DISCUSSION PAPER SERIES

No. 6814

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INTERNATIONAL MACROECONOMICS

Centre for Economic Policy Research

www.cepr.org

Available online at: www.cepr.org/pubs/dps/DP6814.asp

ISSN 0265-8003

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Discussion Paper No. 6814
May 2008

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CEPR Discussion Paper No. 6814

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ABSTRACT

Monetary and Fiscal Policy Coordination when Bonds Provide Transactions Services*

It is commonly asserted that monetary and fiscal policy may have to be coordinated if they are to provide a nominal anchor and avoid the pathological outcomes of sunspots or explosive price paths. In this paper, we study a model in which government bonds are an imperfect substitute for money in the transactions technology, providing a new channel for debt dynamics to feed into inflation dynamics. This modification of an otherwise standard NNS model substantially alters the conditions for local determinacy and the requirements for macroeconomic policy coordination: the Taylor Principle is no longer sacrosanct; a weak fiscal response to debt is no longer the panacea for a weak monetary policy; sunspot equilibria may be less relevant than previously thought; and the need for coordination may be less than previously thought. In addition, our model provides a new way of thinking about the structural break that is thought to have occurred around 1980 in monetary policy and in the dynamics of government spending and private consumption.

JEL Classification: E51 and E52
Keywords: bonds, monetary and fiscal policies and transaction services

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Submitted 21 April 2008

1. Introduction

It is commonly asserted that monetary and fiscal policy may have to be coordinated if they are to provide a nominal anchor and avoid the pathological outcomes of sunspots or explosive price paths. The problem is most acute when monetary policy is governed by an interest rate rule.[1] Starting with Leeper (1991), and continuing with Woodford's (1995) fiscal theory of the price level (FTPL), a series of papers has analyzed the conditions for price level determinacy and assessed their requirements for the coordination of macroeconomic policy. In this paper, we study a model in which government bonds are an imperfect substitute for money in the transactions technology, providing a new channel for debt dynamics to feed into inflation dynamics. This modification of an otherwise standard new neoclassical synthesis (NNS) model substantially alters the conditions for local determinacy and the requirements for macroeconomic policy coordination;[2] in addition, it provides a new way of thinking about the structural break that is thought to have occurred around 1980 in monetary policy and in the dynamics of government spending and private consumption.[3]

There is ample precedent for attributing transactions services to bonds.[4] In this paper, we follow tradition by modeling these transactions services in a reduced form way. In Canzoneri et al.

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[1] The notion that interest rate rules may not provide a nominal anchor is a very old one in monetary theory, with roots that trace back to Wicksell ([1898], 1965).

[2] This paper extends the work of Canzoneri and Diba (2005), who studied price level determinacy in an exchange economy. Linneman and Schabert (2005) also added transactions services of bonds to a model with price rigidity. The main novelty of the present paper is on the quantitative front.

[3] References to the literature on these empirical issues will be provided later in the paper.

[4] Patinkin (1965) presents a model in which both money and bonds appear in the household utility function. More recent work on applied topics includes Bansal and Coleman (1996), who study the equity premium puzzle and related issues.

(2008), we take a more structural approach, modeling banks that use cash and Treasury bills to manage the liquidity of their demand deposits.[5] In the present paper, we skip the modeling of financial institutions and assume that money and bonds directly provide transactions services to households. This simplification, as we shall see, makes it easier to build a quantitative model because we can pin down a number of important parameters in our model by matching the sample averages of some key monetary and fiscal variables in U.S. data.

Leeper (1991) characterized his monetary and fiscal policies as an interest rate rule responding to observed inflation and a (lump sum) tax rule responding to the level of the debt; our macroeconomic policies are similarly defined. Leeper found that an interest rate rule obeying the Taylor Principle (raising the nominal interest rate more than any increase in observed inflation) coupled with a tax rule that is stabilizing (in the sense that taxes rise more than enough on average to pay the interest on any increase in debt) would produce local determinacy; he also found, somewhat paradoxically, that an interest rate rule violating the Taylor Principle coupled with a tax rule that is not stabilizing would result in determinacy. Other policy combinations produce either sunspot equilibria or explosive solutions.

Leeper's model featured competitive firms and flexible prices. Inflation dynamics are decoupled from debt dynamics in that setting, and this property of Leeper's model is what allowed

[5] Our basic premise that U.S. Treasury bills provide transactions services should not be controversial. Treasury bills clearly facilitate transactions in a number of ways: they serve as collateral in many financial markets, banks hold them to manage the liquidity of their portfolios, and individuals hold them in money market accounts that offer checking services. In our model, households are homogenous in their borrowing and lending; so, government bonds are the only financial asset that is held in equilibrium. But this feature of our model clearly overlooks the fact that commercial paper – and other money market assets issued by the private sector – provide some of the same transactions services as T- bills; for example, they too are held in money market accounts with checking privileges.

him to characterize the policy coordination problem in such a simple way. NNS models add monopolistic competition and some form of nominal inertia, and inflation dynamics become more complicated; the easy characterization of the coordination required for determinacy breaks down. However, as Clarida, Gali and Gertler (2000), Woodford (2003) and others have shown, the Taylor Principle remains an approximate necessary condition for determinacy in models that (implicitly or explicitly) assume a stabilizing fiscal policy. Indeed, the Taylor Principle has become rather sacrosanct in the literature on determinacy.

When we let government bonds substitute for money in the transactions technology, there is a very direct channel for debt dynamics to feed into inflation dynamics: government deficits increase effective transactions balances and this affects inflation.[6] We find that this new channel significantly alters the Leeper view of the coordination required for determinacy – and much more so than the addition of sticky prices. The range of monetary and fiscal policies that deliver determinacy is greatly increased – which is good news – but so is the range that causes explosive behavior. In the interior of the determinacy region, monetary and fiscal policies can be changed independently, but in a neighborhood of the borders of the determinacy region, coordinated changes are required if sunspot equilibria and explosive solutions are to be avoided.

Of particular interest is the fact that the Taylor Principle is no longer sacrosanct.[7] Most empirical analyses of US monetary policy claim that the policies of the pre-Volker period violated

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[6] While Ricardian Equivalence does not hold in our model (since bonds provide transactions services), our assumptions and results are not related to Woodford's FTPL.

[7] Of more academic interest is the fact that interest rate pegs do not result in sunspot equilibria as long as fiscal policy is not too stabilizing. We discuss this in detail in Section III.

the Taylor Principle.[8] Taking this empirical claim at face value, the existing literature offers two alternative views of inflation dynamics during the period. One view invokes variants of the FTPL and emphasizes the potential role of fiscal policy in providing a nominal anchor.[9] The alternative view presumes that fiscal policy stabilized the debt, and concludes that sunspots played a role in inflation dynamics.[10] Our analysis in this paper highlights a third possible interpretation: even the weak response to inflation estimated for the pre-Volcker period was strong enough to determine a unique equilibrium. Indeed, when we calibrate our model to the data for this period, we find that a unique equilibrium exists for a very wide range of fiscal policies, including those estimated by Bohn (1998, 2004).

Our model also suggests that the structural break in monetary policy after 1979 may be related to documented breaks in the response of private consumption and the real interest rate to fiscal shocks.[11] In particular, the strong interest rate response to inflation in the Volker-Greenspan era may have choked off the effect of an increase in government spending before it reached private consumption spending; the weak interest rate response in the pre-Volker period may have allowed

[8] Orphanides (2004) is a notable exception.

[9] The classic reference is Woodford (1995). A recent example is Sala (2004). Davig and Leeper (2006) present an interesting variation in which the prevailing policies (i.e., the fiscal response to debt and the monetary response to inflation) are themselves governed by a stochastic process.

[10] Clarida, Gali and Gertler (2000) highlighted this possible interpretation. Lubik and Schorfheide (2004) presented supporting empirical evidence. A less explored alternative is related to the expectations trap hypothesis of Chari, Christiano and Eichenbaum (1998). According to this view the Fed was pushed into producing the high inflation out of a fear of violating the public's inflation expectations. A comparison of the views is discussed in Christiano and Gust (2000).

[11] See Perotti (2005), Mihov (2003) and Sala (2004).

private consumption to rise.[12]

The rest of the paper is organized as follows: In Section II, we outline our model. It is a standard NNS model – with fixed, firm specific capital, Calvo price setting, and flexible wages – except for the fact that we allow bonds to be an imperfect substitute for money. We use Schmitt-Grohe and Uribe's (2004) modeling of transactions costs, but we define "effective transactions balances" to be a CES aggregate of money and bonds. At the end of the section, we discuss our method of calibrating the model and our approach to robustness and comparative steady state exercises. Details of the (log) linearization of our model are relegated to an appendix. In Section III, we illustrate the regions of determinacy, sunspot equilibria and explosive solutions under alternative calibrations of the model. Our benchmark calibration reflects data from the Volker-Greenspan era, but we also calibrate the model to the more inflationary period of the 1970s and discuss the shift in monetary policy that is thought to have occurred around 1980. Then, we show how the regions shift when we decrease price rigidity and do other robustness checks. In Section IV, we discuss the structural break in the dynamics of government spending and private consumption that is also thought to have occurred around 1980. Here, we show how the response of private consumption to a government spending shock changes as we move from the monetary policies reminiscent of the pre-Volker period to the policies of the Volker-Greenspan era. Section V concludes with some caveats and some suggestions for future research.

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[12] Our model may also speak to a related issue about taxes. We do not pursue the issue in this paper, but tax cuts reduce real interest rates with our calibration for the pre-Volker period but raise real rates with our calibration for the later period – as they do in the VARS reported by Sala (2004).

II. The Model, Calibration, and Dynamic Analysis

Here, we modify a standard NNS model by letting bonds have some transactions value. First, we outline the model; then, we describe its calibration and our dynamic analysis. Our NNS model is characterized by Calvo-style price setting, flexible wages, and a fixed capital stock. Capital is firm specific; there is no rental market for capital.

II. A. The Model

Households –

There is a continuum of households on the unit interval. The utility of a representative household is

(1) $U_t = E_t \sum_{j=t}^{\infty} \beta^{j-t}[\log(c_j) - (1+\chi)^{-1} n_j^{1+\chi}]$

where c_t is consumption of a composite good (defined below), and n_t is hours of work. Households are identical in this model; so, we can dispense with household indices. Moreover, the population has measure one; so in equilibrium, per capita supplies and demands will be equal to aggregate supplies and demands. The household's budget constraint is

(2) $m_t + b_t + (1+\tau_t)c_t = w_t n_t + (m_{t-1} + R_{t-1}b_{t-1})/\Pi_t - t_t + div_t$.

m_t and b_t are real money and bond holdings, $w_t n_t$ is real wage income, R_{t-1} is the gross nominal interest rate on period t-1 bonds, $\Pi_t = P_t/P_{t-1}$ is the gross inflation rate, t_t is a lump sum tax and div_t represents dividends. $\tau_t c_t$ represents transactions costs, which will be described next.

Following Schmitt-Grohe and Uribe (2004), we assume that transactions costs are proportional to consumption and the factor of proportionality is an increasing function of velocity.

(3) $\tau_t = \begin{cases} (A/v_t)(v_t - v^*)^2 & \text{for } v_t > v^* \\ 0 & \text{for } v_t \le v^* \end{cases}$

where v* is the satiation level of velocity. The new element here is in our definition of velocity

(4) $v_t = c_t/\tilde{m}_t$

where effective transactions balances – $\tilde{m}_t$ – are a CES bundle of money and bonds

(5) $\tilde{m}_t^{\rho} = a^{1-\rho}m_t^{\rho} + (1 - a)^{1-\rho}b_t^{\rho}$

a ε [0, 1] is a parameter that measures the importance of money in effective transactions balances. $1/(1 - \rho)$ is the elasticity of substitution between money and bonds in effective transactions balances. If $0 < \rho < 1$, money and bonds are "substitutes"; and if $\rho < 0$, money and bonds are "complements".

The household's first order conditions are

(6) $w_t\lambda_t = n_t^{\chi}$

(7) $1/c_t = \lambda_t[1 + 2A(v_t - v^*)]$

(8) $1 - A[v_t^2 - (v^*)^2](a\tilde{m}_t/m_t)^{1-\rho} = 1/R_t^*$

(9) $1 - A[v_t^2 - (v^*)^2][(1-a)(\tilde{m}_t/b_t)]^{1-\rho} = R_t/R_t^*$

where λ_t is the marginal utility of wealth, and R_t^* is the CCAPM interest rate; that is, $1/R_t^* = \beta E_t[(\lambda_{t+1}/\lambda_t)/\Pi_{t+1}]$. It will facilitate our discussion to think of R_t^* as the rate of return on a hypothetical bond, b_t^*, that does not provide transactions services.

(6) is a standard labor supply curve, and (7) defines the marginal value of wealth. When real resources are depleted in the purchase of consumption goods, the marginal value of wealth is less than the marginal utility of consumption. (8) and (9) are the first order conditions for money and bonds; they can be combined to show that

(10) $$\frac{S_t}{R_t^* - 1} = \left(\frac{1-a}{a}\right)^{1-\rho}\left(\frac{m_t}{b_t}\right)^{1-\rho}$$

where $S_t = R_t^* - R_t$ is the spread between the CCAPM rate and the return on government bonds.

Since b provides transactions services, it will be held at a lower rate of return than b*; the spread, S_t, will be positive in equilibrium. S_t is the pecuniary opportunity cost of holding the bond that does provide transactions services, and R^*_t - 1 is the opportunity cost of holding money. So, (10) says that in the optimal portfolio, the relative price of m and b is equated to the marginal rate of substitution of m and b in the "effective transactions services" aggregator, (5). Note that as bonds lose their usefulness in the aggregator ($a \rightarrow 1$), the required spread, S_t, falls to zero; and as bonds become perfect substitutes for money ($\rho \rightarrow 1$), the required return on bonds must fall to the fixed return on money ($R_t \rightarrow 1$).

Firms –

There is a continuum of firms indexed by f on the unit interval. Each firm has a fixed, firm specific, capital stock, $\bar{k}$. At time t, the firm hires labor, $n_t(f)$, at the competitive wage rate, w_t, and produces a differentiated product using a decreasing returns technology

(11) $y_t(f) = z_t\bar{k}n_t(f)^\alpha,\ \ 0 < \alpha < 1$

Total factor productivity, z_t, follows a process that is common to all firms

(12) $\ln(z_t) = (1 - \rho_z)\ln(\bar{z}) + \rho_z\ln(z_{t-1}) + \varepsilon_{z,t}$

where $0 < \rho_z < 1$ and $\bar{z}$ is the steady state value of z.

The modeling of monopolistic competition is standard in the NNS literature. We assume the artifice of a competitive bundler: the bundler acquires the firms' products, paying the prices $P_t(f)$ set by the firms, and assembles a composite good

(13) $y_t = [\int_0^1 y_t(f)^{(\varepsilon-1)/\varepsilon}df]^{\varepsilon/(\varepsilon-1)},\ \ \varepsilon > 1$

The bundler then sells the composite good to households and the government at the price P_t. The constant elasticity aggregator (13) reflects household and government preferences; so, the bundler chooses the same combination of products that households and the government would, and the bundler's demand for $y_t(f)$ is equal to the total demand for the firm's product. Cost minimization and the zero profit condition imply that the aggregate price is

(14) $P_t = [\int_0^1 P_t(f)^{1-\varepsilon} df]^{1/(1-\varepsilon)}$

and the bundler's demand for the product of firm f is

(15) $y_t(f) = (P_t / P_t(f))^{\varepsilon} y_t$.

Firms set prices in staggered price 'contracts' of random duration. In any given period, the firm gets to announce a new price contract with probability (1-θ); otherwise, its old contract remains in effect, and the firm's price is simply updated by steady state inflation, $\bar{\pi}$. With this scheme, the average duration of a price contract is $(1-\theta)^{-1}$ periods (quarters).

If a firm gets to announce a new contract in period t, it chooses a new contract price, $\tilde{P}_t$, to maximize the value (measured in units of household utility) of its profit stream over the states of nature in which the new price holds. The firm's problem is to

(16) $\max_{\tilde{P}_t} E_t \sum_{j=t}^{\infty} (\theta\beta)^{j-t} \lambda_j [(\tilde{P}_t \bar{\pi}^{j-t}/P_j) y_j(f) - w_j n_j(f)]$

subject to (11) and (15). The first order condition is

(17) $\left(\frac{\tilde{P}_t}{P_t}\right)^{1+\frac{\varepsilon}{\alpha}-\varepsilon} = \left(\frac{\varepsilon}{\alpha(\varepsilon-1)}\right)\left(\frac{PB_t}{PA_t}\right)$

where

(18) $PB_t = E_t \sum_{j=t}^{\infty} (\theta\beta)^{j-t} \lambda_j w_j [(P_j/P_t)/\bar{\pi}^{j-t}]^{\varepsilon/\alpha} (y_j / z_t \bar{k})^{1/\alpha}$

(19) $PA_t = E_t \sum_{j=t}^{\infty} (\theta\beta)^{j-t} \lambda_j [(P_j/P_t)/\bar{\pi}^{j-t}]^{\varepsilon-1} y_j$

Given the Calvo framework, aggregate price dynamics follow

(20) $P_t^{1-\varepsilon} = \theta(P_{t-1}\bar{\pi})^{1-\varepsilon} + (1-\theta)\tilde{P}_t^{1-\varepsilon}$

Aggregate Employment and Output –

We will want to express our model in terms of economy wide aggregates. As has already been mentioned, households are identical, and their per capita supplies and demands are equal to aggregate supplies and demands. Firms are not identical in this model since staggered price setting implies that they may be charging different prices. Following Yun (1996), however, we can keep track of price dispersion and derive an aggregate production function.

The production function (11) implies that, the firm's demand for labor is

(21) $n_t(f) = [y_t(f)/z_t\bar{k}]^{1/\alpha}$

So, making use of the firm's demand curve (15), aggregate labor demand is

(22) $n_t = \int_0^1 n_t(f)df = (1/z_t\bar{k})^{1/\alpha}\int_0^1 y_t(f)^{1/\alpha}df = (y_t /z_t\bar{k})^{1/\alpha}\int_0^1(P_t /P_t(f))^{\varepsilon/\alpha} df$

Letting $Disp_t \equiv \int_0^1(P_t /P_t(f))^{\varepsilon/\alpha}df$, we arrive at the aggregate production function

(23) $y_t = z_t\bar{k}n_t^{\alpha}/(Disp_t)^{\alpha}$

Recall that aggregate output, y_t, is defined by the aggregator (13); it is not the simple sum of firm outputs. And while (23) bears a striking resemblance to the firm's production function, it does indicate that price dispersion lowers aggregate output (since $Disp_t \geq 1$). However, to a first order of approximation, the difference between our aggregators and a simple linear sum is just a constant and $Disp_t = 1$. So, these distinctions, while characteristic of the NNS paradigm, do not play a role in what follows.

Finally, since resources are used up in transacting, market clearing requires

(24) $y_t = (1+\tau_t)c_t + g_t$

We assume that government spending follows an exogenous AR(1) process

(25) $\ln(g_t) = (1-\rho_g)\ln(\bar{g}) + \rho_g \ln(g_{t-1}) + \varepsilon_{g,t}$

where $0 < \rho_g < 1$, and $\bar{g}$ is the steady state value of g_t.

Monetary and Fiscal Policy –

Following Leeper (1991), monetary policy will be characterized by an interest rate rule

(26) $\ln(R_t/\bar{R}) = \varphi_\pi \ln(\Pi_t/\bar{\Pi})$

where steady state values are denoted by a bar. Note that the central bank's instrument is the money market rate, the interest rate on the bond that provides transactions services. If $\varphi_\Pi > 1$, a rise in inflation induces an even greater increase in the interest rate. We will call this a monetary policy that satisfies the Taylor Principle.[13]

The government's flow budget constraint is

(27) $m_t + b_t = (m_t + R_{t-1}b_{t-1})/\Pi_t + g_t - t_t$

Letting $l_t = m_t + b_t$ represent total government liabilities, (27) can be rewritten as

(28) $l_t = l_{t-1}/\Pi_t + d_t$

where d_t is the total deficit (inclusive of interest payments).

As noted earlier, government spending is an exogenous process. We assume the government's instrument is the lump sum tax, t_t, and we assume fiscal policy is characterized by a tax rule

(29) $t_t = t + \varphi_d(b_{t-1} - \bar{b})$

When $\varphi_d > \bar{R}/\bar{\Pi} - 1$, we will say that fiscal policy is " debt stabilizing", since tax increases are more than sufficient to pay the interest on any increase in the debt.[14]

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[13] Leeper (1991) called monetary policy "active" if $\varphi_\pi > 1$, and "passive" if $\varphi_\pi < 1$.

[14] Leeper (1991) called fiscal policy "passive" if $\varphi_d > \bar{R}/\bar{\Pi}-1$ and "active" if $\varphi_d < \bar{R}/\bar{\Pi}-1$.

In Section III, we will study inflation dynamics for various combinations of φ_π and φ_d. As is well known from the work of Leeper (1991) and others, monetary and fiscal policy must be properly coordinated to avoid sunspots or explosive inflation behavior.

B. Calibration and Steady State Solution

The particular way we solve for the steady state equilibrium is dictated by our approach to the model's calibration. Our model has a number of parameters (in our specifications of transactions costs and the transactions technology) that we cannot pin down in a standard way.[15] Our strategy is to set our parameters to match the key monetary and fiscal variables in the data. Specifically we begin by setting the steady state values $\bar{\Pi}$, $\bar{R}$, $\bar{b}/\bar{c}$, $\bar{b}/\bar{m}$, and $\bar{g}/\bar{y}$ equal to their sample averages in our data. Then, $\bar{R}^*$ (= $\bar{\Pi}/\beta$) and $\bar{S}$ (= $\bar{R}^*$ - $\bar{R}$) are determined by the discount factor β. Equation (28) implies a steady state relationship between monetary and fiscal policy:

(30) $\bar{d}/\bar{c} = [(\bar{\Pi} - 1)/\bar{\Pi}][(\bar{m}/\bar{c}) + (\bar{b}/\bar{c})]$,

which pins down the steady state deficit to consumption ratio.[16] This is the easy part of the calibration.

We show in the appendix that for given values of ρ and $\bar{\tau}$, the steady state equations pin down the values of the remaining parameters in the transactions technology – a, A, v* and and $\bar{v}$. In our benchmark calibration, we assume that transactions costs are 0.1% of consumption; we think

[15] Earlier work does not offer us much guidance in setting these parameters. In particular, Schmitt-Grohe and Uribe's (2004) calibration of transactions costs was based on an estimated money demand equation. Once we introduce bonds into the transactions technology, we lose the money demand interpretation.

[16] This in turn pins down the ratio of taxes to consumption in the steady state equilibrium. Later, we derive an equation for steady-state consumption, and this determines taxes in the steady state.

that this is a rather conservative estimate. We don't have much intuition about the value of $(1\text{-}\rho)^{-1}$ (the elasticity of substitution between money and bonds). So, we consider two cases: in the first, $(1\text{-}\rho)^{-1} = 2$ (money and bonds are "substitutes"); in the second, $(1\text{-}\rho)^{-1} = 2/3$ (money and bonds are "complements"). Given these values, and the steady state values we discussed above, we can calculate the values of a, v*, $\bar{v}$, A and $\bar{c}$ from the steady state equations:[17]

$$(31)\quad a = \frac{\bar{m}/\bar{b}}{\left[\bar{m}/\bar{b} + \beta\,\bar{S}/(\bar{\Pi} - \beta)\right]^{1/(1-\rho)}}$$

$$(32)\quad \bar{v} = (\bar{\tilde{m}}/\bar{c})^{-1} = [a^{(1-\rho)}(\bar{m}/\bar{c})^{\rho} + (1-\bar{a})^{(1-\rho)}(\bar{b}/\bar{c})^{\rho}]^{-(1/\rho)}$$

$$(33)\quad \frac{v^{*}}{\bar{v}} = \left(\frac{\dfrac{1-\beta/\bar{\Pi}}{a\left(\bar{\tilde{m}}/\bar{m}\right)^{1-\rho}\bar{v}} - \bar{\tau}}{\dfrac{1-\beta/\bar{\Pi}}{a\left(\bar{\tilde{m}}/\bar{m}\right)^{1-\rho}\bar{v}} + \bar{\tau}}\right)$$

$$(34)\quad A = \frac{1-\beta/\bar{\Pi}}{\bar{a}\left(\bar{\tilde{m}}/\bar{m}\right)^{1-\rho}\left(\bar{v}^{2} - v^{*2}\right)}$$

$$(35)\quad \bar{n} = \left[\frac{\alpha\,(\varepsilon - 1)}{\varepsilon(1 - (\bar{g}/\bar{y}))}\right]\left[\frac{1+\bar{\tau}}{1+2A(\bar{v} - v^{*})}\right]^{1/(\chi+1)}$$

$$(36)\quad \bar{y} = \bar{k}\bar{n}^{\alpha}$$

$$(37)\quad \bar{c} = \left[\frac{1-(\bar{g}/\bar{y})}{1+\bar{\tau}}\right]\bar{y}$$

The benchmark calibration of our model is based on U.S. data from 1985 to 2004, a period we will refer to as the Volker-Greenspan era. We use sample averages to estimate the steady state

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[17] See the appendix for a discussion of the derivation of these equations.

values of $\bar{\Pi}$, $\bar{R}$, $\bar{b}/\bar{c}$, $\bar{b}/\bar{m}$, and $\bar{g}/\bar{y}$;[18] we set β equal to 0.99 (as is usual in quarterly models) to calibrate $\bar{R}^*$. The first two columns of Table 1 report these estimates, along with the values for a, v*, $\bar{v}$, A and $\bar{c}$ implied by equations (31) through (37).

Table 1 also specifies the other parameters in the model; they are standard in the literature: $\theta = 0.75$ implies that the average duration of prices is four quarters; $\varepsilon = 7$ implies that the steady state markup is 1.17; $\chi = 1$ implies that the disutility of work is quadratic; $\alpha = .66$ implies that capital's share is one third.

In the next section, we will want to see how our results change when we re-calibrate the model to fit the more inflationary 1970s, and we will also want to check the robustness of our basic results to changes in various parameter values. There is no really clean way of performing these exercises: we can change one parameter value while holding all of the other parameters constant, or we can require our perturbations in the parameter space to be model consistent. We have chosen to do the latter. So, when for example we change the value of steady state inflation (while holding $\bar{\tau}$ and ρ constant), the parameters in the transactions technology – a, $\bar{v}$, v^* and A – will shift in accordance with equations (31) through (34).

C. Dynamic analysis

The primary purpose of this paper is to determine how monetary and fiscal policy – characterized by parameters φ_π and φ_d – must be coordinated to eliminate sunspots and explosive

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[18] Data on CPI inflation and federal funds rate from 1985-2004 were averaged to estimate $\bar{\Pi}$ and $\bar{R}$. We rounded the sample average of the ratio of the monetary base to personal consumption expenditure to obtain its steady state value. Due to the large swings in the ratio of the publicly held Federal debt to personal consumption expenditures during this period, we chose a value reflecting the ratio near the end of the sample.

behavior. The condition for local determinacy is that the number of eigenvalues outside the unit circle, N_u, be equal to the number of jumping variables, N_j. If $N_u < N_j$, the jumping variables are not uniquely determined and sunspot equilibria are possible; if $N_u > N_j$, then there are not enough jumping variables to suppress explosive behavior. The secondary purpose of the paper is to investigate some of the implications of this stability analysis for current questions in the macroeconomic literature.

First, we (log) linearize the model and calculate its eigenvalues. It turns out that the linearized model can be reduced to three dynamic equations with two jumping variables: consumption and inflation. The third variable is a linear combination of debt, consumption and inflation; this is the state variable representing debt dynamics.[19] So, the condition for local determinacy is that two of the eigenvalues are outside the unit circle. We compute the number of stable and unstable eigenvalues for a fine grid of values of the policy parameters φ_π and φ_d.

We have also coded the non-linear equations into Dynare. This program will linearize the model and calculate its eigenvalues numerically for given values of φ_π and φ_d. There are two reasons for doing this: first, we can numerically spot check the rather tedious algebra; and second, Dynare is convenient for calculating the model's impulse response functions.

III. Regions (in Policy Space) of Determinacy, Sunspots and Explosive Behavior

In this section, we show how monetary and fiscal policies – as characterized by values of φ_π and φ_d – must be coordinated to rule out two extreme forms of price instability: sunspots and explosive inflation behavior. As mentioned in Section II.C, the condition for local determinacy is

[19] A full discussion of this linearization and system reduction is available in the Appendix.

that the number of eigenvalues outside the unit circle be equal to the number of jumping variables. In our log linearized model, we have three eigenvalues and two jumping variables (inflation and con-sumption). For combinations of φ_π and φ_d that produce two eigenvalues outside the unit circle, the model determines the endogenous variables uniquely. We will call this the "determinacy" region of the policy space (φ_π, φ_d). For combinations of φ_π and φ_d that produce only one eigenvalue outside the unit circle, the model does not determine the endogenous variables uniquely, and sunspot equilibria are possible. We call this the "sunspot" region. For combinations of φ_π and φ_d that produce three eigenvalues outside the unit circle, the model exhibits explosive behavior. We call this the "explosive" region. These three regions are illustrated in Figures 1 through 5.

Figure 1: Our Benchmark Calibration, the Volcker-Greenspan Era.

Figure 1 illustrates the three regions for the benchmark calibration of our model. Money and bonds are substitutes ($\rho = 0.5$, elasticity = 2) in the top panel, and complements ($\rho = -0.5$, elasticity = 2/3) in the bottom panel. The axes in Figure 1 are set at $\varphi_\pi = 1$ (the cutoff point for the Taylor Principle) and $\varphi_d = 0.006$, which is the quarterly real interest rate (2.4% annual) in the steady state. The determinacy region in Figure 1 is the area between the two shaded areas. The darker shaded area is the sunspot region, and the lighter shaded area is the explosive region.

To put the three regions in perspective, we will review the standard results due to Leeper (1991) and others. In the NE quadrant, monetary policy obeys the Taylor Principle; that is, the central bank raises the nominal interest rate more than any increase in observed inflation. And, fiscal policy raises the primary surplus more (on average) than the interest on any increase in government debt. In the SW quadrant, monetary policy does not obey the Taylor Principle and fiscal policy does not stabilize the debt. Leeper's model featured competitive firms and flexible prices, but his monetary and fiscal policy rules are the same as ours. In his model, the sunspot region is the entire SE quadrant and the explosive region is the entire NW quadrant; the determinacy region is the NE and SW quadrants.

Inflation dynamics are decoupled from debt dynamics in Leeper's model. This property allowed him to characterize the three regions in such a simple way. NNS models add some form of nominal inertia, and as a result, inflation dynamics become more complicated; the easy characterization of regions breaks down. However, as Clarida, Gali and Gertler (2000) and others have shown, the Taylor Principle remains an approximate necessary condition for determinacy. Indeed, the Taylor Principle has become rather sacrosanct in the literature.

We have let bonds provide transactions services, and as Canzoneri and Diba (2005) noted, this creates a new channel for fiscal policy to affect inflation dynamics: fiscal policy affects the supply of bonds, and bonds are a component in what we have called effective transactions balances. This further complicates the classification of regions. And as Figure 1 shows, Leeper's characterization of the three regions is substantially altered.

Figure 1 has a number of striking features. First, the sunspot region is dramatically reduced, and the explosive region is somewhat increased. Sunspots are less of a problem than in the conventional view, while explosive behavior is more. It also appears to matter whether bonds are a good substitute for money or a poor substitute: if bonds are a poor substitute, then the shifts in the regions are magnified. A second striking feature of Figure 1 is that the Taylor Principle no longer appears to be sacrosanct: monetary policies that violate this principle fall within the determinacy region as long as fiscal policy is not too aggressive in stabilizing the debt.[20] And this brings us to a

[20] This is not just the Fiscal Theory of the Price Level dressed in new clothing. In particular, fiscal policies that Woodford (1995) would classify as "Ricardian" can be paired with

third striking feature of Figure 1: the boundaries of the regions are upward sloping. On the frontiers, regime switches may need to be coordinated to avoid the extremes of sunspot equilibria and explosive behavior: on the sunspot frontier, a more stabilizing fiscal policy must be accompanied by a more aggressive monetary policy; and on the explosive frontier, a more aggressive monetary policy must be accompanied by a more stabilizing fiscal policy.

One regime switch that has received a lot of attention is the perceived change in monetary policy that occurred around 1980: monetary policy is thought to have satisfied the Taylor Principle during the Volker-Greenspan era, but not in the period that preceded it. Typical estimates of φ_π range from about 1.5 to 2.2 for the Volker-Greenspan era, and from 0.8 to 0.9 for the period that preceded it.[21] The literature discussing this regime switch generally accepted the Leeper characterization of the regions (or something close to it), and it was not clear what pinned down nominal variables during the pre-Volker period. Indeed, monetary policy has often been criticized as being too lax during that period.[22]

The Fiscal Theory of the Price Level (FTPL) provided an interesting alternative to the conventional view.[23] In particular, Woodford (1995) argued that if fiscal policy was non-Ricardian

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monetary policies that violate the Taylor principle and still fall within the determinacy region. We will return to the FTPL below.

[21] There is a large literature on the estimation of Henderson-McKibbin-Taylor rules for monetary policy. Prominent examples include: Taylor (1999) who estimated φ_π to be 0.81 for the period 1960:1 - 1979.4, and 1.53 for the period 1987:1 - 1997:3; Clarida, Gertler and Gali (2000) who estimated φ_π to be 0.83 for the period 1960:1 - 1979.2, and 2.15 for 1979:3 - 1996:4; and Lubik and Schorfeide (2004) who estimated φ_π to be either 0.77 or 0.89 for the period 1960:1 - 1979:2 and 2.19 for 1982:4 - 1997:4.

[22] See, for example, Clarida, Gertler and Gali (2000) or Taylor (1999).

[23] The correspondence between Woodford's FTPL and our analysis here is not exact. We require local stability of the real government debt; Woodford only required a No-Ponzi game

(in a sense that he clearly defined) during the pre-Volker period, the price level could have been determined by a household transversality condition. This was an ingenious (and provocative) solution to the determinacy problem, but it also introduced a formidable coordination problem. Determinacy in the FTPL required that a monetary policy satisfying the Taylor Principle had to be accompanied by a Ricardian fiscal policy. Did fiscal policy make the required switch in 1980? And if so, how was the coordination of monetary and fiscal policy achieved?

Figure 1 suggests a different resolution of the determinacy problem – one that does not require nearly as much coordination.[24] In fact, if money and bonds are substitutes, no coordination at all is needed for the range of monetary and fiscal policies that would appear to be relevant. As reported above, φ_π has been estimated to be in the range [0.8, 2.2], greater than one in the Volker-Greenspan era and less than one in the pre-Volker period. Bohn (1998, 2004) has provided estimates of φ_d in the range [0.0125, 0.0300]. This whole rectangle falls in the determinacy region in the top panel of Figure 1. Within this rectangle, monetary and fiscal policies can be shifted without any need for coordination. If money and bonds are complements, fiscal policy has to be sufficiently stabilizing to allow to allow values of φ_π in the upper range of the estimates; in particular, φ_d must be greater than 0.010 (almost two times the real interest rate) to provide determinacy when $\varphi_\pi = 2.2$.

This last observation illustrates the increased importance of the explosive region, which has received little attention in the literature. Given the proclivity of newly independent central banks for inflation targeting, some recent studies have considered very high values of φ_π. If bonds provide

condition.

[24] Davig and Leeper (2006) suggest an alternative resolution.

transactions services, Figure 1 suggests that these monetary policies could be dangerous unless they are accompanied by fiscal policies that are sufficiently stabilizing. And the risk is inversely related to the substitutability of money and bonds.

Of more academic interest is the issue of interest rate pegs ($\varphi_\pi = 0$). Interest rate pegs fall into the sunspot region in conventional models. Figure 1 shows that interest rate pegs fall into the determinacy region in our model as long as fiscal policy is not too aggressive in stabilizing debt. Here again, the substitutability of money and bonds seems to matter: if money and bonds are substitutes, φ_d must be less than 0.013 (approximately twice the real interest rate); if money and bonds are complements, φ_d must be less than 0.022 (about 3 times the real interest rate). In any case, this provides a new resolution to a very old problem in monetary theory.

Figure 2: the pre-Volker Period.

In the benchmark solution (upon which Figure 1 was based), the steady state of the model was calibrated to match U.S. data from 1985 to 2004, the Volker-Greenspan era. However, many of the issues discussed in the last subsection were motivated by comparisons of the Volker-Greenspan era with the pre-Volker period. So, for Figure 2, we re-calibrated the steady state of our model with the more inflationary data of the 1970s in mind. We raised the quarterly inflation rate to 0.2%, we increased the quarterly interest rate to 1.2% (increasing the spread to 0.9%), and we lowered the ratio of debt to quarterly consumption to1.0; the ratio of money to consumption did not change. The implied values for the other parameters in the transactions technology are given in Table 1.

In Figure 2, the solid lines reproduce the same three regions illustrated in Figure 1. The shaded areas show how the regions shift for the more inflationary period of the 1970's. Once again, money and bonds are substitutes (elasticity = 2) in the top panel, and complements (elasticity = 2/3) in the bottom panel.

The most striking feature in Figure 2 is that the sunspot region is greatly reduced. In fact, if money and bonds are complements, the sunspot region virtually disappears in our model. Interest rate pegs are in the determinacy region as long as φ_d is less than .042 (or seven times the real interest rate!); this is way outside the range of Bohn's estimates; if money and bonds are substitutes, φ_d must be less than 0.02 (or 3.3 times the real interest rate). Our resolution of the determinacy problem associated with this period seem quite conceivable.

It is indeed ironic that as OECD countries have been successful in lowering trend inflation, they may also have increased the possibility of sunspot equilibria. It is also ironic that the possibility of sunspot equilibria is enhanced by making fiscal policy more aggressive in its debt stabilization effort. This result puts some qualifications on the conventional notion that a sound fiscal policy is required for a stable inflation rate. It appears that there can be too much of a good thing: the Augustinian admonition of "everything in moderation" may apply to fiscal policy as well.

Robustness of the Three Regions in our Benchmark Model.

Figure 1 illustrates the thee regions in our benchmark case. Figures 3, 4 and 5 test the robustness of our results in various ways. Figure 3 tests the sensitivity of our results to the degree of price stickiness; Figure 4 increases the steady state transactions costs; and Figure 5 increases the steady state interest rate spread (by decreasing the household discount factor). Changing the degree of price stickiness will not affect the model's steady state, but changing transactions costs or the interest rate spread will. In these exercises, we leave the $\bar{\Pi}$, $\bar{R}$, $\bar{b}/\bar{c}$, $\bar{b}/\bar{m}$, $\bar{g}/\bar{y}$ and ρ at their benchmark values, and we use equations (31) through (35) to calculate the remaining parameters in the transactions technology; the new values are reported in Table 1.[25]

We have set the Calvo parameter, θ, equal to 0.75, which is standard in the literature and consistent with aggregate price data. More recent studies of disaggregated price data suggest that prices may be more flexible. We can allow greater price flexibility by setting the Calvo parameter equal to 0.3; this decreases the average duration of a price contract from 4 quarters to about 1.5 quarters. Figure 3 shows the results. As before, the solid lines reproduce the regions illustrated in Figure 1, and the area between the shaded areas is the determinacy region with more flexible prices. The determinacy region does shift slightly, but the shift is not visible to the naked eye in Figure 3.

In the benchmark case, steady state transactions costs are set at one tenth of a percent of consumption. We do not know how high transactions costs are in the U.S. economy, but we think this is a rather conservative estimate. In Figure 4, we raise transactions costs to one half of a percent of consumption. Once again, the solid lines reproduce the regions illustrated in Figure 1. If the cost of transacting is higher than in our benchmark, then the sunspot region is larger and the explosive region is smaller. However, the shapes of the three regions are the same as in Figure 1; so, our basic results are robust across a range of estimates.

In the benchmark case, the steady state interest rate spread is 0.4 % (1.6% annual). This spread was chosen to fit the data from the Volker-Greenspan era, assuming $\beta = 0.99$. This value of β is standard in the literature that equates the CCAPM rate with the money market rate. In our model, the CCAPM rate is larger than the money market rate, and this suggests that a lower value of β may be appropriate. In Figure 5, we left $\bar{\Pi}$, $\bar{R}$ $\bar{b}/\bar{c}$, $\bar{b}/\bar{m}$ and $\bar{\tau}$ at their benchmark values, but we decreased the discount factor, β, from 0.99 to 0.988. This has the effect of increasing $\bar{R}^*$ and raising

[25] The steady state values of consumption and output can be obtained from (36) and (37).

$\bar{S}$ to 0.6%.[26] Raising the interest rate spread in this way decreases the sunspot region and increases the explosive region. This suggests that the proper calibration of the "risk free" rate is important in this kind of model. Once again, however, the general shapes of the regions are the same as in Figure 1, and in this sense, our basic results seem robust.

Finally, we did a robustness check that, like the increase in price flexibility, did not visibly change the regions in Figure 1. So far, we have assumed that capital is fixed and firm specific. This dampens the response of inflation to movements in marginal cost and helps NNS models in fitting aggregate inflation dynamics. However, making the production function linear in labor does not change our results.

IV. The Dynamics of Real Interest Rates, Consumption and Government Debt

We coded our model in Dynare for two basic reasons. First, Dynare will linearize the full model for specific parameterizations and calculate the eigenvalues. This allowed us to spot check the results presented in the last section. The spot checks indicated that the two approaches were consistent to a very high degree of accuracy. Second, Dynare is a useful tool for exploring the dynamics of real interest rates, consumption and debt. It turns out that the liquidity of government bonds may help us explain some rather puzzling results in the empirical literature.

In particular, there is a controversy about the effects of a government spending shock on private household consumption. The conventional result is due to Blanchard and Perotti (2002), Fatas and Mihov (2003), Gali, Lopez-Salido and Valles (2007) and others, who used VAR techniques on U.S. data to show that a government spending shock increases consumption. However,

[26] The other parameters in the transactions technology will be affected; see Table 1.

in subsequent work Perotti (2004), Mihov (2003) and Bilbiie, Meier, and Muller (2006) found that a structural break may have occurred around 1980. For example, Perotti's impulse response functions for the U.S., Germany, Great Britain, Canada and Australia showed that a government spending shock lowered real interest rates and raised consumption in the pre-1980 sample, but raised real interest rates and lowered consumption in the post-1980 sample in all countries except the U.S.; in the U.S., the response of the consumption was still positive but considerably weakened.

Impulse response functions from NNS models tend to show that a government spending shock decreases consumption. As Fatas and Mihov note, this response is reminiscent of the RBC literature: households save to pay off the future taxes that an increase in government spending implies. Adding sticky prices, and the demand determination of output, does not seem to overturn this result. Gali, Lopez-Salido and Valles (2007), Erceg, Guerrieri and Gust (2004), Coenen and Straub (2005) and others have tried – with some success – to make consumption rise following a government spending shock by modeling "rule of thumb" agents, agents that simply spend any increase in current income. However, these modeling efforts do not address the structural break in the dynamics of consumption, real interest rates, and government spending that was reported by Perotti (2004).

Bilbiie, Meier, and Muller (2006) tried to explain this structural break in terms of three separate factors: (1) the increase in the Fed's interest rate response to inflation, which is generally thought to have occurred at about the same time; (2) a decline in the importance of "rule of thumb" agents; and (3) a decrease in the persistence of government spending shocks. They argue that the first factor was the most important single determinant. However, an interest rate rule that did not satisfy the Taylor Principle would (presumably) not have produced determinacy in their model;

indeed, they set $\varphi_\pi = 1.012$ for their pre-1980 simulations. As noted in the last section, others have estimated φ_π to have been between 0.8 and 0.9 during that period.

Modeling transactions services for government bonds may help explain the break in dynamics in two ways. First, to the extent that the increase in government spending is bond financed, "effective" transactions balanced are increased and this has an expansionary effect in a model with sticky prices. And second, as shown in the last section, monetary policies that violate the Taylor Principle can fall in the determinacy region when bonds provide transactions services. The impulse response functions pictured in Figures 6 and 7 illustrate the possibilities.[27]

Figure 6 reflects our calibration of the Volcker-Greenspan period, in which the Taylor Principle is followed. A government spending shock increases inflation and the interest rate rule raises the real return on bonds; debt rises and consumption falls. The wealth effect, combined with the effect of higher real interest rates on aggregate demand, chokes off household consumption. This happens when money and bonds are substitutes (Figure 6A), and when they are complements (Figure 6B).

Figure 7 reflects our calibration of the pre-Volcker era, in which the Taylor Principle is violated. A government spending shock increases inflation, but the interest rate rule lowers the real return on bonds; debt rises and consumption rises, although it takes four quarters for the latter to happen when money and bonds are substitutes. Here, the effect of lower real interest rates on aggregate demand allows household consumption to rise despite the negative wealth effect.

[27] In generating the IRFs, we have set $\rho_g = 0.85$.

V. Conclusion

In this paper, we modified a standard NNS model by letting government bonds be an imperfect substitute for money. With this modification, there is a new – and very direct – mechanism for debt dynamics to feed into inflation dynamics: deficits increase "effective" transactions balances, and this affects inflation. We showed that the existence of this mechanism has a number of important implications. First and foremost, it alters our views on the coordination of monetary and fiscal policy that is required to avoid sunspot equilibria and explosive behavior. The Taylor Principle is no longer sacrosanct. And a weak fiscal response to debt is no longer the panacea for a weak monetary policy. Along the frontiers of the determinacy region, policy changes may need to be coordinated to avoid the extremes of sunspot equilibria and explosive behavior: on the sunspot frontier, a more stabilizing fiscal policy must be accompanied by a more aggressive monetary policy; and on the explosive frontier, a more aggressive monetary policy must be accompanied by a more stabilizing fiscal policy.

We also argued that our model offers a way of thinking about the shift in monetary policy that is generally thought to have occurred around 1980, and also a break in the dynamics of consumption, real interest rates and government spending that is thought to have occurred around the same time. Here however we must admit that our findings are only suggestive. A more serious study of the shift in monetary policy would require a more detailed calibration of our model to the pre and post 1980 periods, and a more serious study of the effect of a government spending shock on private consumption would require that we model capital formation.

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Table 1: Calibration Parameters

	Figure 1 Benchmark		Figure 2 1970s Calibration		Figure 4 Increasing $\bar{\tau}$		Figure 5 Increasing $\bar{S}$	
	$\rho = .5$	$\rho = -.5$	$\rho = .5$	$\rho = -.5$	$\rho = .5$	$\rho = -.5$	$\rho = .5$	$\rho = -.5$
Hard Wired Parameters								
$\bar{\tau}$	0.001	0.001	0.001	0.001	0.005	0.005	0.001	0.001
$\bar{\Pi}$ (quarterly)	1.007	1.007	1.020	1.020	1.007	1.007	1.007	1.007
$\bar{R}^*$ (quarterly)	1.017	1.017	1.030	1.030	1.017	1.017	1.022	1.022
$\bar{R}$ (quarterly)	1.013	1.013	1.021	1.021	1.013	1.013	1.013	1.013
$\bar{S}$ (quarterly)	0.004	0.004	0.009	0.009	0.004	0.004	0.009	0.009
$\bar{b}/\bar{c}$ (quarterly)	2.0	2.0	1.0	1.0	2.0	2.0	2.0	2.0
$\bar{b}/\bar{m}$	5.0	5.0	2.5	2.5	5.0	5.0	5.0	5.0
$\bar{g}/\bar{y}$	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Implied Parameters								
A	0.09	0.13	0.11	0.14	0.03	0.04	0.18	0.23
a	0.78	0.34	0.82	0.47	0.78	0.34	0.67	0.30
v^*	0.59	0.42	0.91	0.73	0.33	0.24	0.51	0.41
$\bar{v}$	0.68	0.48	1.00	0.80	0.68	0.48	0.56	0.46
Other Fixed Parameters								
θ	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
χ	1	1	1	1	1	1	1	1
ε	7	7	7	7	7	7	7	7
α	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33

Figure 1: Determinacy with Benchmark Parameters

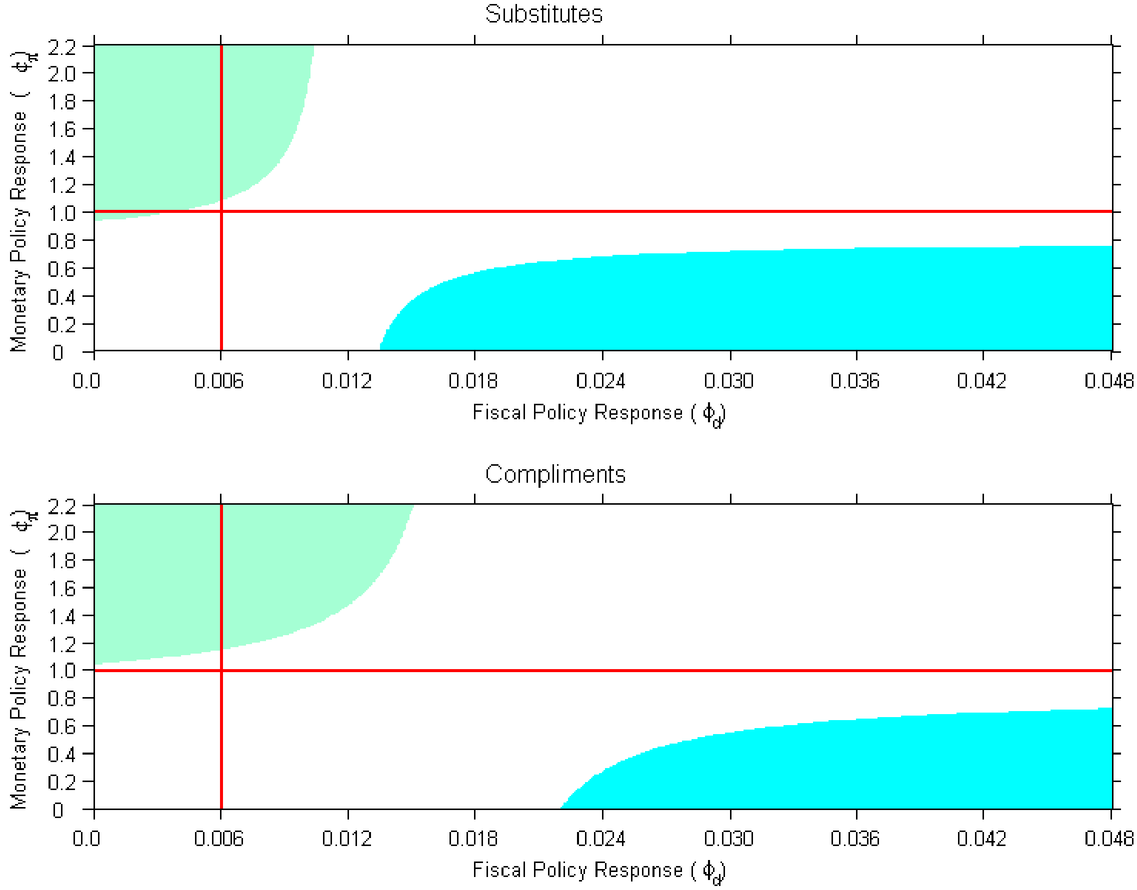

Figure 2: Determinacy with Pre-Volker Parameters

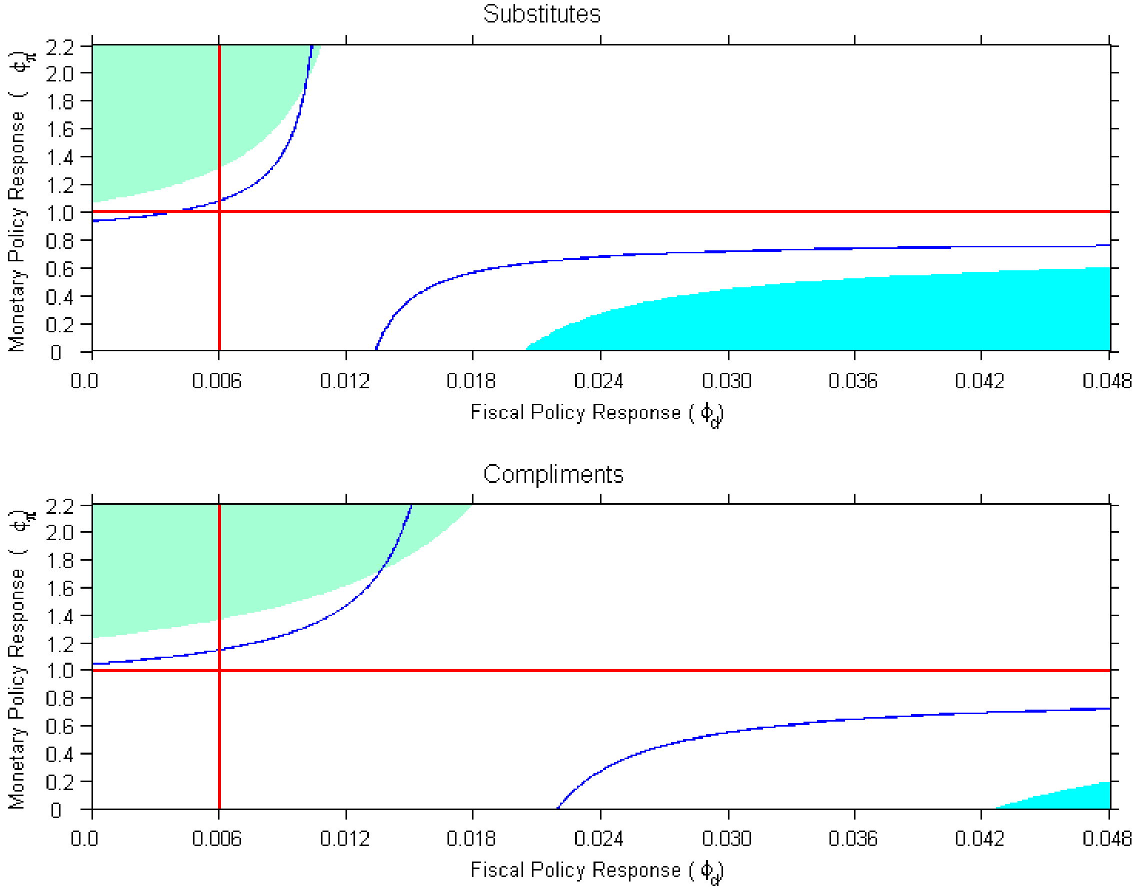

Figure 3: Determinacy with Greater Price Flexibility

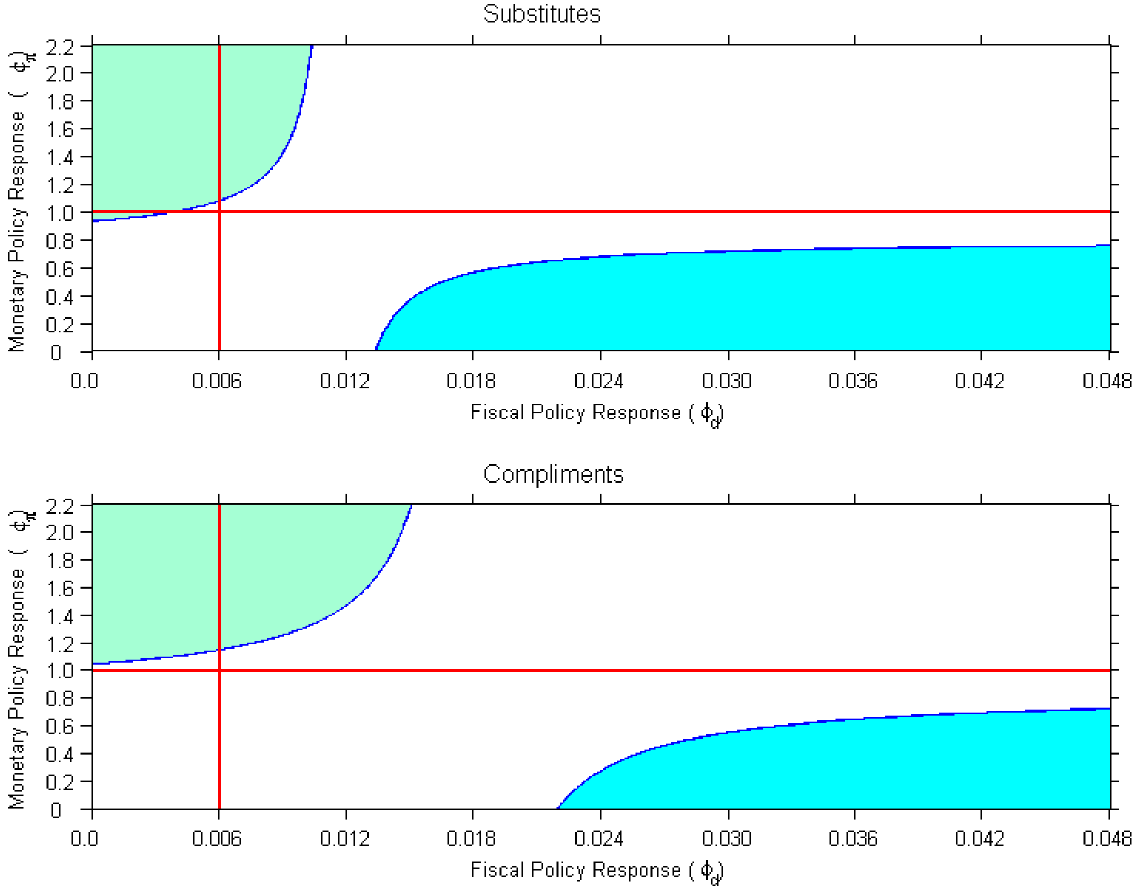

Figure 4: Determinacy with Greater Transactions Costs

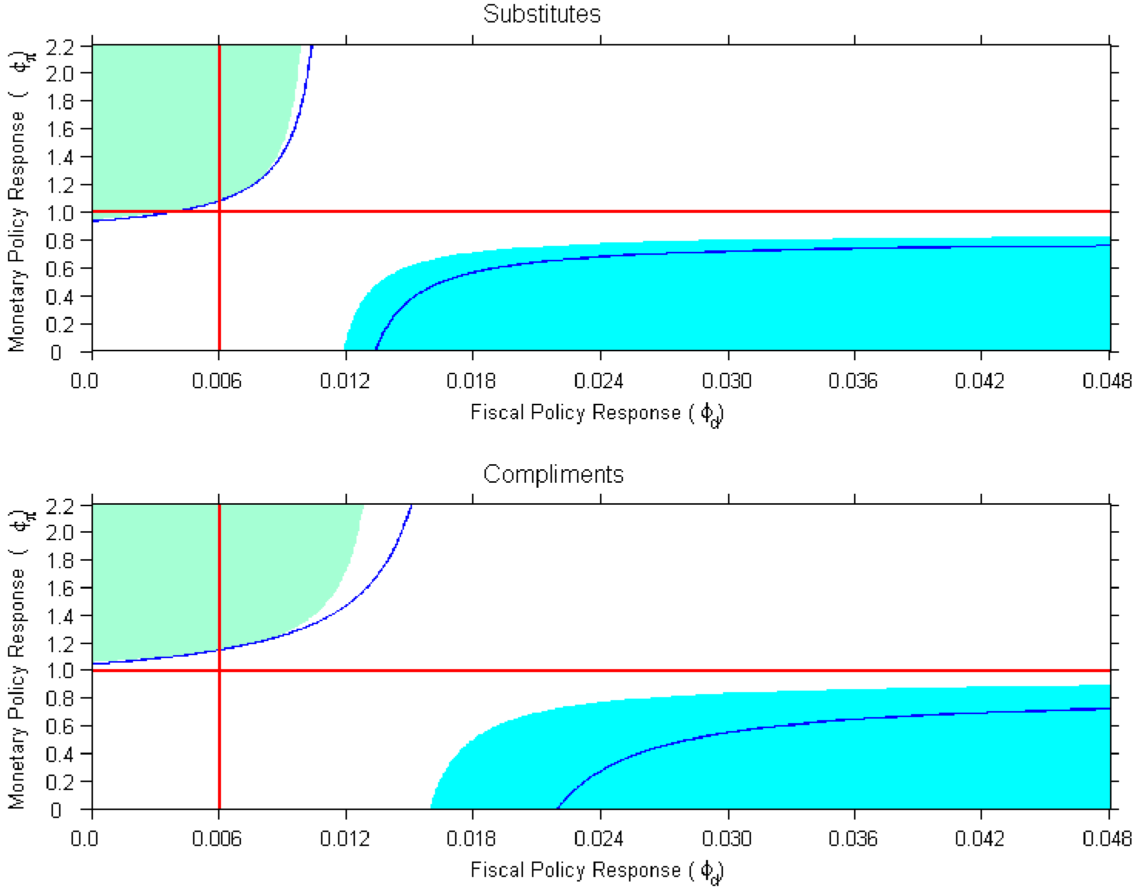

Figure 5: Determinacy with Larger Interest Rate Spread

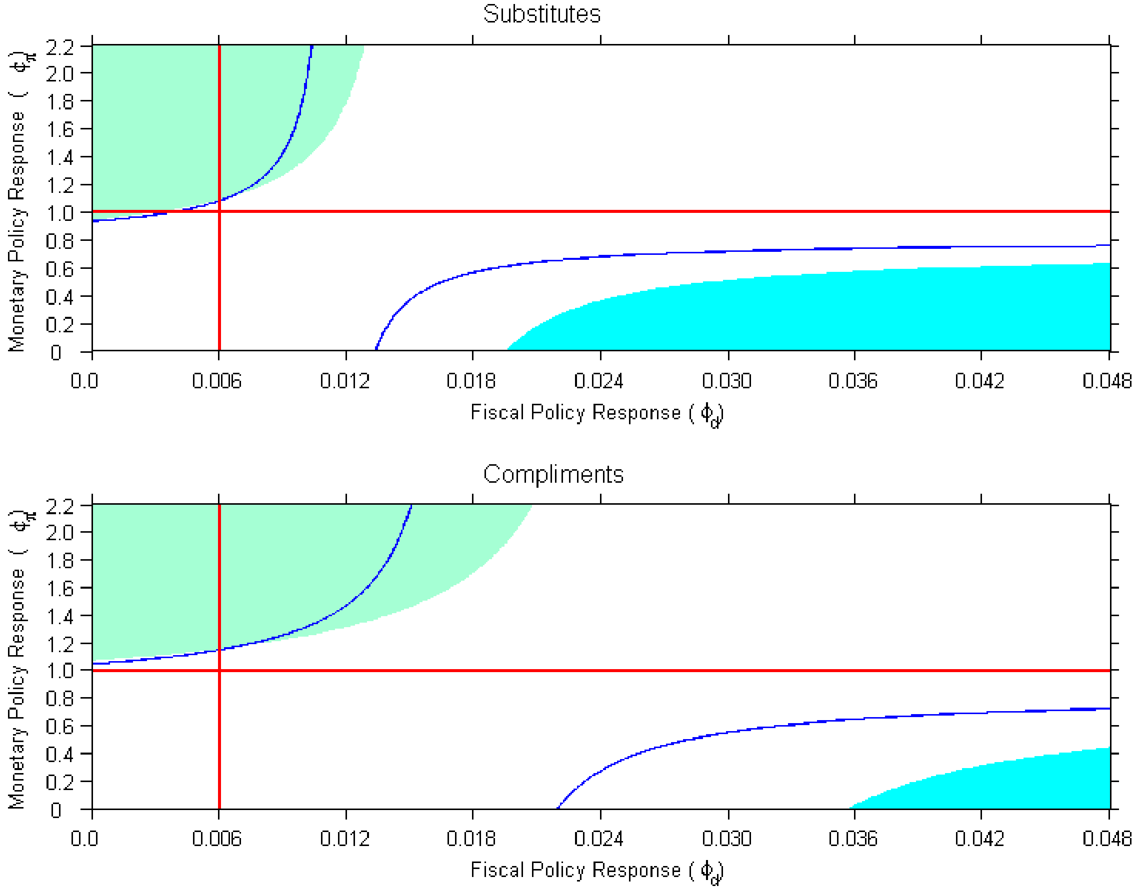

Figure 6A: Impulse Response to a Government Spending Shock
(1985-2004, $\varphi_\pi = 2$, $\varphi_d = .018$, $\rho = .5$)

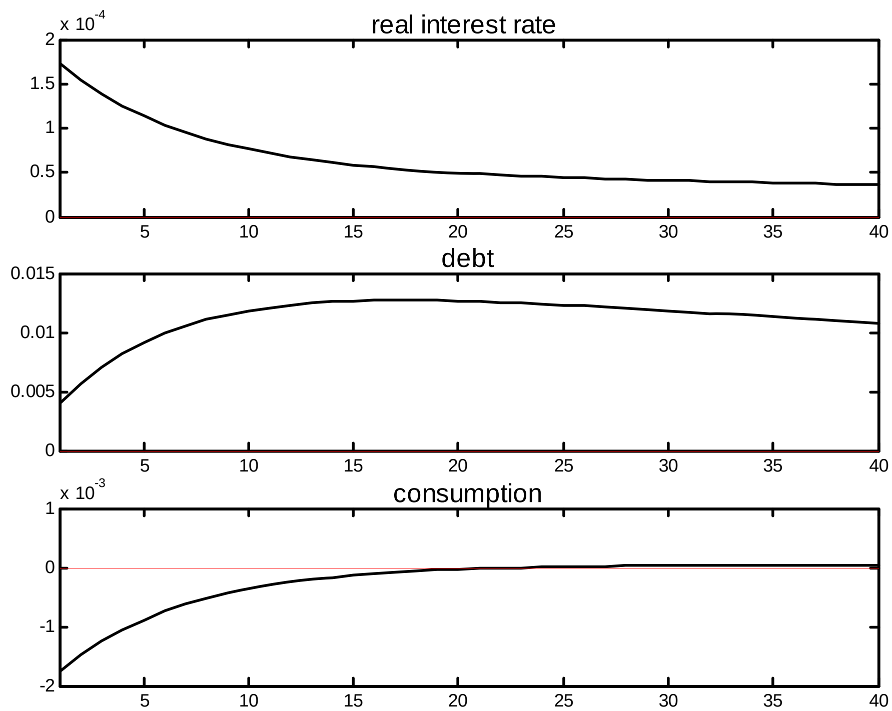

Figure 6B: Impulse Response to a Government Spending Shock
(1985-2004, $\varphi_\pi = 2$, $\varphi_d = .018$, $\rho = -.5$)

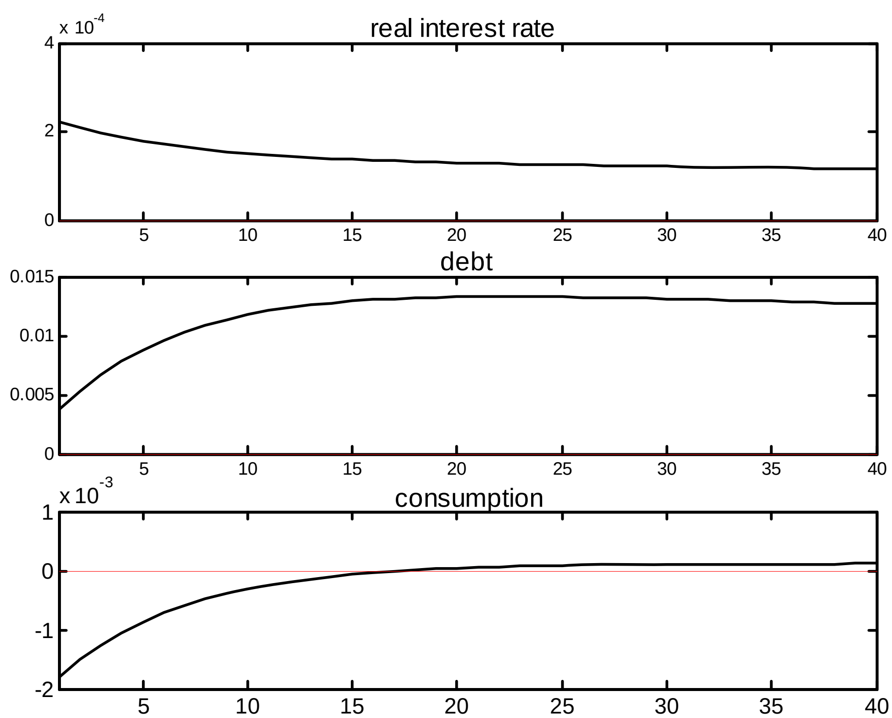

Figure 7A: Impulse Response to a Government Spending Shock
(1970's, $\varphi_\pi = .8$, $\varphi_d = .018$, $\rho = .5$)

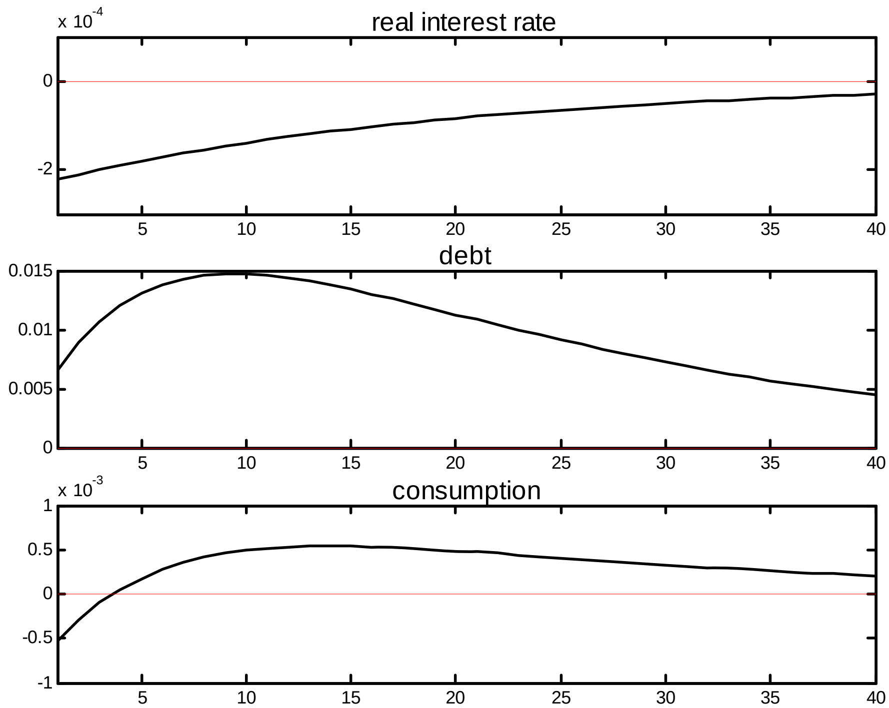

Figure 7B: Impulse Response to a Government Spending Shock
(1970's, $\varphi_\pi = .8$, $\varphi_d = .018$, $\rho = -.5$)