly for consistency with the transversality condition if the price contracts asymptotically at the rate of time preference. Such a growth rate of nominal government liabilities may instead be consistent with the transversality condition as long as the rate of inflation never falls too far below the target rate.

One way of guaranteeing such a floor on the growth rate of nominal government liabilities

⁶⁰See Woodford (1999a, sec. 4.3) for further discussion.

⁶¹The idea is further developed in Benhabib *et al.* (2000c).

is to directly target this variable. A policy of this type that has often been assumed in the theoretical literature is a money growth target,

$$M_t^s/M_{t-1}^s = \mu, \tag{4.8}$$

for some $\mu \geq 1$, together with an implicit commitment to maintain $B_t^s \geq 0$ as well. For example, a policy of this kind is shown to exclude deflationary equilibria in Brock (1975) and in Obstfeld and Rogoff (1983), where it is assumed that there is zero government debt at all times. In these papers, of course, the monetary policy rule is specified by (4.8), rather than by a Taylor rule. But the elimination of the possibility of self-fulfilling deflations is no special property of monetary targeting as opposed to commitment to an interest-rate rule; rather, the result follows from the assumption of a *fiscal* rule that puts a floor on the path of nominal government liabilities. Indeed, the money-growth target alone would not avoid this problem, in the absence of a stipulation that the government budget will ensure that $B_t^s \geq 0$ forever.

A deficit target of the form (4.7) also puts a floor on the path of total nominal liabilities of the government. Note that under our above definition of the deficit, end-of-period total liabilities $D_t \equiv M_t^s + Q_t B_t^s$ evolve according to

$$D_t = D_{t-1} + \Delta_t.$$

Any non-negative value for the deficit target $\bar{\delta}$ therefore implies that $\{D_t\}$ will be a non-decreasing sequence. Hence if prices fall at the rate of time preference, as they do asymptotically in the case of the deflationary path shown in Figure 5, the real value D_t/P_t grows as β^{-t} , and the transversality condition will be violated. In the case of a path in which the deflation is only *asymptotically* this great, the condition may or may not be violated; but one can ensure that it is, in the case of any solution to (4.4), through an appropriate choice of the function $\phi(\Pi)$. (Interest rates must fall to zero quickly enough as the inflation rate falls.)

Alternatively, one can ensure a positive floor on the *growth rate* of nominal liabilities, so that the transversality condition is violated in the case of any sustained rate of deflation

that even approaches the rate of time preference. If one adopts a deficit target of the form

$$\Delta_t = \max(\bar{\delta}P_t, \gamma D_{t-1}), \quad (4.9)$$

where $0 < \gamma < \Pi^* - 1$, $\bar{\delta} > 0$, then in the steady state with inflation at the target rate, the binding constraint is the one defined by $\bar{\delta}$, rather than the one defined by γ . Hence the debt dynamics near the steady state are as defined above, and such a policy is once again locally Ricardian. At the same, such a commitment establishes a floor for the growth rate of total nominal liabilities, as it ensures that

$$D_t/D_{t-1} \geq (1 + \gamma).$$

It follows that any path of prices along which the gross inflation rate eventually satisfies $\Pi_t < \beta(1 + \gamma)$ forever will imply that $\beta^t D_t/P_t$ will be bounded away from zero, and so cannot constitute an equilibrium.

The crucial aspect of such policies, in order to exclude the possibility of a self-fulfilling deflation, is that the government be committed to continued growth of its nominal liabilities (or at the very least, to preventing them from contracting), even if the price level, and hence nominal GDP, *does* steadily decline. This would mean allowing the ratio of government liabilities to GDP to rise, in principle without bound, along such a deflationary path — though if the private sector believes in the government’s commitment, the deflationary path (and hence the explosion of the debt/GDP ratio) should never occur in equilibrium.

Admittedly, this requires a different way of thinking about the “soundness” of fiscal policy than is yet common. An example is provided by recent discussion of Japanese fiscal policy. As shown in Figure 6, the ratio of the public debt to GDP has grown sharply in the 1990s, rising from only 49 percent at the end of 1991 to more than 96 percent by the end of 1999. This is widely deplored as an indication of reckless fiscal policy during the 1990s, and has been accompanied by assurances from the government that a future fiscal retrenchment would prevent further growth of the debt ratio. However, a commitment to maintain a ceiling on the ratio of government liabilities to GDP is exactly the sort of fiscal commitment

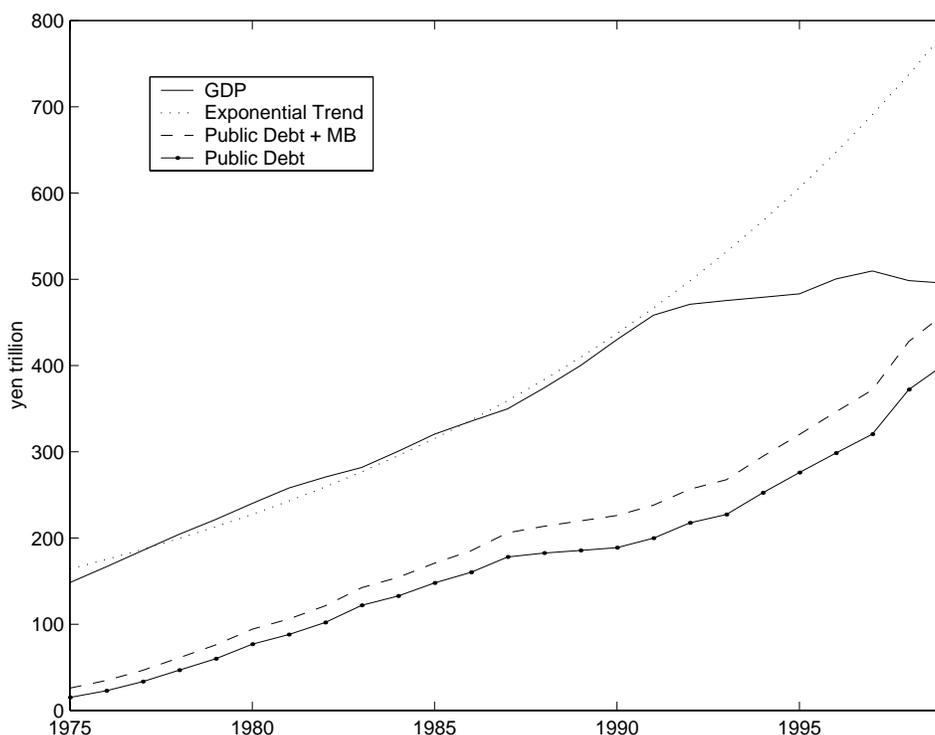


Figure 6: Public debt, the monetary base and nominal GDP for Japan.

that makes self-fulfilling deflations possible, under an interest-rate rule or a money-growth rule alike.⁶² For such a commitment implies that in the event of a self-fulfilling deflation, the government will run surpluses of the size necessary to contract nominal liabilities as fast as prices fall. But then there is no violation of the transversality condition, or alternatively, no accumulation of wealth by households that makes them feel in a position to spend more than the shrinking level of nominal GDP, so that the ever-smaller level of nominal GDP is indeed an equilibrium.

Instead, the exclusion of such equilibria requires a commitment to a target path for nominal government liabilities that will not decline over time even if nominal GDP does;

⁶²They will not be possible in the case of a money-growth rule with $\mu \geq 1$, if there is also a commitment to maintain a non-negative debt in the hands of the public. But in this case, there is no commitment to a bound on the ratio of government liabilities to GDP. The ratio of the monetary base to GDP will grow at the rate of time preference along a deflationary path, and so will the ratio of total liabilities to GDP. Furthermore, insofar as the monetary base is backed by holdings of government debt, the ratio of the public debt to GDP (counting the debt held by the central bank) will also grow at the rate of time preference under such a policy.

this should be explained to the public by reference to a target path for nominal GDP, to which the government is committed to return (through reflation of the economy) even if actual nominal GDP drops below the target path for a time. Interestingly, from this point of view the growth of the Japanese public debt during the 1990s does not seem so alarming. Figure 6 also plots an exponential trend fitted to nominal GDP for the period through 1991; relative to this trend (which might have been a plausible target path for nominal GDP after 1991 as well),⁶³ neither debt nor the sum of the public debt and the monetary base have grown to historically extreme levels. While both have increased some since 1991, each is still well below its typical level, relative to the nominal GDP trend, in the 1970s and 1980s. (Public debt relative to trend GDP had risen to 59 percent by the end of 1999, while it was above 80 percent in the 1970s.) Nonetheless, given the Japanese government's statements, the Japanese public may reasonably have been expecting that the government is not committed to continued growth of nominal liabilities at such a rate, and that the growth of the debt now forecasts tight budgets later. These are exactly the sort of Ricardian fiscal expectations that should undercut any stimulus to aggregate demand from the current deficits, as households judge that they must increase private saving to prepare for the future government budget cuts. They may also have allowed the Japanese economy to fall into a deflationary trap of the kind depicted in Figure 5.

5 Conclusion

Our results imply that a central bank charged with maintaining price stability cannot be indifferent as to how fiscal policy is determined. Commitment to an anti-inflationary monetary policy rule, such as a Taylor rule with a low implicit inflation target, cannot by itself ensure price stability. First of all, fiscal expectations inconsistent with a stable price level may prevent that outcome from occurring. This possibility is often discussed (e.g., in Sargent and Wallace, 1981) as resulting from an *inconsistency* between the policies of the central bank

⁶³This trend grows at approximately 7 percent per year; in the period 1975-91, this consisted of 4 percent average real growth and 3 percent average inflation.

and of the fiscal authority, so that the outcome depends upon which must accommodate the other's policy commitment in practice; this sometimes leads to the argument that a sufficiently independent or sufficiently credible central bank can eliminate the problem, simply by insisting upon its commitment to its own rule. We have seen however, that the problem is more subtle; it is possible that the policies are not actually inconsistent (in the sense that an equilibrium exists in which both commitments are maintained forever), but that the only possible equilibrium will involve an inflationary or deflationary spiral. Policymakers concerned with price stability will not wish to allow expectations of this kind to develop. In the case that the non-Ricardian fiscal expectations assumed in the Loyo (1999) model are unavoidable, the choice of a different type of monetary policy would be prudent; but in general, a more desirable solution will be to constrain fiscal expectations so that stable prices will not require explosive debt dynamics.

We have also seen that, even when both fiscal and monetary policy are *consistent* with an equilibrium with stable prices (as one among many possible outcomes), there may be good reason for people's expectations to coordinate upon an equilibrium other than this one — one in which the price level is determined by expectations regarding the government budget. In such a case, commitment by the central bank to a Taylor rule would again result in inflation far from the target level. To exclude this possibility, one would need a commitment to a fiscal policy that is *locally* Ricardian, and not merely globally Ricardian (as in the case of a primary budget that evolves exogenously until certain debt limits are reached).

An example of a suitable fiscal commitment for this purpose would be a target for the real value of the conventional budget deficit (inclusive of interest on the public debt). Fortunately, commitments to budget balance or to deficit limits have achieved new prominence in macroeconomic policy in the same period that has seen increased emphasis upon central bank independence and actively anti-inflationary monetary policy, both in the U.S. and in the European Union. We have seen that this type of fiscal commitment also has the advantage of placing a floor on the path of the nominal value of total government liabilities, which can be useful as a means of excluding self-fulfilling deflations that would otherwise be

possible equilibria under a Taylor rule. Thus a fiscal commitment of this kind, in conjunction with a monetary policy commitment such as a Taylor rule, represents a sound approach to the achievement of long-run price stability.

REFERENCES

- Auernheimer, Leonardo, and Benjamin Contreras, "Control of the Interest Rate with a Government Budget Constraint: Determinacy of the Price Level, and Other Results," unpublished, Texas A&M University, February 1990.
- — and — —, "A Nominal Interest Rate Rule in the Open Economy," unpublished, Texas A&M University, August 1993.
- Bassetto, Marco, "A Game-Theoretic View of the Fiscal Theory of the Price Level," unpublished, Northwestern University, March 2000.
- Begg, David K.H., and Badrul Haque, "A Nominal Interest Rate Rule and Price Level Indeterminacy Reconsidered," *Greek Economic Review* 6:31-46 (1984).
- Bénassy, Jean-Pascal, "Price-Level Determinacy under a Pure Interest-Rate Peg," *Review of Economic Dynamics* 3: 194-211 (2000).
- Benhabib, Jess, Stephanie Schmitt-Grohé, and Martín Uribe, "Monetary Policy and Multiple Equilibria," *American Economic Review*, forthcoming 2000a.
- —, — —, and — —, "The Perils of Taylor Rules," *Journal of Economic Theory*, forthcoming 2000b.
- —, — —, and — —, "Avoiding Liquidity Traps," unpublished, New York University, April 2000c.
- Bergin, Paul R., "Price Level Determination in a Heterogeneous Monetary Union," unpublished, University of California, Davis, December 1996.
- Bohn, Henning, "The Behavior of U.S. Public Debt and Deficits," *Quarterly Journal of Economics* 113: 949-964 (1998a).
- —, "Comment on John Cochrane, 'A Frictionless View of U.S. Inflation'," *NBER Macroeconomics Annual* 13: 384-389 (1998b).
- Brock, William A., "Money and Growth: The Case of Long-Run Perfect Foresight," *International Economic Review* 15: 750-777 (1974).
- —, "A Simple Perfect Foresight Monetary Rule," *Journal of Monetary Economics* 1: 133-150 (1975).

- Brunner, Karl, "Fiscal Policy in Macro Theory: A Survey and Evaluation," in R.W. Hafer, ed., *The Monetary versus Fiscal Policy Debate*, Totowa, NJ: Rowman and Allanheld, 1986.
- —, and Allan H. Meltzer, "A Credit Market Theory of the Money Supply and an Explanation of Two Puzzles in U.S. Monetary Policy," in T. Bagliotti, ed., *Investigations in Economic Theory and Methodology*, Padova, Italy: CEDAM, 1966.
- Buiter, Willem H., "The Young Person's Guide to Neutrality, Price Level Indeterminacy, Interest Rate Pegs, and Fiscal Theories of the Price Level," NBER working paper no. 6396, February 1998.
- —, "The Fallacy of the Fiscal Theory of the Price Level," NBER working paper no. 7302, August 1999.
- Canzoneri, Matthew B., Robert E. Cumby, and Behzad T. Diba, "Fiscal Discipline and Exchange Rate Regimes," CEPR discussion paper no. 1899, May 1998.
- —, — —, and — —, "Is the Price Level Determined by the Needs of Fiscal Solvency?" unpublished, Georgetown University, June 1999.
- Canzoneri, Matthew B., and Behzad Diba, "Fiscal Constraints on Central Bank Independence and Price Stability," CEPR Discussion Paper no. 1463, September 1996.
- Carlstrom, Charles T., and Timothy Fuerst, "The Fiscal Theory of the Price Level," *Economic Review*, Federal Reserve Bank of Cleveland, forthcoming 2000.
- Christiano, Lawrence J., and Terry J. Fitzgerald, "Understanding the Fiscal Theory of the Price Level," NBER working paper no. 7668, April 2000.
- Clarida, Richard, Jordi Gali and Mark Gertler, "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory," *Quarterly Journal of Economics* 115: 147-180 (2000).
- Cochrane, John H., "A Frictionless View of U.S. Inflation," *NBER Macroeconomics Annual* 13: 323-384 (1998).
- —, "Long-Term Debt and Optimal Policy in the Fiscal Theory of the Price Level," unpublished, University of Chicago, June 1999. [Available at <http://gsbwww.uchicago.edu/fac/john.cochrane/research/Papers.>]
- —, "Money as Stock: Price Level Determination with No Money Demand," NBER working paper no. 7498, January 2000.

- Cushing, Matthew J., "The Indeterminacy of Prices under Interest Rate Pegging: The Non-Ricardian Case", *Journal of Monetary Economics* 44: 131-148 (1999).
- Daniel, Betty C., "A Fiscal Theory of Currency Crises," unpublished, SUNY Albany, April 1999.
- d'Autume, Antoine, and Philippe Michel, " 'Transversality Conditions', Budget Constraints and the Determinacy of a Perfect Foresight Equilibrium in a Monetary Growth Model," *European Economic Review* 31: 1343-1367 (1987).
- Diamond, Peter A., "National Debt in a Neoclassical Growth Model," *American Economic Review* 55: 1126-1150 (1965).
- Dupor, Bill, "Exchange Rates and the Fiscal Theory of the Price Level," *Journal of Monetary Economics* 45: 613-630 (2000).
- Eccles, Marriner, *Beckoning Frontiers*, New York: Alfred A. Knopf, 1951.
- Eichengreen, Barry, and Peter Garber, "Before the Accord: U.S. Monetary-Financial Policy, 1945-51," in G. Hubbard, ed., *Financial Markets and Financial Crises*, Chicago: University of Chicago Press, 1991.
- Evans, George W., and Garey Ramey, "Calculation, Adaptation and Rational Expectations," *Macroeconomic Dynamics* 2: 156-182 (1998).
- Fratianni, Michele, and Franco Spinelli, *A Monetary History of Italy*, Cambridge: Cambridge University Press, 1997.
- Friedman, Milton, "The Role of Monetary Policy," *American Economic Review* 58: 1-17 (1968).
- —, and Anna J. Schwartz, *A Monetary History of the United States, 1867-1960*, Princeton: Princeton University Press, 1963.
- Gordon, David B., and Eric M. Leeper, "Money, Debt and Price Determination: The Quantity and Fiscal Theories," unpublished, Indiana University, July 1999.
- Grandmont, Jean-Michel, *Money and Value*, Cambridge: Cambridge University Press, 1983.
- Grossman, Herschel I., "The Political Economy of War Debt and Inflation," in W. Haraf and P. Cagan, eds., *Monetary Policy for a Changing Financial Environment*, Washington, 1990.

- Kenc, Turalay, William Perraudin, and Paolo Vitale, "A Fiscal Theory of Inflation with Sovereign Default," unpublished, Birkbeck College, July 1997.
- King, Mervyn, "Commentary: Monetary Policy Implications of Greater Fiscal Discipline," in *Budget Deficits and Debt: Issues and Options*, Federal Reserve Bank of Kansas City, 1995.
- Kocherlakota, Narayana, and Christopher Phelan, "Explaining the Fiscal Theory of the Price Level," *Quarterly Review*, Federal Reserve Bank of Minneapolis, 23(4): 14-23 (2000).
- Leeper, Eric, "Policy Rules, Information and Fiscal Effects in a 'Ricardian' Model," International Finance Discussion Paper no. 360, Federal Reserve Board, August 1989.
- —, "Equilibria under 'Active' and 'Passive' Monetary and Fiscal Policies," *Journal of Monetary Economics* 27: 129-147 (1991).
- Leith, Campbell, and Simon Wren-Lewis, "Interactions between Monetary and Fiscal Policy Rules," unpublished, University of Exeter, October 1998.
- Loyo, Eduardo H.M., "Going International with the Fiscal Theory of the Price Level," unpublished, Princeton University, November 1997.
- —, "Tight Money Paradox on the Loose: A Fiscalist Hyperinflation," unpublished, Kennedy School of Government, June 1999.
- —, "Demand-Pull Stagflation," unpublished, Kennedy School of Government, April 2000.
- McCallum, Bennett T., "Indeterminacy, Bubbles, and the Fiscal Theory of Price Level Determination," NBER Working Paper no. 6456, March 1998.
- —, "Theoretical Issues Pertaining to Monetary Unions," NBER working paper no. 7393, October 1999.
- Obstfeld, Maurice, and Kenneth Rogoff, "Speculative Hyperinflations in Maximizing Models: Can We Rule Them Out?" *Journal of Political Economy* 91: 675-687 (1983).
- Santos, Manuel S., and Michael Woodford, "Rational Asset Pricing Bubbles," *Econometrica* 65: 19-58 (1997).
- Sargent, Thomas J., "The Ends of Four Big Inflations," in R.E. Hall, ed., *Inflation*,

- Chicago: University of Chicago Press, 1982.
- — and Neil Wallace, “‘Rational’ Expectations, the Optimal Monetary Instrument, and the Optimal Money Supply Rule,” *Journal of Political Economy* 83: 241-254 (1975).
- — and — —, “Some Unpleasant Monetarist Arithmetic,” *Quarterly Review*, Federal Reserve Bank of Minneapolis, Fall 1981.
- Schmitt-Grohé, Stephanie, and Martín Uribe, “Price Level Determinacy and Monetary Policy under a Balanced-Budget Requirement,” *Journal of Monetary Economics* 45: 211-246 (2000).
- Shim, Sang Dal, “Inflation and the Government Budget Constraint: International Evidence,” unpublished Ph.D. Dissertation, Department of Economics, University of Minnesota, August 1984.
- Sidrauski, Miguel, “Rational Choice and Patterns of Growth in a Monetary Economy,” *American Economic Review* 57(2): 534-544 (1967).
- Sims, Christopher A., “A Simple Model for the Study of the Determination of the Price Level and the Interaction of Monetary and Fiscal Policy,” *Economic Theory* 4: 381-399 (1994).
- —, “Fiscal Foundations of Price Stability in Open Economies,” unpublished, Yale University, September 1997. [Available at <http://www.princeton.edu/~woodford>.]
- —, “Econometric Implications of the Government Budget Constraint,” *Journal of Econometrics* 83: 9-19 (1998).
- —, “Fiat Debt as Equity: Domestic Currency Denominated Debt as Equity in the Primary Surplus,” unpublished, Princeton University, August 1999. [Available at <http://www.princeton.edu/~sims>.]
- Taylor, John B., “Discretion Versus Policy Rules in Practice,” *Carnegie-Rochester Conference Series on Public Policy* 39: 195-214 (1993).
- —, “A Historical Analysis of Monetary Policy Rules,” in J.B. Taylor, ed., *Monetary Policy Rules*, Chicago: University of Chicago Press, 1999.
- Timberlake, Richard H., *Monetary Policy in the United States: An Intellectual and Institutional History*, Chicago: University of Chicago Press, 1993.
- Toma, Mark, *Competition and Monopoly in the Federal Reserve System, 1914-1951*,

Cambridge: Cambridge University Press, 1997.

Woodford, Michael, "Monetary Policy and Price-Level Determinacy in a Cash-in-Advance Economy," *Economic Theory* 4: 345-380 (1994).

— —, "Price-level Determinacy Without Control of a Monetary Aggregate," *Carnegie-Rochester Conference Series on Public Policy* 43: 1-46 (1995).

— —, "Control of the Public Debt: A Requirement for Price Stability?" NBER working paper no. 5684, July 1996. [Shorter version published in G.A. Calvo and M. King, eds., *The Debt Burden and its Consequences for Monetary Policy*, London: Macmillan, 1997.]

— —, "Doing Without Money: Controlling Inflation in a Post-Monetary World," *Review of Economic Dynamics* 1:173-219 (1998a).

— —, "Comment on John Cochrane, 'A Frictionless View of U.S. Inflation'," *NBER Macroeconomics Annual* 13: 390-418 (1998b).

— —, "Public Debt and the Price Level," unpublished, Princeton University, June 1998c. [Available at <http://www.princeton.edu/~woodford>.]

— —, "Price-Level Determination under Interest-Rate Rules," unpublished, Princeton University, April 1999a. [Available at <http://www.princeton.edu/~woodford>.]

— —, "Inflation Stabilization and Welfare," unpublished, Princeton University, August 1999b. [Available at <http://www.princeton.edu/~woodford>.]

— —, "A Neo-Wicksellian Framework for the Analysis of Monetary Policy," unpublished, Princeton University, September 2000. [Available at <http://www.princeton.edu/~woodford>.]