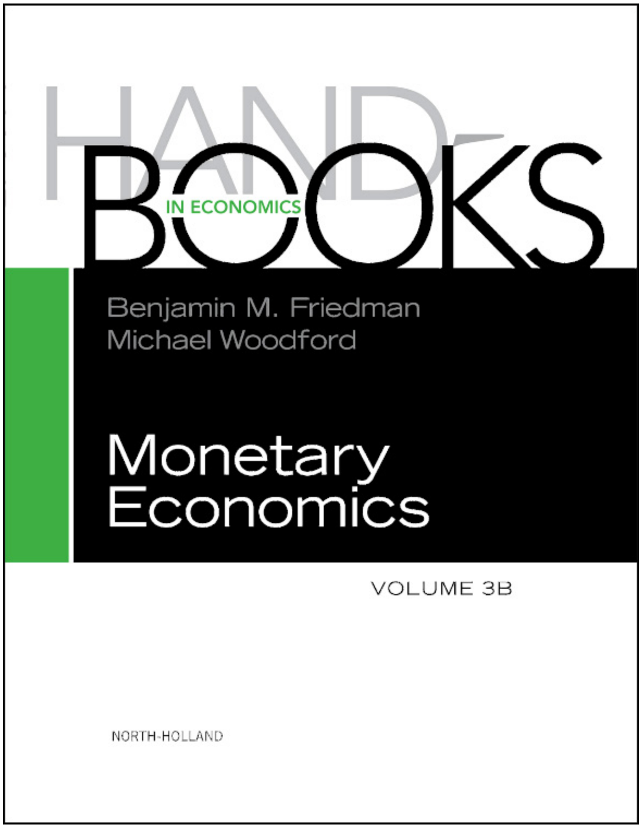

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CHAPTER 17

The Interaction Between Monetary and Fiscal Policy☆

Matthew Canzoneri, Robert Cumby, and Behzad Diba
Economics Department, University of Georgetown

Contents

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Abstract

Our chapter reviews positive and normative issues in the interaction between monetary and fiscal policy, with an emphasis on how views on policy coordination have changed over the last 25 five years. On the positive side, noncooperative games between a government and its central bank have given way to an examination of the requirements on monetary and fiscal policy to provide a stable nominal anchor. On the normative side, cooperative solutions have given way to Ramsey allocations. The central theme throughout is on the optimal degree of price stability and on the coordination of monetary and fiscal policy that is necessary to achieve it.

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Keywords

Coordination
Fiscal Policy
Monetary Police

1. INTRODUCTION

What provides the nominal anchor in a monetary economy? And should price stability be the primary objective, and sole responsibility, of the central bank? The traditional answer to the first question is that the central bank's money supply target sets the nominal anchor. The traditional answers to the second question are more mixed. Following the high inflation of the 1970s, there was a widespread movement in the Organization for Economic Cooperation and Development (OECD) countries toward giving central banks political independence and charging them with the maintenance of price stability. But, in the academic literature, the focus was on macroeconomic performance more generally, and not just price stability. The interaction between monetary and fiscal policy was often modeled as a noncooperative game between a central bank and its government, each having its own priorities over inflation, output, and so forth. The objective of policy coordination was to achieve a Pareto improving set of policies.

The last 25 years have brought a very different way of thinking about these issues, at least in academia. Due in part to central bankers' tendency to choose an interest rate as the instrument of monetary policy, the uniqueness of stable price paths has become an issue again, and fiscal policy is now thought to play a more fundamental role in price determination and control. As a result, a new view of the interaction of monetary and fiscal policy has emerged. In this view, the question is: What coordination of monetary and fiscal policy is necessary to provide a stable nominal anchor? On the normative side, a new view of what is meant by optimal monetary and fiscal policy has also emerged. In this view, the Ramsey planner has replaced the focus on noncooperative games, and maximization of household utility has replaced the ad hoc priorities of monetary and fiscal policymakers. As we will see, price stability is often the hallmark of a Ramsey solution, but the new view of price determination and control suggests that the statutory independence of the central bank may not be sufficient to achieve it. The central bank can only achieve price stability if it is supported by an appropriate fiscal policy.

In this chapter we review the recent literature's perspective on price determination and control, and the coordination of monetary and fiscal policy needed to achieve it. We discuss the positive aspects of the interaction of monetary and fiscal policy in Section 2, and the normative aspects in Section 3.

In Section 2, we begin with Sargent and Wallace's (1981) monetarist arithmetic and quickly turn to the fiscal theory of the price level (FTPL). The FTPL offers a resolution of Sargent and Wallace's game of chicken, and it offers a solution to well-known price determinacy puzzles. More fundamentally, the FTPL suggests the consolidated government present value budget constraint is an optimality condition, rather than a constraint on government behavior, and it shows how Ricardian and non-Ricardian notions of wealth effects play a role in price determination and household consumption. We also discuss a fundamental identification problem in the testing of the FTPL, and a less formal "testing" that has appeared in the literature.

In Section 3, we consider the normative literature on optimal monetary and fiscal policies. This literature follows Friedman (1969) by taking into account the effect of inflation on the monetary distortion and follows Phelps (1973) by treating inflation as one of several distorting taxes available to finance government spending. When prices are flexible, this literature suggests that substantial departures from price stability may be optimal. In much of this literature, Friedman's zero nominal interest rate rule is optimal. Deflation, rather than zero inflation, will minimize the monetary distortion. In addition, unexpected inflation acts as a nondistorting tax/subsidy. Optimal policy can imply highly volatile inflation as a means of absorbing fiscal shocks while keeping distorting tax rates stable. In Section 3.2 we turn to the results of Correia, Nicolini, and Teles (2008) who show that, when the menu of taxes available to the fiscal authorities is sufficiently rich, sticky prices are irrelevant to optimal monetary policy. We show, however, that the optimal tax policy they obtain with sticky prices has some potentially disturbing features. We therefore consider optimal monetary and fiscal policies with sticky prices and a restricted menu of taxes in Section 3.3. The argument for price stability is restored: both trend inflation and inflation volatility are optimally close to zero.

2. POSITIVE THEORY OF PRICE STABILITY

Price determination has always been at the heart of monetary economics. And indeed, traditional discussions of price determination made it sound as if fiscal policy played little or no role. For example, Friedman and Schwartz (1963) famously asserted that "inflation is always and everywhere a monetary phenomenon." At its most elemental (and most superficial) level, monetarism was reduced to the familiar $MV = Py$. If velocity (V) is constant, and if output (y) is exogenously given, then the price level is completely determined by the money supply, and price stability is clearly the responsibility of the central bank. There appeared to be no need to coordinate monetary and fiscal policy as far as price stability was concerned. Over the last 25 years, this view of price determination and control has been radically challenged, suggesting that fiscal policy might even play the dominant role in certain circumstances. At a mechanical level, much of the literature revolves around the way in which the consolidated government budget constraint is thought to be satisfied.

At a more fundamental level, "monetarist arithmetic," and a large literature that followed, characterized the interaction between monetary and fiscal policy as a noncooperative game between the government and its central bank; coordination of monetary and fiscal policies was needed to achieve Pareto improving outcomes. By contrast, the coordination problem for the FTPL and related work is a matter of choosing the right combination of policies to provide a stable nominal anchor. The fact that many central banks use an interest rate, and not the money supply, to implement monetary policy provides the motivation for much of this work. It has been asserted that some interest rate policies — policies that appear to have actually been used — do not provide a nominal anchor, leading to sunspot equilibria or explosive price trajectories.

The range of models that has been used to study monetary and fiscal policy is rather astounding. Some are quite simple, and they are used to make theoretical points; others are far richer, and they are used to obtain quantitative results. In this chapter, we try to illustrate some of the more significant results within a common framework, fully recognizing that no one model can do justice to the whole literature. Our benchmark model is virtually identical to the cash and credit goods model studied by Correia et al. (2008). We will present the full model in Section 3. Here, a stripped down version will suffice. In particular, we can eliminate the credit good, and we can replace distortionary taxes (except for seigniorage) with a lump-sum tax. In addition, we will replace the production economy with an endowment economy; however, when we present numerical results, such as impulse response functions, we will use the full cash and credit goods model with Calvo price setting.

2.1 A Simple cash-in-advance model

Our description of the model used in this section can be brief, since it will be familiar to most readers. The utility of the representative household is

$$U_t = E_t \sum_{j=t}^{\infty} \beta^{j-t} u(c_j) \tag{1}$$

where c_t is consumption. Each period is divided into two exchanges: in the financial exchange, the household receives its endowment, pays its taxes, and trades assets. In the goods exchange that follows, the household must pay for consumption goods with money, leading to the familiar cash in advance constraint

$$M_t \geq P_t c_t \tag{2}$$

where M_t is money and P_t is the price level. The household budget constraint for the financial exchange is

$$[M_{t-1} - P_{t-1}\, c_{t-1}] + I_{t-1}B_{t-1} + P_t y = M_t + B_t + P_t \tau_t \tag{3}$$

where B_t are nominal government bonds, I_t is the gross nominal interest rate, y is the fixed household endowment, and τ_t is a lump-sum tax.

The household's optimization conditions are the consumption Euler equation

$$1/I_t = \beta E_t[(u'(c_{t+1})/u'(c_t))(P_t/P_t + 1)] \tag{4}$$

and a transversality condition that we specify later. If $I_t > 1$, then the household cash in advance constraint is binding. The government also faces a cash in advance constraint; so in equilibrium

$$M_t = P_t(c_t + g) = Py \tag{5}$$

where for simplicity we will let government spending (g) be constant over time. The model is quite monetarist, with velocity set equal to one. Since government spending is constant, consumption is also constant (since $c_t = y - g$), and the Euler equation reduces to

$$1/\beta = I_t E_t[P_t/P_{t+1}] \equiv R_t \tag{6}$$

The gross real interest rate, R_t, is tied to the discount factor.

The consolidated government budget constraint in the financial exchange is

$$I_{t-1}B_{t-1} = S_t + B_t + (M_t - M_{t-1}) \tag{7}$$

where $S_t \equiv P_t(\tau_t - g)$ is the primary surplus. We will allow the lump sum-tax (τ_t) to fluctuate randomly, over time; this is the only stochastic element in our simple CIA model.

2.2 Price stability (or instability) through the lens of monetarist arithmetic

Sargent and Wallace's "monetarist arithmetic" has been presented and interpreted in a number of ways.[1] Here, we discuss what we think are the most important implications of monetarist arithmetic, and for simplicity, we will abstract from uncertainty.

Sargent and Wallace's take on the price stability problem has to do with which government agent — the treasury or the central bank — has to see that the consolidated government present value budget constraint (PVBC) is ultimately satisfied. To derive the PVBC, we rewrite the flow budget constraint in real terms; then, letting small letters represent the real values of assets, Eq. (7) becomes

$$(1/\beta)b_{t-1} = s_t + b_t + [m_t - m_{t-1}(1 - \pi_t)] \tag{8}$$

[1] See Sargent and Wallace (1981) and Sargent (1986, 1987). There have been many extensions, qualifications and criticisms of monetarist arithmetic. Interesting interpretations include (but are hardly limited to): Liviatan (1984), King (1995), Woodford (1996), McCallum (1999), Carlstrom and Fuerst (2000), and Christiano and Fitzgerald (2000).

where $\pi_t \equiv (P_t - P_{t-1})/P_t$ and (it will be recalled) $1/\beta$ is the real interest rate.[2] The bracketed term represents seigniorage, and since $m_t = y$, it reduces to $y\pi_t$. Iterating this equation forward and applying a transversality condition, the PVBC becomes:

$$d_t \equiv (1/\beta)b_{t-1} = K_{cb,t} + K_{gov,t} \tag{9}$$

where $K_{cb,t} \equiv y\sum_{j=t}^{\infty}\beta^{j-t}\pi_j$ and $K_{gov,t} \equiv \sum_{j=t}^{\infty}\beta^{j-t}s_j$. Sargent and Wallace assumed that government bonds are real. So, the real value of the inherited government debt (d) is fixed at the beginning of period t, and it has to be financed by the central bank's collection of seigniorage, $K_{cb,t}$, and/or the government's collection of taxes, $K_{gov,t}$. The problem here is that Eq. (9) is a consolidated budget constraint, and neither agent — the treasury or the central bank — may see it as a constraint on its own behavior.

Sargent and Wallace (1981) characterized the interaction between monetary and fiscal policy in terms of game theory and leadership, or who gets to go first. If the central bank gets to go first, and sets the path of inflation $\{\pi_j\}$ to its own choosing, then $K_{cb,t}$ is determined; the government must set the path of primary surpluses $\{s_j\}$ so that $K_{gov.t} = d_t - K_{cb,t}$. In this case, the monetarist interpretation of price determination and control is accurate. The central bank chooses a target path for inflation, and the rate of inflation will be equal to the rate of growth of money.

The new element in monetarist arithmetic is the possibility that the government gets to go first: $K_{gov,t}$ is set, and the central bank must, sooner or later, deliver the seigniorage to make $K_{cb,t} = d_t - K_{gov,t}$. In this case, the central bank's options for choosing the path of inflation are quite limited, even though the quantity equation — $M_t = P_t y$ — holds every period.

What are the options? The central bank can certainly stabilize the rate of inflation; that is, it can set $\pi_t = \pi$. But then fiscal policy determines the inflation target, since π must satisfy:

$$\pi[y/(1-\beta)] = d_t - K_{gov,t} \tag{10}$$

Alternatively, the central bank can lower inflation today by delaying the collection of seigniorage. But if it does this, it sets in motion an inflation juggernaut that grows with the real rate of interest; if for example, it lowers inflation in period t and makes up for it in period t + T, then:

$$\Delta\pi_{t+T} = (1/\beta)^T(-\Delta\pi_t) \tag{11}$$

When the central bank fails to collect seigniorage today, the government has to borrow to make up the lost revenue, and when the central bank eventually collects more seigniorage, it must pay principal plus interest on that new debt. An inflation hawk at the central bank can look good during his term in office, but only at the expense of his successors.

There have been many reactions to Sargent and Wallace's (1981) monetarist arithmetic. For example, King (1995) and Woodford (1996) noted that seigniorage is a tiny

[2] In future sections, we will use the more usual definition of inflation: $\pi_t \equiv (P_t - P_{t-1})/P_{t-1}$.

part of total revenue in developed countries. Can monetarist arithmetic be relevant for those countries? Carlstrom and Fuerst (2000) noted that fiscal policy can only create inflation in our model because the central bank is forced to increase the money supply, Friedman's dictum — inflation is always and everywhere a monetary phenomenon — would not seem to be violated here.[3]

But most of the reaction to monetarist arithmetic has to do with its implications for policy coordination. Sargent (1987) characterized the coordination problem as a game of chicken: Who will blink first, the government or the central bank? A common view seems to be that if the central bank just stands firm, it will be the government that blinks.[4] For example, McCallum (1999) said that the fiscal authority " . . . will not have the purchasing power to carry out its planned actions. . . .Thus a truly determined and independent monetary authority can always have its way."

Judgments like this seem a bit premature to us. For one thing, we have just shown that an inflation hawk at the central bank can suppress inflation for a long period of time, but this is not evidence that the government has given in or that the inflation juggernaut has been stopped.

More fundamentally, no one to our knowledge has formally modeled Sargent and Wallace's war of attrition. How would financial markets react? Would they limit the government's purchasing power, as McCallum suggests? Would they impose a risk premium on government debt or an inflation premium on all nominal assets? Who would give in first?

In summary, the literature on monetarist arithmetic does not offer a formal resolution of the coordination problem posed by Sargent and Wallace's game of chicken; the outcome remains a puzzle. The fiscal theory of the price level — to which we now turn — offers a way around this dilemma, but, as we will see, the game just comes back in a different guise.

2.3 Policy coordination to provide a nominal anchor and price stability

Interest in central bank independence grew in reaction to both the high inflation of the late 1970s and the debate over a monetary union for Europe. Following monetarist arithmetic, a large and still growing literature continued to view the coordination problem as a game between the government, or governments in the case of Europe, and the central bank. However, that literature is beyond the scope of our chapter.[5] Instead, we turn to a different view of the coordination problem, a view that is at the heart of monetary theory. In particular, we ask what coordination of monetary and fiscal policy is needed to provide a nominal anchor and price stability.

[3] However, Sargent and Wallace (1981) did show that when money demand is sensitive to the interest rate, the price level and the money supply need not move in the same direction.

[4] See, for example, King (1995), Woodford (1996), McCallum (1999), and Christiano and Fitzgerald (2000).

[5] Early contributions include: Blinder (1982) Alesina and Tabellini (1987), and Dobelle and Fischer (1994). More recent examples include: Adam and Billi (2004) and Lambertini (2006). Recent discussions in the context of a currency union include: Dixit and Lambertini (2003), Pappa (2004), Lombardo and Sutherland (2004), Kirsanova, Satchi, Vines, and Lewis (2007), and Beetsma and Jensen (2005); see also Pogorelec (2006).

The FTPL was developed primarily by Leeper (1991), Woodford (1994, 1995, 1996, 1998), Sims (1994, 1997), and Cochrane (1998, 2001, 2005).[6] A basic tenet of the FTPL is that monetary policy alone does not provide the nominal anchor for an economy. Instead, it is the pairing of a particular monetary policy with a particular fiscal policy that determines the path of the price level. Some pairings produce stable prices, some produce explosive (or implosive) price paths, and some produce sunspot equilibria. A good coordination of monetary and fiscal policies is needed for price determination and control.

The FTPL suggests a way around Sargent and Wallace's game of chicken, and it offers a resolution of two well-known price determinacy puzzles. Both puzzles are motivated by central banks' increasing tendency to choose an interest rate, rather than the money supply, as the instrument of monetary policy. The first interest rate policy to be called into question was the interest rate peg, which Woodford (2001) claimed best describes the Federal Reserve's bond price support in the 1940s. A long literature held that the price level would not be pinned down under an interest rate peg. The second interest rate policy to be called into question was the Federal Reserve's weak response to inflation prior to 1980; conventional wisdom held that such a policy would not pin down the price level. As we will see, the FTPL provides a resolution of these puzzles, but in so doing, it poses a new coordination problem for monetary and fiscal policy. We will explore the severity of the coordination problem under different versions of the FTPL, and under an alternative approach to the determinacy puzzles suggested by Canzoneri and Diba (2005).

Woodford's characterization of the FTPL draws a sharp distinction between what he calls Ricardian and non-Ricardian fiscal policies. And indeed, we will argue that the price determinacy puzzles are basically Ricardian in nature. Understanding their Ricardian underpinnings gives us insight into how the puzzles can be resolved.

2.3.1 The basic FTPL and Sargent & Wallace's game of chicken

The FTPL, in contrast with monetarist arithmetic, assumes that government bonds are nominal, and this makes a bigger difference than one might imagine. Since both money and bonds are nominal assets, it is convenient to express the PVBC in a different way. The nominal value of total government liabilities at the beginning of the financial exchange is $A_t \equiv M_{t-1} + I_{t-1}B_{t-1}$ and the flow budget constraint (7) can be rewritten as

$$a_t = \beta a_{t+1} + [(i_t/I_t)m_t + s_t] \tag{12}$$

where $a_t \equiv A_t/P_t$, $s_t \equiv S_t/P_t$, and $(i_t/I_t)m_t$ is real seigniorage revenue earned by the central bank and transferred to the Treasury. Iterating forward, we arrive at the PVBC for the financial exchange,

[6] Woodford's (2001) Lecture reviews the earlier literature, with additional references. Precursors include: Begg and Haque (1984) and Auernheimer and Contreras (1990). Critics include: McCallum (1999, 2001), Buiter (2002), Bassetto (2002, 2005), Niepelt (2004), and McCallum and Nelson (2005). Bai and Schwarz (2006) extended the theory to include heterogeneous agents and incomplete financial markets.

$$a_t \equiv (M_{t-1} + I_{t-1}B_{t-1})/P_t = \sum_{j=t}^{\infty} \beta^{j-t}[s_j + (i_j/I_j)m_j] \Leftrightarrow \lim_{T\to\infty}[\beta^T a_{t+T}] = 0 \quad (13)$$

We should emphasize several aspects of the FTPL from the outset. First, the real value of existing government liabilities (a_t) is not predetermined at the beginning of period t; instead, it fluctuates with the price level that is generated in period t. Events that happen within the period, planned or otherwise, affect the real value of inherited debt. For this reason, Cochrane (2005) and Sims (1999a) viewed the PVBC as a valuation equation. Second, proponents of the FTPL emphasize the fact that the PVBC is equivalent to the household's transversality condition; that is, the sum in the PVBC converges if and only if this optimality condition holds. So, the PVBC is not viewed as a behavioral equation that the government might violate, and should therefore be tested. Instead, Eq. (13) is viewed as one of the equations that define equilibrium. Davig and Leeper (2009), for example, referred to the PVBC as an intertemporal equilibrium condition. We will return to these issues in Section 2.3.6.

To continue our discussion of Sargent and Wallace's game of chicken, we can again separate seigniorage from other tax revenue; the PVBC becomes

$$(M_{t-1} + I_{t-1}B_{t-1})/P_t \equiv a_t = K_{cb,t} + K_{gov,t} \quad (14)$$

where $K_{cb,t} \equiv \sum_{j=t}^{\infty} \beta^{j-t}(i_j/I_j)y$ and $K_{gov,t} \equiv \sum_{j=t}^{\infty} \beta^{j-t} s_j$. Suppose once again that $K_{cb,t}$ and $K_{gov,t}$ are set independently by the central bank and the government and without regard for satisfying the PVBC. Here, the equilibrium price level, P_t, simply "jumps" to satisfy the PVBC, and this provides a solution to Sargent and Wallace's game of chicken. In essence, the FTPL appears to have eliminated the need to model the game of chicken: there is a well-defined equilibrium even if the central bank and the government are at loggerheads.

For the FTPL to work, there must be a positive supply of nominal government assets. And since fiscal policy determines the supply of nominal government assets ($M_t + B_t$), it can play a major role — sometimes the dominant role – in price determination.[7]

2.3.2 The pegged interest rate solution

Woodford's (2001) development of the FTPL focuses on what we will call the pegged interest rate (PIR) solution. In this section, we will assume that the lump-sum tax, τ_t, is stochastic, and that the model's equations are appropriately modified. If the central bank pegs the interest rate ($I_t = I$), then the Euler equation (6) implies $E_t[P_t/P_{t+1}] = 1/\beta I$. Innovations in the surplus may produce unexpected fluctuations in the price level, but the central bank's interest rate policy controls expected inflation. So, is this a fiscal theory of the price level, but a monetary theory of inflation? Not really. While

[7] For simplicity, we will continue to assume that all government bonds are one-period debt. With longer term debt, bond prices would show up on the LHS of the PVBC, and fluctuations in them would be part of the adjustment process. This aspect of the FTPL is explored by Woodford (1998) and Cochrane (2001).

the central bank controls expected inflation, it has to work through total government liabilities, $M_t + I_tB_t$, and the PVBC to do so. In particular, the flow budget constraint (7) implies: $A_{t+1}/A_t = [1 - (\tilde{s}_t/a_t)]I$ where $\tilde{s}_t \equiv (i/I)m_t + s_t$ is the surplus inclusive of seigniorage. Given the stance of fiscal policy, $\tilde{s}_t$, and the real value of existing liabilities, a_t, the central bank's interest rate determines the rate of growth of nominal government liabilities and (via the PVBC) the expected rate of inflation.

The PVBC (Eq. 13), must hold in equilibrium. In our simple model, an innovation in the primary surplus must be fully accommodated by a jump in the price level because output and interest rates are fixed. Fiscal policy provides the nominal anchor, and this is an unvarnished example of a "fiscal theory" of the price level. In a richer model, with a monopolistic competition and Calvo price setting, changes in real interest rates and output can be part of the adjustment process in Eq. (13). Going the other way, changes in expected discount factors originating in other parts of the model can affect the price level even when expectations of present and future primary surpluses are unaltered.[8]

Reactions to equilibria like the PIR solution are often negative. Carlstrom and Fuerst (2000) noted that prices can fluctuate without any change in monetary policy. Christiano and Fitzgerald (2000) described the FTPL as "Woodford's Really Unpleasant Arithmetic." Even the most determined central bank governor cannot control the price level.

One way of thinking about this last comment is to note that the central bank would have to work through seigniorage to stabilize prices in this framework. For example, if the central bank wants to keep fluctuations in the primary surplus from destabilizing prices it could try to change the interest rate so that: $\Delta(s_t/y_t) + \Delta[(i_t/I_t)(m_t/y_t)] = 0$. The problem is that seigniorage revenue is a tiny fraction of total revenue in OECD countries, or equivalently the tax base, m_t/y_t, is very small. A very substantial change in the interest rate would be required to offset typical fluctuations in s_t/y_t. It is probably not reasonable to hold a central bank accountable for price stability in this kind of an equilibrium, no matter what is said in its charter about independence or the primacy of price stability. The central bank can control expected inflation, but not price fluctuations.

On the other hand, Woodford (2001) argued that the PIR solution is a good characterization of the bond price support policy that existed between 1942 and the Treasury-Federal Reserve "Accord" of 1951. Furthermore, he asserts that "This sort of relationship between a central bank and the treasury is not uncommon in wartime, . . . [and in other] cases where the perceived constraints on fiscal policy have been similarly severe."

2.3.3 Non-Ricardian fiscal policies and the role of government liabilities

The PIR solution suggests two insightful questions about the FTPL: (1) If Ricardian Equivalence holds that fluctuations in a lump-sum tax will have no effect on prices,

[8] Our simple example of the FTPL is analogous to the monetarist equation — MV = PY — where velocity is assumed constant and output is assumed exogenous, and the price level is fully determined by monetary policy.

or anything else of importance, why does the price level fluctuate in the PIR solution? (2) Doesn't conventional wisdom hold that interest rate pegs lead to price indeterminacy, as noted by Sargent and Wallace (1975)? The answers to these questions are that Ricardian Equivalence and the analysis of Sargent and Wallace (1975) assume a very different type of fiscal policy. We discuss the first question in this section and the second question in the following section.

Consider a cut in the lump-sum tax. Ricardian Equivalence holds that households assume the present value of their tax liabilities, and therefore their net wealth, has not changed. They do not spend the tax cut; they just save it because they expect to be taxed later on to pay off the principal and interest on the debt that the government issues to finance the tax cut. There is no change in the preexisting equilibrium, other than the timing of tax collections. And the price level should not jump, as in the PIR solution.

The logic inherent in Ricardian Equivalence presumes that households expect a type of fiscal policy that Woodford (1995) called Ricardian. A "Ricardian fiscal policy" adjusts the path of primary surpluses to hold the present value of current and future surpluses equal to the real value of inherited government liabilities for any possible price path. The fiscal policy we have assumed in the PIR solution is what Woodford (1995) called "non-Ricardian." Households do not expect the tax cut to be offset by future tax increases; they think that the present value of their tax liability has fallen, and that their wealth has increased. Household consumption demand rises until the price level jumps enough to eliminate the discrepancy between a_t and the expected present value of primary surpluses. Note that by this reasoning, government debt is net wealth to the household, and the model is non-Ricardian in this sense as well.

In the following section, we will see that Ricardian policies generally lead to conventional results. Non-Ricardian policies are what is new, and the FTPL — while it recognizes the existence of Ricardian regimes — tends to be associated with Non-Ricardian regimes.

2.3.4 The Ricardian nature of two old price determinacy puzzles

We turn now to the second question raised in the last section: Doesn't conventional wisdom hold that interest rate pegs lead to price indeterminacy or sunspot equilibria? Why is the price level pinned down in the PIR solution? The answer is, once again, that the conventional analysis presumes a Ricardian fiscal policy. Here, we consider a more general case than the interest rate peg. Let $\Pi_t \equiv P_t/P_{t-1}$ be gross inflation, $\pi_t \equiv \log(\Pi_t)$ be net inflation, and let a star denote the central bank's inflation target; consider a nonstochastic version of the model. Conventional wisdom holds that an interest rate rule like

$$I_t = (\Pi^*/\beta)(\Pi_t/\Pi^*)^\theta \tag{15}$$

must obey the Taylor principle ($\theta > 1$) if the path of inflation is to be uniquely determined. A common interpretation of this result is that the central bank must respond to

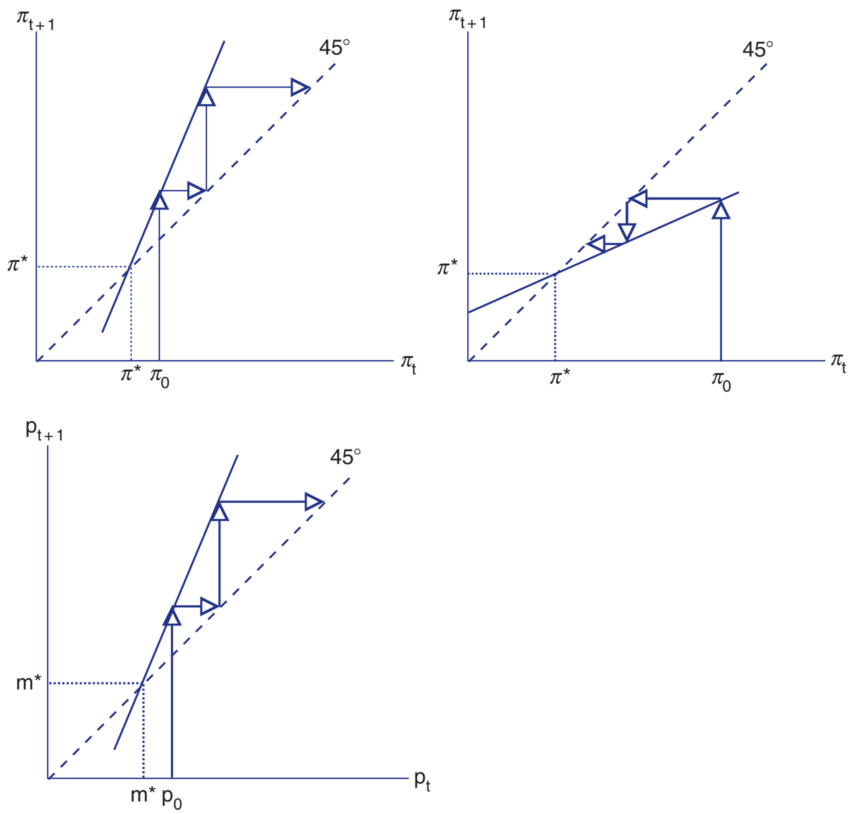

Figure 1 Phase diagrams.

an increase in inflation by increasing the real interest rate, lowering aggregate demand; however, we will see that this interpretation misses the point.

Combining Eq. (15) with the consumption Euler equation, and taking logs, the process for inflation becomes:

$$\pi_{t+1} = \pi^* + \theta(\pi_t - \pi^*) \tag{16}$$

Phase diagrams for this difference equation are illustrated in Figure 1.[9] In the first diagram, the policy rule obeys the Taylor principle. For any initial value π_0 that is not equal to π^*, inflation exhibits explosive behavior; $\pi_t = \pi^*$ is the only stable solution. Now, we add two (sometimes implicit) assumptions behind the conventional wisdom: (1) fiscal policy is Ricardian, and (2) we should focus on stable solutions. Since fiscal policy is Ricardian, the PVBC (or equivalently, the household's transversality condition) is satisfied for any π_0; no need to worry about it. Since we only focus on stable

[9] The model is linear, but we show phase diagrams because the graphical view helps.

solutions, the Taylor principle would seem to be a necessary and sufficient condition for inflation determination.

Cochrane (2007) challenged the conventional view on two grounds. First, the Taylor principle does not work by curbing aggregate demand; Cochrane calls this "old" Keynesian thinking. Instead it works by having the central bank threaten to create a hyperinflation (or deflation) if the initial inflation does not jump to a certain value, and the credibility of such a threat might be questioned. But more fundamentally Cochrane (2007) argued that there is nothing wrong with the explosive solutions, at least in our endowment economy with flexible prices. The household's transversality condition is satisfied. The explosive behavior is only in the nominal variables; in fact, the real variables of interest are the same in all of these solutions.[10] The households in this economy do not care if the central bank creates a hyperinflation, therefore, the credibility of such a policy should not be an issue for them.

To save the conventional wisdom (with its auxiliary assumption of a Ricardian fiscal policy), it would seem necessary to explain why we should focus on the unique stable path for inflation. McCallum (2009) provided a reason. He showed that the explosive solutions are not least-squares learnable; the stable solution is learnable.[11] Atkeson, Chari, and Kehoe (2010) took a different approach; instead of looking for an equilibrium selection mechanism, they described a credible way in which a central bank might avoid the explosive solutions. In particular, they developed "sophisticated" policies that specify what the central bank would do if private agents start along one of the explosive paths; these policies make it individually rational for agents to choose the stable solution instead. In any case, local stability is now a standard selection criterion when there are multiple solutions from which to choose.[12]

In the second diagram of Figure 1, the interest rate rule violates the Taylor principle ($\theta < 1$). The interest rate peg ($\theta = 0$) is one such policy, but there are many others. Any initial π_0 produces a stable solution, so the initial price level cannot be pinned down on the basis of stability.

This then is the price determinacy puzzle: The Taylor principle is thought by many to have been violated at various points in U.S. history. As has already been noted, Woodford (2001) argued the Federal Reserve's bond price support between 1942 and the Treasury-Federal Reserve "Accord" of 1951 is best described as an interest rate peg. Clarida, Gali, and Gertler (2000) and Lubik and Schorfheide (2004) among others provided empirical evidence for a structural break in U.S. monetary policy around

[10] We will argue later that the real path of government debt is not pinned down, but since the model is Ricardian, this does not matter to the households.

[11] See Evans and Honkapohja (2001) for a discussion of the notion of learnability.

[12] Instead of making a selection argument, Loisel (2009) and Adao, Correia, and Teles (2007) proposed feedback rules for monetary policy that implement a unique stable solution and have no unstable solutions.

1980: the Taylor principle was violated in the period prior to 1980, and satisfied thereafter.[13] What determined the price level during these periods in U.S. history?

The indeterminacy just illustrated is sometimes called a "nominal" indeterminacy because consumption, real money demand, and the real rate of interest are all determined. However, in Canzoneri and Diba (2005), we note that this is a misnomer: when the price level is not pinned down, then neither is the real bond supply. To see this, divide the government's flow budget constraint (7) by P_t; with a little rearranging, we have

$$m_t + b_t + s_t = (M_{t-1} + I_{t-1}B_{t-1})/P_t \tag{17}$$

where $b_t \equiv B_t/P_t$. Note that m_t $(= y)$ is determined in period t, as is the numerator on the RHS of Eq. (17), and fiscal policy sets $s_t(=\tau_t - g)$. So, if P_t is not pinned down, then neither is b_t.

This observation provides a crucial insight into ways in which the price determinacy puzzle might be resolved. If a non-Ricardian element can be introduced to "make bonds matter," pinning down b_t, then P_t may be determined. The FTPL offers one way to do that.

As already noted, conventional wisdom assumes a Ricardian fiscal policy, so that the PVBC is satisfied for any π_0 determined by Eq. (16). Now suppose instead that fiscal policy is non-Ricardian. The PVBC pins down P_0, and thus π_0, and a unique stable solution is determined (in the second diagram of Figure 1) for monetary policies that do not obey the Taylor principle.

So, the FTPL provides a resolution to the price determinacy puzzles. But in the process, it poses a new coordination problem for monetary and fiscal policy, and the problem is quite severe. A monetary policy that satisfies the Taylor principle must be coupled with a Ricardian fiscal policy, and a monetary policy that violates the Taylor principle must be coupled with a non-Ricardian policy. The wrong pairings create either an over determinancy or an indeterminacy of the price level. If, for example, a non-Ricardian fiscal policy determines π_0 in the first phase diagram, and that π_0 does not happen to be π^*, then a hyperinflation (or deflation) results. If a Ricardian fiscal policy does not pin down a π_0 in the second phase diagram, then the price level is not determined, and sunspot equilibria result.

2.3.5 Woodford's policy coordination problem

The new coordination problem is this: How do a central bank and its government come to a stable pairing of policies? How did President Reagan know to switch to a Ricardian fiscal policy when Chairman Volcker switched to a policy that obeyed the

[13] These results are not universally accepted. Orphanides (2004) argued that the estimated interest rate rule for this period does obey the Taylor principle if real time data are used.

Taylor principle around 1980? How did the government know to implement a non-Ricardian policy when the Federal Reserve's bond price support was instituted after the Accord? It seems unlikely that these joint policy switches were serendipitous.

In fact, the work of Loyo (1999) suggested that coordination might be difficult in practice. Inflation in Brazil was high, but stable, in the latter part of the 1970s; it began rising in the early 1980s, and accelerated into hyperinflation after 1985. Loyo suggested that the central bank shifted to a policy that obeyed the Taylor principle in 1985, trying to reduce inflation, but the public expected a non-Ricardian fiscal policy to continue. These expectations determined a $\pi_0 > \pi^*$ (in the second diagram of Figure 1), and hyperinflation ensued. To us, Loyo's example demonstrates that the FTPL did not really settle Sargent and Wallace's game of chicken; the game just comes out in a different guise.

In conclusion, the coordination problem seems severe in Woodford's version of the FTPL: monetary and fiscal policies must shift together in a coordinated way to achieve price stability. Leeper (1991); Canzoneri, Cumby, Diba, and Lopez-Salido (2008, 2010); and Davig and Leeper (2006, 2009) approached the price determinacy puzzle in different ways, and we will see that their characterizations of the coordination problem are less severe. But first, the FTPL has always been controversial; we turn next to some of its critics.

2.3.6 Criticisms of the FTPL and unanswered questions about non-Ricardian regimes

Buiter (2002), Bassetto (2002, 2005), and Niepelt (2004) questioned the nature of the equilibria that the FTPL proposes. Buiter (2002) noted an implicit commitment to monetize the debt in standard treatments of the FTPL; however, if the central bank follows a money supply rule instead of an interest rate rule, there is no such commitment, and the theory of non-Ricardian regimes would appear to be incomplete, at least without some modeling of default. McCallum (1999, 2001, 2003a,b) questioned the plausibility of some of the solutions proposed by the FTPL, and Kocherlakota and Phelan (1999) and McCallum and Nelson (2005) discussed the FTPL within the context of monetarist doctrine.

We will begin with the fundamental concerns about the nature of FTPL equilibria, and then turn to a discussion of money supply rules. Finally, we will consider a natural extension of the FTPL to include multiple fiscal authorities, for example, in a currency union. We discuss this extension here because the theory of non-Ricardian regimes appears to be incomplete in some interesting cases, even when the central bank is following an interest rate rule.

2.3.6.1 The nature of the equilibrium proposed by the FTPL

Buiter (2002) argued that the PVBC is a real constraint on government behavior, both in equilibrium and along off equilibrium paths. The government must obey its budget constraint just like households, and equilibria that suggest otherwise are invalid. Woodford's (2001) response is that the government knows that it can (and should) move equilibrium prices and interest rates. Non-Ricardian fiscal policies can be sensibly modeled from the perspective of "time zero trading" in dynamic stochastic general equilibrium models; that is, fiscal policy can be viewed as setting a state contingent path for future surpluses, once and for all, at time zero. And this, together with monetary policy, determines the sequence of equilibrium prices. Indeed, the optimal Ramsey policies we discuss in the next section are specified in just this way.

The PVBC does place some restrictions on the non-Ricardian policies that are allowable. For example, in the benchmark case with positive nominal liabilities, the sequence of surpluses must have a positive present value.[14] But the positive value may be large or small, depending on the present value of surpluses and the inherited nominal liabilities. The point is that public sector liabilities are nominal, and their real value is determined in equilibrium as a residual claim on the present value of surpluses. This is why Cochrane (2005) and Sims (1999a) viewed the PVBC as an asset valuation equation.

Note however that our discussion so far simply assumes that there is nominal government debt outstanding at time zero. Niepelt (2004) argued that a fully articulated theory should also explain how the debt was first introduced and what payoffs bond holders anticipated when it was introduced. Suppose there are no nominal liabilities at time zero. In this case, there are no initial money or bond holders to serve as residual claimants, and the government is constrained to make the expected present value of surpluses (inclusive of seigniorage) zero.[15] Moreover, Eq. (13) cannot determine the price level at date zero.[16] Nominal bonds and money may be issued at time zero to finance a deficit, but their equilibrium values are not pinned down by the model.

Although this scenario gives rise to indeterminacy of the nominal variables, the nature of fiscal policy will matter for the dimension of that indeterminacy. Daniel (2007) pointed out that we can still envision a non-Ricardian fiscal authority that issues nominal debt at date zero and sets an exogenous (state contingent) sequence of real surpluses from date 1 on. This pins down the state contingent inflation rates. If fiscal policy were instead Ricardian, then state contingent inflation rates would also be indeterminate; the nominal interest rate set by the central bank (and the Fisher equation) only pins down the expected value of the inflation rate, or more precisely the RHS of Eq. (4).

[14] Woodford (2001) articulated the restrictions on policy that keep nominal liabilities and the RHS of Eq. (13) positive for all t. This addresses Buiter's (2002) criticism that the FTPL may imply a negative price level.

[15] This reasoning implies that the fiscal theory cannot offer a resolution of Sargent and Wallace's coordination problem, which was predicated on the assumption that the initial debt is real.

[16] Niepelt (2004) proposed an alternative model in which some fiscal flow variables (e.g., transfer payments) are set in nominal terms, and this pins down the price level.

At a deeper level, Bassetto (2002, 2005) questioned the adequacy of general equilibrium theory to address the credibility of fiscal commitments at date zero. Bassetto (2002) revisited the FTPL in a game theoretic framework that makes the actions available to households and the government explicit. He concluded that a fiscal policy setting a sequence for future surpluses, once and for all, at time zero is not a valid strategy. A well-defined strategy would also have to specify what the government would do about satisfying its budget constraint if consumers deviated from the equilibrium path. Of course, this criticism is not confined to fiscal policy or the FTPL. Atkeson et al. (2009) discussed the problem within the context of monetary policy, and their "sophisticated" policies attempt to provide well-defined strategies for monetary and (presumably) fiscal policies.

2.3.6.2 Money supply rules

So far, we have assumed that the central bank uses an interest rate as the instrument of monetary policy. Most of the FTPL literature, following the recent practice of most central banks in the OECD, makes this assumption. There is of course no need to do so, and indeed, traditional discussions of monetary policy often do not. In this section, we consider money supply rules.

2.3.6.2.1 Should the FTPL model default? Take1: Money supply rules As Buiter (2002) noted, when the central bank follows an interest rate rule, it commits itself to pegging the price of government debt at a level implied by its interest rate target. If a non-Ricardian fiscal policy requires the issue of new debt, then the central bank will use open market operations to accommodate the sale at the implied debt price. In this case, the price level can be determined by the PVBC (Eq. 13), as described earlier. Non-Ricardian fiscal policies can be supported in equilibrium.

If instead, the central bank holds the money supply fixed, then there is no commitment to monetize any new debt. The central bank is instead committed to its money supply target, and the cash in advance constraint determines the price level. The price level is not free to satisfy the PVBC and, in general, non-Ricardian fiscal policies cannot be supported in equilibrium. Absent an explicit modeling of the possibility of government default, we do not seem to have a complete theory of price determination when fiscal policy is non-Ricardian.

The example just given is particularly stark because of our CIA constraint (and our assumption of an endowment economy). If instead money demand is interest elastic, then the arguments are more subtle. Woodford (1995) used a money in the utility function model to show that a non-Ricardian policy can be sustained in equilibrium even when the money supply is fixed, but the price path is explosive. This solution is valid in the sense that it violates no transversality condition, and it is the only solution to the model. Here, there is no multiplicity of solutions looking for some equilibrium selection mechanism, such as McCallum's (2003a,b) learnability criterion. However, some might think the explosive solution is unappealing. Adding the possibility of government default might give rise to other equilibria.

2.3.6.2.2 Compatibility of the FTPL with monetarist doctrine In this subsection, we replace the CIA constraint with Cagan's money demand function

$$m_t - p_t = -(1/\kappa)(p_{t+1} - p_t) \tag{18}$$

where in this section m_t and p_t are logs of the nominal money supply and the price level, and κ is a positive parameter. For simplicity we continue to assume that the model is nonstochastic. Letting the nominal money supply be fixed at m^*, Eq. (18) implies:

$$p_{t+1} = (1 + \kappa)p_t - \kappa m^* \tag{19}$$

The last phase diagram in Figure 1 describes these price dynamics, and the symmetry with the first phase diagram is obvious. Sargent and Wallace (1973) argued that if the fundamentals are stable (here, $m_t = m^*$), then we should generally choose a solution for the price level that is stable; that is, we should rule out "speculative bubbles" unless those solutions are the specific objects of interest. More recently, Kocherlakota and Phelan (1999) called this the "monetarist selection device."[17]

In our example, p_t is then always equal to m^*. If there is an unexpected, and permanent, increase in the money supply, then the price level will jump in proportion. As is clear from the discussion in the last section, Sargent and Wallace (1973) implicitly assumed a Ricardian fiscal policy; primary surpluses move to satisfy Eq. (13) no matter what p_0 is fed into it. If fiscal policy is non-Ricardian, and the PVBC determines a $p_0 \neq m^*$, then a hyperinflation (or deflation) ensues. This is reiterated from the preceding section.

However, Kocherlakota and Phelan (1999) look at the third diagram in Figure 1 and give it a different interpretation. They see the non-Ricardian fiscal policy as "an equilibrium rejection device." It rejects all price paths except the explosive path that is illustrated. By contrast, the Ricardian policy implies the monetarist selection device: rule out speculative bubbles and let $p_t = m^*$. Kocherlakota and Phelan (1999) asserted that the FTPL "is equivalent to giving the government an ability to choose among equilibria." This is a very different view of the coordination problem described earlier when government policy, fiscal and monetary, chooses an appropriate equilibrium.

[17] Sargent and Wallace's (1973) prescription amounts to an equilibrium selection argument. Obstfeld and Rogoff (1983) and others, showed that standard monetary models exhibit global indeterminacy under money supply rules. Nakajima and Polemarchakis (2005) discussed the dimension of indeterminacy in the model with cash and credit goods by considering the infinite horizon model as the limit of a sequence of finite horizon economies. They showed that the dimension of indeterminacy is the same regardless of the monetary policy instrument (interest rates or money supplies) and assumptions about flexibility or rigidity of prices.

Since Kocherlakota and Phelan (1999) doubted that the government would knowingly choose the explosive price path in the phase diagram, they concluded: "One cannot 'believe in' the fiscal theory device and the monetarist device simultaneously. We choose to believe in the latter."

McCallum and Nelson (2005) also looked at the FTPL in a different light; they wanted to distinguish between what is new in the FTPL and what is consistent with traditional monetarist thought. This does not always correspond to distinguishing between Ricardian and non-Ricardian fiscal policies. Some non-Ricardian regimes are not, they argue, at odds with monetarist doctrine. For example, Woodford (2001) might see the PIR solution as the quintessential example of the FTPL, but McCallum and Nelson (2005) argued that the PIR solution is perfectly consistent with monetarist doctrine. Pegging the interest rate pins down the expected rate of inflation, via the Fisher equation. But, given the quantity equation (postulated in the PIR solution), the central bank has to set the expected rate of growth of the money supply equal to this expected rate of inflation in order to institute the interest rate policy. Nothing new here, they would seem to argue; price trends follow money trends. (However, we should remember that there really is something new: conventional wisdom states that the price level was not determined for an interest rate peg, and the FTPL offers a resolution to that problem.)

By contrast, McCallum and Nelson (2005) argued that the coupling of a non-Ricardian fiscal policy with a fixed money supply, as depicted in the third phase diagram of Figure 1, is not consistent with monetarist doctrine. The upward price trend is completely at odds with the fixed money supply. Moreover, in this solution, it is the nominal bond supply that must be trending up with prices. Quoting from an earlier McCallum paper, McCallum and Nelson (2005) said

> *... it has been argued that the distinguishing feature of the fiscal theory is its prediction of price-level paths that are dominated by bond stock behavior and [are] very different from the path of the nominal money stock.*

This they would argue is a genuine example of a fiscal theory of the price level.

2.3.6.3 Should the FTPL model default? Take 2: Multiple fiscal authorities

A natural extension of the FTPL is to consider multiple fiscal authorities.[18] Most countries have a central fiscal authority and regional fiscal authorities, and there may be an explicit or implicit guarantee of a central government bailout for a regional authority that gets into trouble. Currency unions — like the European Monetary

[18] We do not have space to review the long literature on monetary and fiscal policy in monetary unions. Papers specifically pertaining to the FTPL include Woodford (1996), Sims (1999b), Bergin (2000), and Canzoneri, Cumby and Diba (2001a).

Union — also include sovereign national fiscal authorities, and the possibility of bail-outs is generally less certain. This raises a number of intriguing questions.

For concreteness, we will consider a currency union. Expand the model we have been using to include N countries, each with its own fiscal policy. Assume the countries are of equal size and have identical government spending processes (but possibly different tax processes); assume also that there are complete markets for international consumption smoothing. These assumptions allow us to aggregate the N national consumers into an area-wide representative consumer.

The central bank follows an interest rate rule, and the national fiscal policies may be Ricardian or non-Ricardian. The traditional view is represented by the case where the central bank's interest rate rule obeys the Taylor principle and the national fiscal policies are all Ricardian. The union-wide price level is determined in the CIA constraint.

But what if one or more of the fiscal policies are non-Ricardian? That is, let n ($0 < n < N$) of the policies be non-Ricardian, while the remaining policies are Ricardian. The FTPL suggests several possibilities that would seem well worth investigating.

One possibility, following Canzoneri, Cumby, and Diba (2001a), is to assume there is a rule for sharing seigniorage revenue, and that one country will not guarantee another's debt; in this case, each country has a PVBC analogous to Eq. (13). Suppose the central bank pegs the interest rate (in keeping with the earlier discussion). The price level is uniquely determined as long as $n = 1$. The PVBC of the one country running a non-Ricardian policy determines the price level for the union, and the Ricardian policies of the other countries satisfy their PVBCs. Those countries running Ricardian policies may not be happy with the price volatility generated by the fiscal policy of the country that is running a non-Ricardian policy. This may not be a sustainable outcome.

The outcome is more complicated if $n > 1$. The union-wide price level cannot generally move to satisfy more than one PVBC. Here, the price level is overdetermined. Alternatively, as in our discussion of money supply rules, the theory of non-Ricardian regimes would appear to be incomplete absent an explicit modeling of bankruptcy.

Perhaps it is more interesting to continue to assume that the central bank's policy obeys the Taylor principle. In this case, non-Ricardian policies would seem to lead to overdeterminacy or explosive equilibria. However, Bergin (2000) and Woodford (1996) suggested another possibility. If countries running Ricardian policies are willing to guarantee the debt of the non-Ricardian governments, then we can aggregate the N individual PVBCs into a single constraint. The price level can be determined as described in Section 2.3.4, and the aggregate PVBC can be satisfied by the countries running Ricardian fiscal policies.

However, this outcome is not as sanguine as it might seem. The countries running Ricardian policies may be forced to buy the debt of those who do not; in effect, they are bailing out the countries that are running non-Ricardian policies. This may not be viewed as politically or economically acceptable. In fact, this case represents one interpretation of events that are unfolding in the Euro Area. Greece is running chronic fiscal deficits,[19] and unions are demonstrating in the streets against rather half-hearted attempts by the government to retrench. There is speculation in the financial press about the possibility of a bailout from the other Euro Area countries, and there is political posturing that suggests otherwise. The euro is depreciating amid this uncertainty. Future readers will be able to see how this scenario works out.

2.3.7 Leeper's characterization of the coordination problem

Leeper (1991) looked for equilibria in which a set of well-specified feedback rules for monetary and fiscal policy produced a unique, locally stable, solution for both inflation and government liabilities. Note that Leeper was looking for a subset of the equilibria considered by Woodford: Leeper (1991) required the path of government liabilities to be stable, while Woodford only required the path of liabilities to satisfy the PVBC.

Woodford's requirement makes sense, because the PVBC is equivalent to the household transversality condition, an optimality condition that must hold in equilibrium. Leeper's additional stability requirement seems plausible for certain kinds of analyses, and as noted earlier, it has been widely accepted in the literature generally without any discussion of its possible limitations. So far, we have been working with very simple models. A major advantage of Leeper's approach is that it can be applied numerically to much richer models and to models with complex interactions between inflation and debt dynamics. Of course there is a price to pay: Leeper (1991) had to posit specific feedback rules for monetary and fiscal policy. We will look at the simple rules:

$$i_t = \rho_m i_{t-1} + (1-\rho_m)[(\Pi^*/\beta) + \theta_m(\pi_t - \pi^*)] + \varepsilon_{i,t} \tag{20}$$

and

$$\tau_t = \bar{\tau} + \theta_f(b_{t-1} - \bar{b}) + \varepsilon_{\tau,t} \tag{21}$$

where bars indicate steady-state values, $\rho_m > 0$, and $\varepsilon_{i,t}$ and $\varepsilon_{\tau,t}$ are policy shocks. Leeper's coordination problem is to find the set, *S*, of parameter pairs, (θ_m, θ_f), that results in a unique, locally stable solution. This can be done numerically by linearizing the model and calculating eigenvalues; see Blanchard and Kahn (1980).

The parameter pairs that are included in *S* depend on the particular model analyzed; any change in the model's structure that affects its eigenvalues can modify *S*. In general, there is little more that can be said about Leeper's coordination problem. However, certain reference values for θ_m and θ_f are well worth noting. An interest rate rule satisfies the Taylor principle if $\theta_m > 1$. In Leeper's terminology, these rules are *active*, while

[19] Spain, Italy, and Portugal may be added to the list.

rules that violate the Taylor principle are *passive*. If $\theta_f > \bar{r}$, the steady-state real rate of interest, then fiscal policy stabilizes debt dynamics. Leeper calls these rules *passive*, while rules for which $\theta_f < \bar{r}$ are *active*. The fiscal rule is non-Ricardian if $\theta_f = 0$; Bohn (1998) showed (in an unpublished appendix) that the rule is Ricardian if $0 < \theta_f$. The intuition for Bohn's result is straightforward: fiscal policy only has to pay a little interest on the debt to satisfy the PVBC.

Leeper (1991) illustrated his approach using a model with flexible prices, making inflation and debt dynamics rather simple (as is the case in the model we have been considering). To illustrate his results in our model, note that inflation and debt dynamics are given by Eqs. (16) and (12).

Abstracting from uncertainty, letting $\rho_m = 0$ in Eq. (20), replacing Eq. (21) with $\tilde{s}_t - \tilde{s} = \theta_f(a_t - a)$ (where $\bar{s}$ and $\bar{a}$ are steady-state values) and recalling that $\bar{r} = \beta^{-1} - 1$, inflation and debt dynamics become:

$$\pi_{t+1} = \pi^* + \theta_m(\pi_t - \pi^*) \tag{22}$$

$$a_{t+1} = (\bar{r} + 1)(a_t - \tilde{s}_t) = [1 + (\bar{r} - \theta_f) - \bar{r}\theta_f]a_t + \text{constant} \tag{23}$$

where $\tilde{s}_t \equiv (i_t/I_t)m_t + s_t$ is the surplus inclusive of seigniorage. Ignoring the second-order term, $\bar{r}\theta_f$, the feedback coefficient in the debt equation is less than one when fiscal policy is passive, and greater than one when fiscal policy is active.

The conventional case is characterized by active monetary policy and passive fiscal policy. Monetary policy provides the nominal anchor in the conventional case: P_t is determined by Eq. (22), as described in Section 2.3.5, and illustrated in the first phase diagram of Figure 1. With P_t pinned down, a_t is determined, and Eq. (23) is a stable (backward-looking) difference equation. We have a unique stable solution. The case usually associated with the FTPL is characterized by active fiscal policy and passive monetary policy. In this case, everything is turned around. Fiscal policy provides the nominal anchor: Eq. (23) is now the unstable equation, and P_t must jump to make a_t jump to the unique stable solution. And with P_t pinned down, π_t is determined, and Eq. (22) is a stable difference equation.

Now, we can see the significance of Leeper's extra requirement on the equilibria to be considered, namely, that the path of a_t is stable. Consider a fiscal policy for which $0 < \theta_f < \bar{r}$. For his policy, Eq. (23) is an unstable difference equation. But the policy is Ricardian in Woodford's sense, so, there are a continuum of paths for a_t that satisfy the PVBC. All but one of these paths is unstable, and Leeper's requirement chooses that unique path.[20]

Leeper's stability requirement is rather appealing. The unstable debt paths imply ever-increasing interest payments. Personal income (which includes the interest payments)

[20] Woodford (2001) articulated a focal point argument for selecting Leeper's (1991) equilibrium in this case and refers to Leeper's "active" fiscal policy as a "locally non-Ricardian" fiscal policy.

grows with the debt and would be sufficient to pay the rising tax burden. If the government has access to a lump-sum tax, then these unstable equilibria would be sustainable; but if the government had to use a distortionary tax to pay the ever-increasing interest payments, then the unstable equilibria would probably not be sustainable.

Inflation and debt dynamics are very simple in the model we have been considering, and we should note once again that the boundaries of the stable set S depend upon the particular model analyzed. However, active monetary policies can often be paired with passive fiscal policies, and passive monetary policies can often be paired with active fiscal policies.

Turning to what is conventional and what is not, any pair (θ_m, θ_f) in S produces a stable equilibrium. But, policy innovations have very different effects for Ricardian and non-Ricardian fiscal policies or more generally for active and passive fiscal policies. Following Kim (2003), we use impulse response functions to illustrate those differences.[21] Here, we use the complete cash and credit goods model outlined in Section 3; it has Calvo price-setting. For the Ricardian (or passive fiscal policy) example, we let $\theta_m = 1.5$ and $\theta_f = 0.012$, which is greater than $\bar{r}$, the steady-state real interest rate (on a quarterly basis). For the non-Ricardian example, we set θ_m and θ_f equal to zero; this is an interest rate peg. In each case we let $\rho_m = 0.8$, so interest rate shocks have persistence. And in each case, the Calvo parameter is set at 0.75, implying an average price "contract" of 4 quarters.

Figure 2 shows the responses to positive interest rate and government spending shocks. Figure 2A shows impulse response functions (IRFs) for the Ricardian example. They tell a conventional story. An increase in government spending raises the tax burden on households who then increase their work effort and curtail their spending. Consumption falls, and output and inflation rise. An increase in the policy rate raises the real interest rate, lowering household spending, output, and inflation.

Figure 2B shows IRFs for the non-Ricardian example. They tell a very different story. Households with non-Ricardian expectations do not think that an increase in government spending raises their tax burden. Quite the contrary, they think the present value of surpluses has fallen; at the initial price level, the government debt they hold exceeds that present value, and this represents a positive wealth effect. Households increase their spending until the price level rises enough to eliminate the discrepancy. Since prices are sticky, this takes some time. We should also note that with sticky prices, real interest rates are endogenous; so changes in current and expected future discount factors help the price level balance the PVBC. In any case, consumption rises, in sharp contrast with the Ricardian example. The increase in output is four times larger, and the increase in inflation is ten times larger.

[21] Kim (2003) performed a similar exercise using a money-in-utility model; he got very similar results.

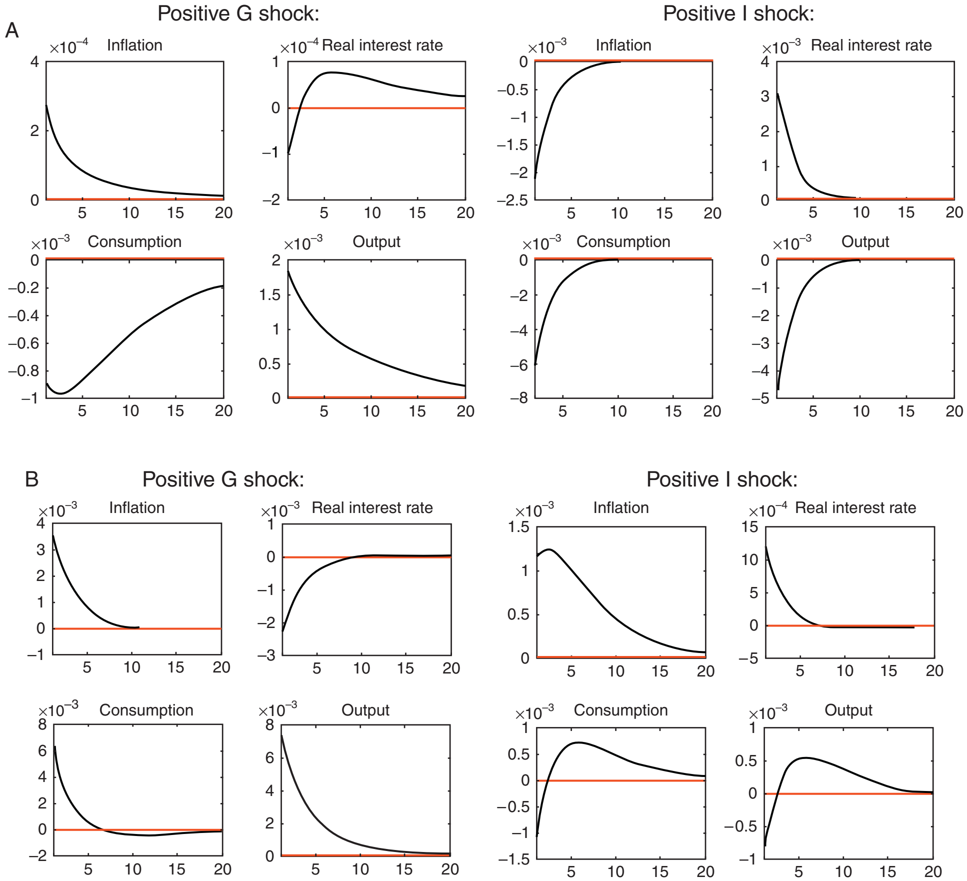

Figure 2 (A) Cash-credit goods model: $\theta_m = 1.5$ and $\theta_f = 0.012$ ($>$ r, Ricardian or passive rule), (B) cash-credit goods model: $\theta_m = 0.0$ (an interest rate peg) and $\theta_f = 0.0$ (non-Ricardian).

Increasing the policy rate produces what may be even more surprising results: inflation rises instead of falling; consumption rises and so does output (after a slight delay). Once again, there is a non-Ricardian story behind this outcome. A persistent rise in interest rates means that the exogenous path of primary deficits will be more expensive to finance; more government liabilities will have to be issued. But then, along the original price path, the beginning of period liabilities will be greater than the present value of surpluses. As before, this produces a positive wealth effect. Households increase spending until prices rise to eliminate the discrepancy, and with sticky prices, this takes some time.

Trying out different values of θ_f in our model, it can be shown numerically that if $\theta_m = 0$, then virtually all θ_f less than $\bar{r}$ would put us in *S*, and virtually all θ_f greater than $\bar{r}$ would put us outside *S*. Similarly, if $\theta_m = 1.5$, virtually all passive θ_f would put us in *S*;

and virtually all active θ_f would put us outside S. When the central bank switches from an active to passive rule, fiscal policy must shift from passive to active and vice versa. Fiscal policy must shift in a coordinated way, but it does not shift to a non-Ricardian policy, where $\theta_f = 0$. Leeper's coordination problem is less severe than Woodford's problem.

As a final note, it is worth mentioning that Leeper's MP/FA policy mixes produce the same kind of unconventional IRFs as the non-Ricardian example shown in Figure 2B. The policy mixes associated with the FTPL tend to produce results that look like a non-Ricardian regime.

2.3.8 More recent, and less severe, characterizations of the coordination problem

Davig and Leeper (2006, 2009) and Canzoneri et al. (2008, 2010) provided new characterizations of the coordination problem, and their work suggests that the problem is not nearly as severe as earlier characterizations portrayed them to be. Indeed, when monetary policy shifts from a policy that obeys the Taylor principle to one that does not (or vice versa), there may be no need for any change in fiscal policy.

Davig and Leeper (2006, 2009) extended the FTPL by allowing monetary and fiscal policies to switch randomly between active and passive. While they do not have a general theoretical result, they do find that an estimated Markov switching process produces a unique solution. In Canzoneri et al. (2010), we depart from the FTPL by focusing on passive fiscal policies. Following Canzoneri and Diba (2005), we assume that government bonds provide liquidity services, and we find that both active and inactive monetary policies can be paired with the same passive fiscal policy in many cases.

2.3.8.1 Stochastically switching policy regimes

Davig and Leeper (2006, 2009) postulated monetary and fiscal policy rules like Eqs. (20) and (21), but with extra variables; the interest rate rule has an output gap, and the tax rule has government spending and an output gap. The novelty is that the coefficients in these rules are modeled as Markov chains. Using post-war data for the United States, Davig and Leeper (2006, 2009) estimated Markov switching rules showing how each rule has switched back and forth between active and passive. In any given period, the policy mix may be monetary active/fiscal passive (MA/FP; the conventional pairing), or monetary passive/fiscal active (MP/FA; the matching associated with the FTPL), or monetary passive/fiscal passive (MP/FP; the sunspot case), or monetary active/fiscal active (MA/FA; the unstable case).

Davig and Leeper's (2006, 2009) estimate of the coefficient on lagged debt is negative for their fiscal active policy rule, and we find this rather difficult to interpret.[22] Regardless of whether the fiscal rule is Ricardian or non-Ricardian, we would expect a positive estimated coefficient. As noted earlier, a rule that reacts positively to the debt

[22] Eric Leeper noted in private conversation that setting this coefficient to zero would not change the results.

is Ricardian. In a non-Ricardian regime, the PVBC implies that debt is a good predictor of future surpluses. Actually, a nonpositive estimate may be easier to interpret in terms of a Ricardian regime. As we will see in the next section, the surplus need only react (positively) to the debt on a very infrequent basis to make the policy Ricardian; indeed, it does not need to react at all in any finite data set.

To digress a bit, it may be worth noting that it is easy to find active fiscal policy rules for which the regression coefficient should actually be greater than the real rate of interest (suggesting incorrectly that the rule was passive). We know surpluses are serially correlated in the data, so consider active policy rules of the form:

$$(\tilde{s}_t - \tilde{s}) = \rho(\tilde{s}_{t-1} - \tilde{s}) + \varepsilon_t \tag{24}$$

where $0 < \rho < 1$; $\tilde{s}$ is a steady-state value, and ε_t is a random term. The PVBC, together with Eq. (24), implies that

$$\tilde{s}_t = \rho(1 - \rho\beta)a_{t-1} + \varepsilon_t + \text{a constant} \tag{25}$$

For values of ρ between 0.5 and 1, $\rho(1 - \rho\beta) > \beta^{-1} - 1$, the real rate of interest. This example illustrates an identification problem that we will explore in the next section: Finding a regression coefficient that is greater than the real rate of interest does not necessarily imply that the policy is Ricardian.

Davig and Leeper's (2006, 2009) estimates of the transition probabilities show that there is persistence in the policy matchings. The estimates suggest a MP/FP regime for the early 1950s when the Federal Reserve was supporting bond prices. This is consistent with Woodford's (2001) judgment that an interest rate peg best describes monetary policy in this period, but it is not consistent with his assertion of a non-Ricardian (or active) fiscal policy. Their estimates suggest the same regime for the late 1960s and most of the 1970s, which is consistent with estimates of interest rate rules for this period. Their estimates suggest a MA/FP regime for the mid-1980s through the 1990s. This is consistent with estimates of the interest rate rule for this period. Interestingly, Davig and Leeper's (2009) estimates suggest a reversion to the MP/FA mix in the 2000s.

Davig and Leeper (2006) combined their estimated regime switching process with a standard DSGE model (with Calvo pricing) and found an equilibrium solution is determined. Despite the fact that there are periods with MP/FP and MA/FA mixes, which one might think would lead to sunspots or explosive behavior, the expectation of future stable policy mixes leads to a determinate solution.

This result suggests that policy coordination has not been a problem in practice. Monetary and fiscal policies may have switched randomly from active to passive and back again without causing sunspot equilibria or explosive behavior. These numerical results are based on estimates of past transition probabilities. There is no theoretical guarantee that expected future regime switching will lead to such sanguine results.

Davig and Leeper (2006) noted that "the FTPL is always operative" in their model, even when the current regime is the conventional MA/FP. This is because there is always an expectation of active fiscal policies in the future. To illustrate this fact, Davig and Leeper (2006) presented impulse response functions for an increase in the lump-sum tax. This shock would have no effect in a permanent MA/FP regime, but the expectation of an MP/FA regime sometime in the future causes the tax shock to have the non-Ricardian wealth effects previously described.

2.3.8.2 Liquidity Services of Bonds

In Canzoneri et al. (CCDL; 2008, 2010), we explore another way of "making bonds matter" to resolve the price determinacy puzzle. And as we will see, policy coordination is much less demanding in our framework than in Woodford or in Leeper (1991): fiscal policy may not even have to change when, say, monetary policy switches from active to passive.

Our approach is to recognize that government bonds provide liquidity services; they are imperfect substitutes for money.[23] In Canzoneri and Diba (2005), we allow bond holdings to ease a cash in advance constraint; in CCDL (2008), we assume banks use both money and bonds in managing the liquidity of their demand deposits; and in CCDL (2010), we assume households face the transactions costs described by Schmitt-Grohe and Uribe (2004a), but with the money balances replaced by a CES aggregate of money and bonds. In this framework, fiscal policy determines the total supply of liquid assets,[24] $M_t + B_t$, while the central bank's open market operations determine its composition; the composition matters because money and bonds are imperfect substitutes.

Figure 3 illustrates the stable set *S* for two parameterizations of the model presented in CCDL (2010). For the top plot, we calibrated the model to U.S. data prior to 1980; for the bottom plot, we used post-1980 data.[25] The white areas represent the stable set *S*. The darker shaded areas are regions of indeterminacy, or sunspot equilibria; the lighter shaded areas are regions of over determinacy, or explosive equilibria. The vertical line in these plots is at $\bar{r}$. θ_f to the right of the line are passive fiscal policies, and θ_m above the 1.0 line are active monetary policies.[26]

The two figures show how the stable set *S* can shift over time, even for the same basic model. We can use the figures to discuss the change in Federal Reserve policy that is thought to have occurred around 1980. As noted earlier, Lubik and Schorfheide (2004)

[23] We are, of course, not the first to have done this. As far back as Patinkin (1965), modelers have put both money and bonds in the household utility function. More recent papers include: Bansal and Coleman (1996), Lahiri and Vegh (2003), Schabert (2004), and Linnemann and Schabert (2009, 2010).

[24] Rearranging the flow budget constraint (6), we have: $M_t + B_t = (I_{t-1} B_{t-1} + M_{t-1}) - S_t$.

[25] In CCDL(2010), we did not model interest rate smoothing; that is, $\rho_m = 0$.

[26] In Leeper's (1991) simpler model, with flexible prices, the set *S* consisted of the entire NE and SW quadrants.

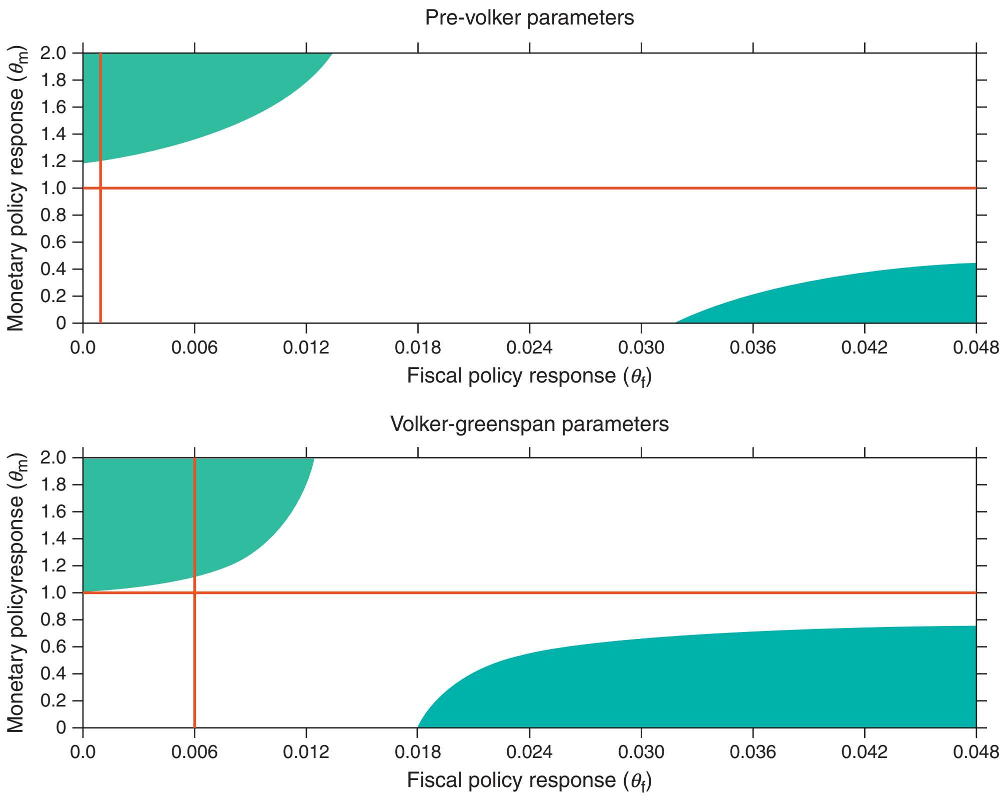

Figure 3 The stable set *S* for the model described in CCDL (2010).

estimated θ_m to be 0.8 for the earlier period, and a variety of estimates put the value of θ_m between 1.5 and 2.0 for the later period. Could this shift in monetary policy have been carried out without any change in fiscal policy? Looking at either plot, the answer would be yes if the pre-existing θ_f were greater than 0.010. There would not have been a coordination issue if the fiscal response to debt was strong enough.

Figures 4A and B show IRFs for the two calibrations of the CCDL (2010) model. It is interesting to compare them with Figures 2A and B for the cash and credit goods model; the IRFs look very similar. In particular, Figure 4B shows the same unconventional results as Figure 2B, even though the fiscal policy is passive.[27] Once again, the difference is that in the CCDL model, we can keep the same passive fiscal policy ($\theta_f = 0.12$) for both calibrations. In the cash and credit goods model, we had to shift from a passive fiscal policy to an active fiscal policy.

[27] The major difference is that it takes inflation a few quarters to rise in Figure 4B.

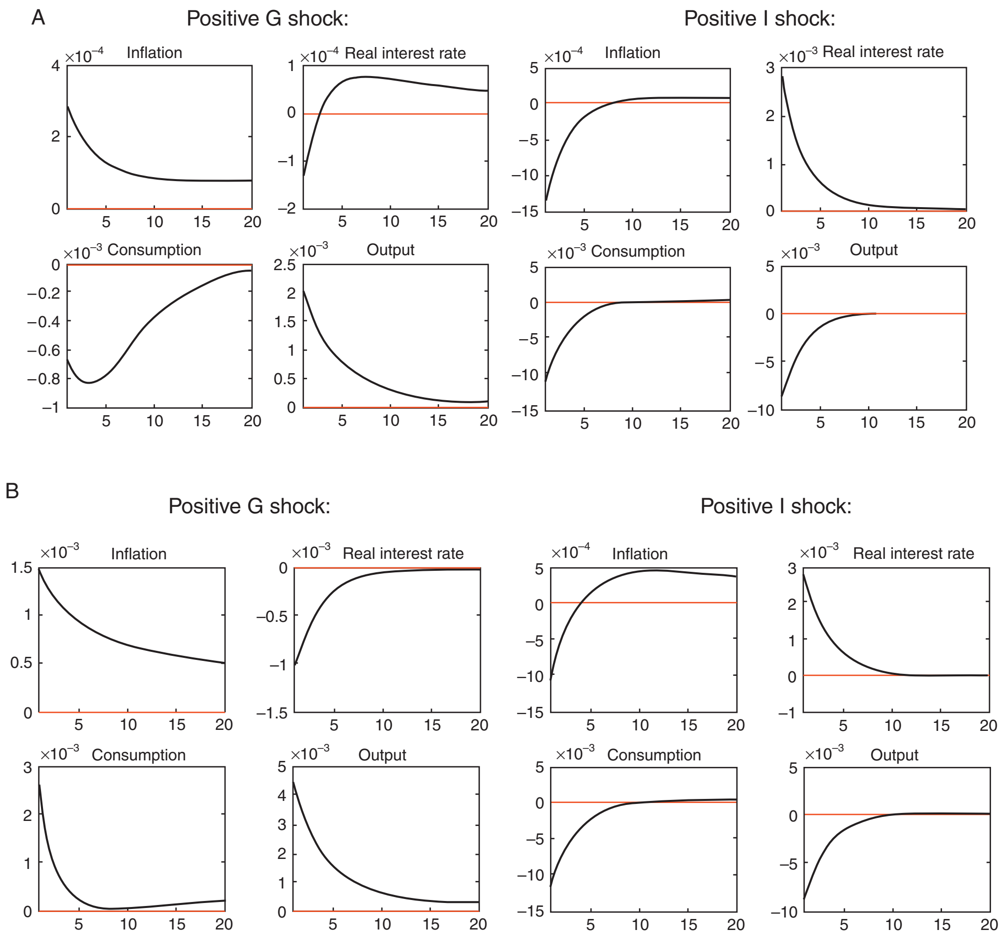

Figure 4 (A) CCDL model (1980s parameterization): $\theta_m = 0.15$ and $\theta_f = 0.012$, (B) CCDL model (1970s parameterization): $\theta_m = 0.8$ and $\theta_f = 0.012$.

2.4 Is fiscal policy Ricardian or non-Ricardian?

One would naturally like to subject the FTPL to standard statistical testing: infer from the data whether fiscal policy was Ricardian or non-Ricardian, or active or passive, in a given time period. This may, however, be impossible due to a seemingly intractable identification problem. This difficulty has caused a great deal of frustration for some economists: Why should we be interested in concepts or assertions that cannot be subjected to the usual statistical inference? We begin with the identification problem, and then we proceed to alternative approaches to "testing."

2.4.1 An important identification problem

As already noted, Bohn (1998) showed that a fiscal rule like Eq. (21) is Ricardian if θ_f is positive. So, it only seems natural to look at regressions of the surplus on the debt. Bohn and others have shown that there is a significantly positive correlation. The problem here is that a non-Ricardian policy will also imply a positive correlation. The PVBC indicates that fluctuations in the real value of government liabilities will be positively correlated with current and/or future surpluses even if the path of those surpluses is exogenous. A valid test would be to see if surpluses react to debt for off-equilibrium price paths, but one cannot construct such a test.

This brings us to the nub of the identification problem. As Cochrane (1998) noted, the FTPL uses exactly the same equations — except, of course, for the policy rules specifying the evolution of primary surpluses — to explain any possible equilibrium outcome, or in empirical work any given data set. In other words, there will be a Ricardian explanation and a non-Ricardian explanation for any possible equilibrium, or for any historical episode. It seems impossible to use standard methods of testing to differentiate between the two explanations.

The literature has therefore proceeded in a different direction. There may be Ricardian and non-Ricardian explanations for any particular aspect of the data, but some of the explanations may be more credible than others. So, an alternative approach to "testing" is to ask which explanation seems more plausible. This approach has been adopted to explain surplus and debt dynamics in the post-war U.S. data by Cochrane (1998) to promote a non-Ricardian interpretation, and by Canzoneri, Cumby, and Diba (2001b) to support a Ricardian interpretation. Sims (2008) presented a non-Ricardian explanation of the high inflation of the 1970s and early 1980s, and Cochrane (2009) provided a non-Ricardian interpretation of the current financial crisis. The new approach is less satisfying than conventional statistical testing, and in the end, plausibility like beauty may be in the eye of the beholder.

2.4.2 The plausibility of non-Ricardian testing

As an illustration of the new approach, we begin with the Ricardian and non-Ricardian interpretations of two historical episodes that we have already discussed: the interest rate peg that may best describe the bond price support policy of the 1940s, and the passive monetary policy prior to 1980. Price determinacy in these periods is readily explained in terms of non-Ricardian policies or active fiscal rules. We have described the impulse response functions associated with these explanations (shown in Figure 2B) as unconventional. However, the positive response of consumption to government spending shocks and the big output response are consistent with the VAR evidence of Perotti (2004) who found that for many OECD countries both consumption and output multipliers were stronger prior to 1980. The conventional Ricardian interpretation, passive monetary policy and passive fiscal policy, may be a tougher sell as it implies sunspot equilibria for these periods.

In an ambitious example of the new approach, Cochrane (1998) provided a non-Ricardian interpretation of the history of post-war inflation in the United States. Cochrane begins by arguing that a Ricardian interpretation is not plausible. He identifies the Ricardian interpretation with a quantity theoretic approach to price determination, which depends on a transactions demand for money. Cochrane argues that transactions demand for money is disappearing due to financial innovation.

In his own words: "If we had a realistic and empirically successful monetary theory . . . most of our interest in the fiscal theory would vanish." Cochrane could be accused of setting up a straw man when he identifies the Ricardian interpretation with transactions frictions. As we have seen, a Ricardian fiscal policy can be paired with an interest rate rule that obeys the Taylor principle; there is no need to even discuss money supply and demand. In any case, Cochrane goes on to present a non-Ricardian interpretation that does not depend on transactions frictions.

Cochrane's (1998, 2005) rendition of the non-Ricardian regime has a curious twist. In Section 2.2.1, we noted that the central bank's interest rate policy controls expected inflation (via the Fisher equation), while innovations in the surplus create unexpected fluctuations in the price level. Cochrane essentially does away with the central bank. He assumes that fiscal authorities set both the real surplus and the face value of nominal debt to control (in equilibrium) the price level, the nominal interest rate, and expected inflation. Thus, in Cochrane's rendition we have an entirely fiscal theory of both price levels and inflation. This seems a bit odd given the strong trend toward institutional independence of central banks in the OECD.

Cochrane concludes: "The important ingredient [in the non-Ricardian interpretation] is that extra nominal debt sales in recessions must come with implicit promises to increase subsequent surpluses." We will discuss this correlation, and Cochrane's explanation for it, in the next section.

More recently, Sims (2008) gave a non-Ricardian interpretation of the high inflation of the mid-1970s and early 1980s using arguments that we have already developed. He noted that the deficit to GDP ratio spiked dramatically in 1975, and he questioned whether forward-looking agents thought that the huge bond issue would be fully backed by future taxes. If not, then prices would have had to rise to bring the real value of government liabilities in line with the lower expected present value of surpluses. He also noted that interest rates were high in the early 1980s, and interest payments on the debt spiked. This implies a higher rate of growth in nominal government liabilities, which would also be inflationary in a non-Ricardian interpretation.

2.4.3 The plausibility of non-Ricardian regimes

In Canzoneri, Cumby, and Diba (CCD; 2001b), we argue that Ricardian policies are theoretically plausible and that a Ricardian interpretation of U.S. surplus and debt dynamics is more straightforward than the non-Ricardian interpretation. We begin with the theoretical plausibility of Ricardian fiscal policies.

For a recursive definition of equilibrium, it seems natural to think of the public debt as the state variable that links the policy choices of governments over time. This motivates specifying fiscal policy as a feedback rule that links surpluses to inherited debt. Bohn (1998) and CCD (2001b) argued that Ricardian policies seem more plausible once we consider such a feedback rule.

The literature on the FTPL focuses on non-Ricardian policies as they are new here. But, this may give the impression that they are the natural policies to consider, and that Ricardian policies are in some sense a special case. We try to dispel this impression by showing that Ricardian policies can be quite demanding, or they can be very lax. There is considerable latitude for countercyclical policy, political inertia, or political noise.

We will illustrate this basic idea with a simple example. Consider the nonstochastic version of our model and rewrite the flow budget constraint (12) as

$$a_t = \beta a_{t+1} + \tilde{s}_t \tag{26}$$

where $\tilde{s}_t \equiv (i_t/I_t)m_t + s_t$ is the surplus inclusive of seigniorage. The PVBC becomes

$$a_t = (M_{t-1} + I_{t-1}B_{t-1})/P_t = \sum\nolimits_{j=t}^{\infty} \beta^{j-t}\tilde{s}_j \Leftrightarrow \lim_{T-\infty} \beta^T a_{t+T} = 0 \tag{27}$$

A fiscal policy is Ricardian if it satisfies Eq. (27) for any value of P_t, or equivalently, for any value of a_t. ${}_t$In CCD, we found it convenient to focus on the limit term.

Consider fiscal policy rules of the form

$$\tilde{s}_j = f_j a_j + x \tag{28}$$

where $\{f_j\}$ is a deterministic sequence of feedback coefficients and x is a constant. Substituting Eq. (28) into Eq. (26) and iterating forward,

$$a_{t+T} = \left[\beta^T \prod_{j=t}^{t+T-1} (1 - f_j)\right] a_t + F \tag{29}$$

where F is a term that also involves the feedback coefficients. Substituting this result into the transversality condition, we have

$$\lim_{T\to\infty} \beta^T a_{t+T} = \left[\prod_{j=t}^{t+T-1} (1 - f_j)\right] a_t + G \tag{30}$$

where G is again a term involving the feedback coefficients. If this limit goes to zero for any value of a_t, then the policy is Ricardian. Then the question is, What restrictions do we have to put on the sequence $\{f_j\}$ to make the limit go to zero? In CCD, we prove that G_t goes to zero for any of the restrictions considered next. Our purpose here is to give intuition about the term involving an arbitrary value of a_t.

The policy is certainly Ricardian if the government reacts to the debt each and every period. To see this, let f^* be a positive number arbitrarily close to zero. If $f^* \leq f_j < 1$ for all j, then the limit goes to zero. However, this is a very strong assumption, and it would not seem to be very realistic; governments appear to show little concern for debt for long periods of time.

But this restriction is much stronger than necessary. To see this, suppose $f^* < f_j$ infinitely often, and $f_j = 0$ otherwise. Once again, the limit goes to zero. In theory, the government need only react to the debt once every decade, once every century, or once every millennium. Moreover, the government need not react to the debt in any finite data set, which is another example of the difficulty in "testing." Ricardian policies can be very loose.

In CCD, we extend this result to a stochastic setting. The discount factors are stochastic, and rule (28) has a random ε_t tacked on. The ε_t could reflect countercyclical policy or political factors unrelated to economic performance. Moreover, Bohn (1998) showed that fiscal policy needs to respond to the debt only when it gets sufficiently large. So in theory, Ricardian regimes are far from a special case; they seem highly plausible. At a more fundamental level the private sector must believe that the government will eventually react to debt, and repeatedly so. How credible is a policy that is only seen to react to debt say once every century? Rational expectations models do not generally address this kind of question.

The theoretical arguments of Bohn (1998) and CCD focus on Woodford's definition of equilibrium and policy regimes; that is, they focus on the fiscal response necessary to satisfy the transversality condition and assure a Ricardian regime. As we noted earlier, a Ricardian policy with a weak response of surpluses to debt may generate equilibria with explosive debt, and we may wish to rule out such equilibria. At a broader level, the observations in Bohn (1998) and CCD suggested that simple feedback rules for fiscal policy —for example, with constant coefficients or with exogenously changing coefficients as in Davig and Leeper (2006, 2009) — may not adequately capture either the endogenous nature of fiscal policy choices or expectations about future fiscal policy.[28] Fiscal policy may not respond immediately to growing debt but future policymakers may be expected to stabilize the debt when fiscal sustainability makes it to the political agenda or fortuitous circumstances make fiscal adjustment less painful.

[28] Feedback rules with constant or exogenously changing coefficients may also be inadequate to interpret past policies. Bohn (2008) noted that U.S. GDP growth rates exceeded the interest rate on U.S. government debt for sustained periods, resulting in a falling debt-to-GDP ratio. A feedback rule with a constant coefficient would have a passive fiscal policy to cut the surplus-to-GDP ratio to "stabilize" the debt-to-GDP ratio, and a regression would characterize a policy that fails to do so as active. In reality, however, a government concerned with fiscal sustainability that pursues a passive fiscal policy may view such a phase as an opportune time to reduce the burden of debt.

The results in Bohn (1998) and CCD can be modified to obtain the requirements for fiscal policy to stabilize the debt to GDP ratio. This might involve, for example, stronger fiscal responses as the debt to GDP ratio grows. But again these responses could be in the future and infrequent.

In CCD, we also argue that a Ricardian interpretation of U.S. surplus and debt dynamics is more plausible than a non-Ricardian interpretation. Figure 5 shows IRFs from a VAR using annual data on the government surplus and total government liabilities, both scaled by GDP. The IRFs show the response to a shock in the surplus. In the top panel, the surplus comes first in the ordering, which makes sense in a non-Ricardian interpretation. In the bottom panel the ordering is reversed, which may make more sense in a Ricardian interpretation. With either ordering, a positive surplus innovation makes liabilities fall for several years, and the response remains significantly negative for ten years.

The Ricardian explanation of this surplus–debt dynamics is straightforward. An innovation in the surplus pays off some of the debt, so liabilities fall. And since

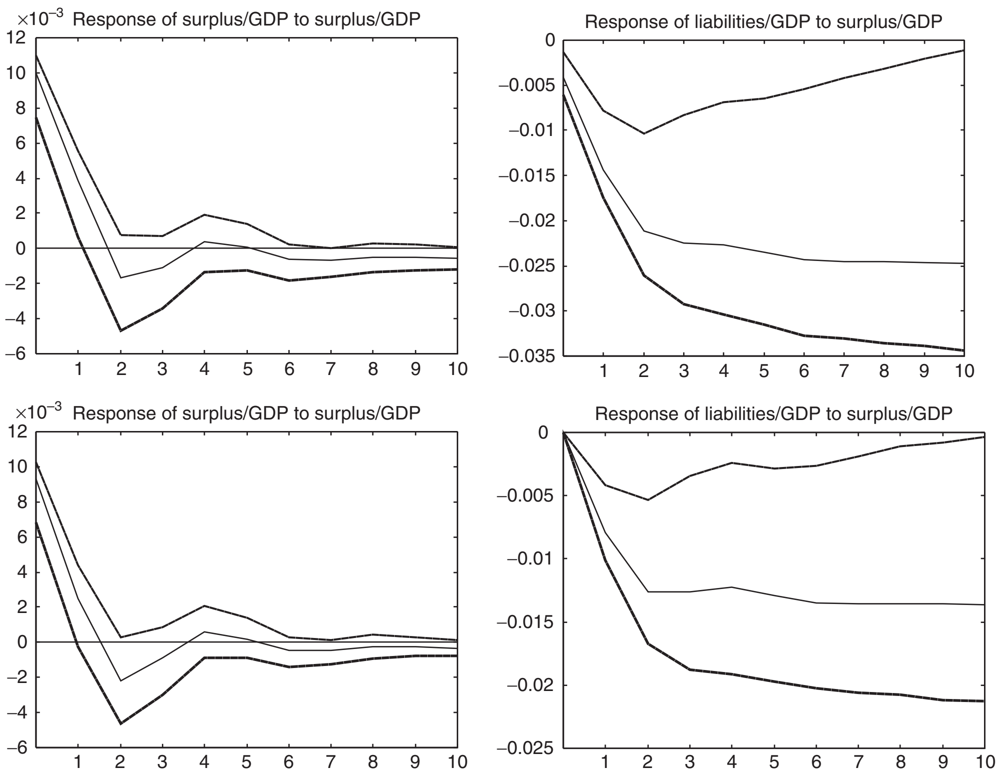

Figure 5 U.S. surplus and debt dynamics. *(From Canzoneri, Cumby, and Diba, 2001b.)*

the surplus process is serially correlated, next period's surplus pays off more debt and liabilities fall again. There is a non-Ricardian explanation for the same statistical results, but it is more complicated.

Figure 6 shows why the non-Ricardian explanation is not as straightforward. It shows IRFs from our cash-credit goods model. Once again, we use policy rules (20) and (21), but we have added tax smoothing, analogous to the interest rate smoothing, to the tax rule. The surplus shock is an increase in the lump-sum tax;, and the IRFs show the response in the primary surpluses (i.e., the tax) and total government liabilities.

In the top panel, fiscal policy is Ricardian ($\theta_m = 1.5$ and $\theta_f = 0.012$), and we see IRFs that are similar to those from the VAR.[29] The Ricardian interpretation of these IRFs has already been given. In the bottom panel, we have assumed the same non-Ricardian policy that was discussed earlier ($\theta_m = \theta_f = 0$). Here, an increase in the surplus raises the value of government liabilities, rather than lowering it. And there is the now familiar non-Ricardian explanation for this: An increase in the surplus causes the present discounted value of surpluses to rise, and the real value of government liabilities has to rise in response.

What must a non-Ricardian policy do to explain the surplus–debt dynamics found in the data? The only way to make the value of government liabilities fall is to engineer a policy in which the discounted value of future surpluses falls.[30] The increase in the current surplus must imply that expected future surpluses fall enough to lower the present value. Table 1 presents autocorrelations for the U.S. surplus to GDP ratio; these correlations are positive for ten years. So, these expected decreases in the surplus have to be far out into the future, and they have to be large enough to overcome the discounting and make the present value fall.

So, there is a non-Ricardian policy that can explain the IRFs observed in the data, but how plausible is it? Is there a political theory that would generate a negative correlation between present surpluses and distant future surpluses? The answer cannot be like the following: (1) politicians (or voters) wake up every decade and respond to the growing level of debt or (2) politicians fight wars (against poverty, other countries, or other politicians) for extended periods of time and pay off the debt later. We know that these are Ricardian policies. The explanation of the negative correlation has to be a political theory that is unrelated to debt.

Cochrane (1998) recognized the necessity of explaining this negative correlation between present surpluses and distant future surpluses. In a rather ingenious exercise, he chose parameters in a bivariate statistical model to produce impulse response

[29] Recall that the cash and credit goods model is calibrated to quarterly data, not annual.

[30] This, must be the case under either policy regime because the PVBC must hold next period either way. In the Ricardian regime, future surpluses respond to debt — as Eq. (24) illustrates, and perhaps in the distant future — to reduce the discounted value of future surpluses.

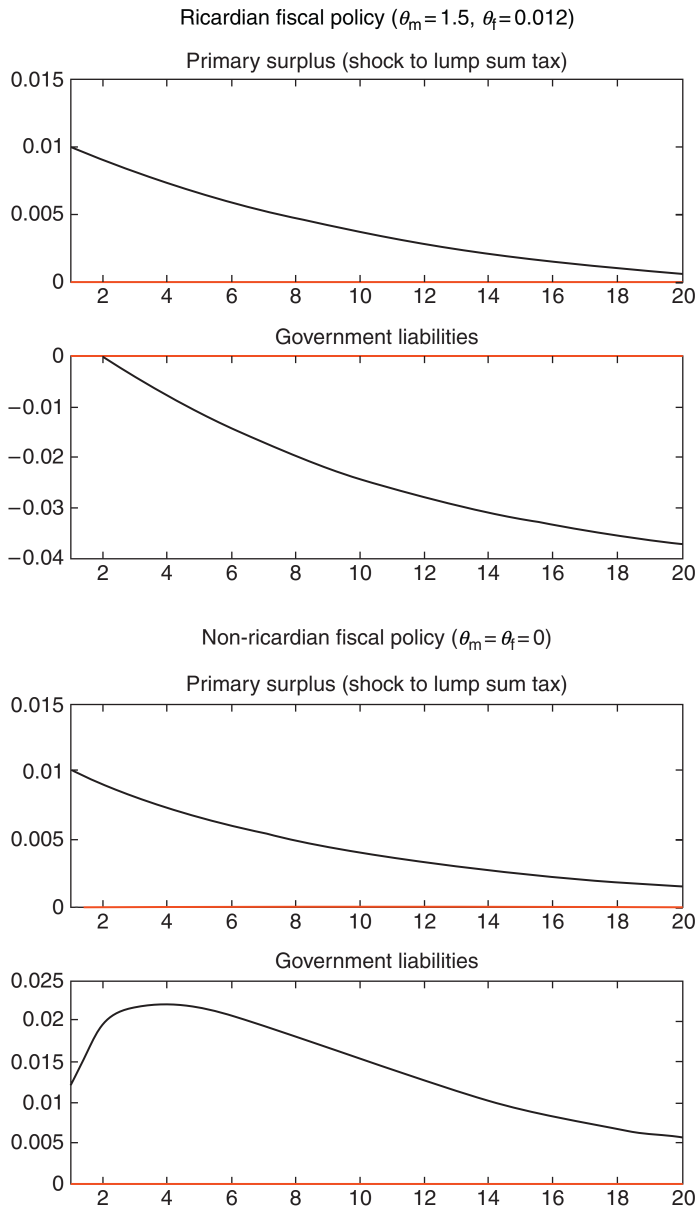

Figure 6 Response to a surplus innovation in the cash and credit goods model.

functions like those in Figure 5. In his model, the surplus is the sum of two components, one cyclical and the other long run (reflecting changes in tax rates and spending policy). Cochrane assumed that the structural component is more persistent than the

Table 1 Autocorrelations of Surplus/GDP

Lag	Autocorrelation	Q-statistic	P-value
1	0.452	9.8084	0.0020
2	0.173	11.274	0.0040
3	0.221	13.74	0.0030
4	0.252	17.022	0.0020
5	0.301	21.797	0.0010
6	0.231	24.698	0.0000
7	0.265	28.611	0.0000
8	0.266	32.652	0.0000
9	0.332	39.132	0.0000
10	0.114	39.914	0.0000
11	−0.068	40.203	0.0000
12	−0.035	40.284	0.0000
13	0.018	40.306	0.0000
14	0.024	40.344	0.0000
15	0.027	40.396	0.0000

cyclical component and that the correlation between the innovations in the two components is highly negative (−0.95). Given these assumptions, a positive innovation in the cyclical surplus induces a negative innovation in the long-run surplus. The higher persistence of the long-run component eventually leads to the required decrease in future surpluses.

A negative correlation between the innovations in cyclical and long-run components of the surplus is critical here, and it has the problematic implication that politicians raise tax rates or cut spending in response to a deficit caused by a recession; however, Cochrane (1998) provided a theoretical rationale for this procyclical fiscal policy by assuming that fiscal authorities choose the long-run (noncyclical) component of the surplus each period to minimize the variance of inflation. So, in the end, the reader is left to choose between these two interpretations of the U.S. surplus and debt dynamics.

Finally, we should note one more difficulty in assessing the plausibility of non-Ricardian policies: the implications of these policies may depend upon our assumptions about debt maturity. For example, the IRFs for a positive interest rate shock in Figure 2B show an increase in inflation and output, and this contradicts a large body of empirical evidence for monetary shocks. But our theoretical IRFs are for a model with one period debt. Woodford (2001) showed that interest rate hikes reduce inflation in a model with long-term debt (and a non-Ricardian fiscal policy). And Cochrane (2001) argued that a model with long-term debt can generate the surplus–debt dynamics reported in CCD.

2.5 Where are we now?

So, what are we to make of the last 30 years' thinking on the policy coordination needed for price determination and control? What have we learned from the FTPL? What policy mix is most amenable to price determination and control? What is the current policy mix, and is it adequate? There is no strong consensus on the answers to these questions, even among the original proponents of the FTPL.

Woodford (2001), for example, noted that the Federal Reserve shifted to an anti-inflation policy that obeyed the Taylor principle around 1980, and he asked why the shift did not produce an inflationary spiral as in Brazil. A possible answer, he says, is that

> *in the U.S. this kind 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, . . . 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.*

But, Woodford also warns that the lessons from the FTPL, and the history of Brazil, should convince high inflation countries that a strong anti-inflation policy from the central bank is not a panacea. The monetary reform must be accompanied by expectations of a Ricardian fiscal policy, and this may require a fiscal reform.

Woodford (2001) also discussed the possibility of controlling prices by managing fiscal expectations in a non-Ricardian regime. For example, the nominal interest rate could be fixed (as in the bond price support of the early 1950s), and a path for primary surpluses could be announced that would lead to price stability via the PVBC. However, he acknowledges the difficulty of controlling expectations, especially expectations into the distant future. He concludes that "Controlling inflation through an interest rate rule . . . represents a more practical alternative, . . ." He then goes on to discuss ways to assure that the accompanying fiscal policy is Ricardian. So, for Woodford, the FTPL contains important lessons and warnings, but his interest in the heart of the FTPL — the non-Ricardian regime — seems to have waned.

Cochrane's views are quite different, and strongly pro-FTPL. He examined alternative theories of price determination and found them wanting, saying in his 2007 paper that: "There is one currently available economic theory remaining that can determine the price level in modern economies: the fiscal theory." And Leeper, Sims and others continue to write papers on the FTPL.

Moving away from the proponents of the FTPL, there have been a number of prominent critics, and we have reviewed some of their arguments. The FTPL has always been controversial, and some seem to react to it in an emotional way. It is fair to say that this theory, with its emphasis on non-Ricardian regimes, has not been very popular at central banks.

Our own work and thoughts regarding the FTPL lead us to agree with the views we ascribed to Woodford at the beginning of this section. But the legacy of the FTPL will be that it has profoundly changed the way we think about a variety of issues in what is popularly known as "monetary theory." Before the FTPL, we had an incomplete understanding of price determination. In particular, we had an incomplete understanding of the way in which monetary and fiscal policy interact to produce a unique price level, sunspot equilibria, or explosive price paths. Now, we have a better understanding of the policy coordination needed for price determination and control. And before the FTPL, we tended to view the PVBC as a restriction on government behavior, a restriction that the government might be tempted to violate in the equilibria we considered. Now, we may think of the PVBC as an optimality condition that must hold in equilibrium. This fundamentally changes our view of the transmission of monetary and fiscal policy to the rest of the economy. The PVBC is one of the equilibrium conditions through which a change in monetary and fiscal policy moves prices and interest rates. And finally, before the FTPL, we tended to view the money supply as the only nominal monetary aggregate that mattered in price determination; we tended to think all monetary aggregates could be safely ignored if the central bank implemented its policy with an interest rate rule, rather than money supply rule. Now, we understand that even if the central bank is committed to an interest rate rule, total government liabilities — $M_t + I_t B_t$ — may play an important role in price determination. Thus, the FTPL restores our interest in monetary aggregates, but turns the emphasis away from a narrow definition of money.

3. NORMATIVE THEORY OF PRICE STABILITY: IS PRICE STABILITY OPTIMAL?

The literature on monetary policy often either assumes (perhaps implicitly) that price stability ought to be the goal of the monetary authorities or ignores the question of how much price stability is optimal. Rather than assuming that price stability should be the authorities' goal, in this section we consider the literature on the optimality of price stability and on the interactions of monetary and fiscal policy in determining the optimal degree of price stability.

We begin with an overview of the literature in which we frame the issues addressed in this section. Next, we set out the cash and credit goods model used by Correia et al. (2008) as well as by Chari, Christiano, & Kehoe, 1991 and others. After setting out the key results in Correia et al. (2008) we use a calibrated version of the model to illustrate other results in the literature, emphasizing the effects of sticky prices on optimal monetary and fiscal policy when the fiscal authorities have a set of taxes that is less rich than that considered by Correia et al. (2008). We then consider implementation of Ramsey policies. We ask whether simple policy rules can be used to implement optimal policies or yield outcomes that are similar to the Ramsey allocation and then briefly consider the dynamic consistency of optimal policies.

3.1 Overview

Friedman's (1969) celebrated essay, *The Optimum Quantity of Money*, argued that the monetary authorities ought to determine the rate of creation (or destruction) of fiat money to equate the marginal value of cash balances with the marginal social cost of creating additional fiat money, which is effectively zero. Alternatively, the nominal rate of interest should be zero. Steady deflation, not price stability, is therefore optimal, and the rate of deflation should equal the real rate of interest.[31] Friedman's focus was on the long run in a competitive economy.

Phelps (1973) placed the question of the optimality of price stability firmly in a public finance context by considering the choice of an optimal inflation rate as a general equilibrium problem in which the inflation tax is chosen optimally along with other tax rates. He notes that without lump-sum taxes, less use of the inflation tax required greater use of other distortionary taxes. Friedman's partial equilibrium analysis ignores that potential trade-off.[32] Phelps placed money in the utility function of his representative consumer and derived the (Ramsey) optimal inflation and wage tax, which is assumed to be the only other source of government revenue. When he added the assumption that there are no cross-price effects (e.g., that hours worked do not respond to inflation and money balances do not respond to the wage tax rate), he showed that the nominal interest rate is positive if and only if the tax rate on wages is positive. A government needing to raise revenue should then optimally tax both liquidity (through the inflation tax) and wages.

Phelps' lasting contribution was to place questions concerning the optimal rate of inflation in a general equilibrium context in which inflation is chosen jointly with other distorting taxes. He recognized that his result that inflation should exceed the Friedman rule was model-specific and depended, in particular, on his assumptions about alternative taxes and about cross-price effects. When concluding, he noted, "It does not follow, of course, that liquidity should be taxed 'like everything else';

[31] Woodford (1990) called Friedman's "doctrine . . . one of the most celebrated propositions in modern monetary theory. . ." (p. 1068)

[32] Phelps (1973) colorfully noted, "Professor Friedman has given us Hamlet without the Prince" by using a partial equilibrium framework.

some other tax might conceivably dominate the inflation-taxation of liquidity." Ironically, Phelps' contribution is often remembered as claiming that inflation should, in fact, be used so that liquidity is taxed like everything else.

A substantial literature has considered the optimality of the Friedman rule in deterministic models and has found that optimality depends on the details of model specification and the choice of functional forms.[33] Chari et al. (1991) departed from the previous literature by solving the Ramsey problem for optimal monetary and fiscal policy in a stochastic model, which allows them to characterize both optimal average inflation and tax rates and their volatilities. They used the cash and credit goods model of Lucas and Stokey (1983), in which a positive nominal interest rate implies that the cash good will be taxed at a higher rate than the credit good. Assuming that utility is separable in leisure and homothetic in the cash and credit goods, they show that the Friedman rule is optimal in their model.[34]

Unlike Lucas and Stokey (1983), who consider real, state-contingent debt, Chari et al. (1991) assumed that the government issues only nominal debt that is not state contingent. This has important implications for monetary policy in their model. Although the nominal interest rate is zero at all dates and in all states so that expected inflation is equal to minus the real interest rate (apart from a risk premium), unexpected inflation can be used as a lump-sum tax on nominal assets. In other words, unexpected inflation can be used to make the nominal debt state contingent in real terms. By inflating when revenue is unexpectedly low (due to an adverse productivity shock) or purchases are high (due to a positive spending shock) and deflating when revenue is unexpectedly high, the authorities use unexpected inflation as a fiscal shock absorber that allows them to stabilize distortionary taxes.

In a calibration of their model Chari et al. find that the tax rate on labor income is relatively stable and that inflation is highly volatile. In their benchmark calibration, annual inflation has a standard deviation of 20% per annum. Although the Friedman rule, which dictates a low deflation rate, represents a relatively minor departure from price stability, their results on the use of unexpected inflation as a tax on nominal assets represents a significant departure from a goal of price stability. And given Friedman's

[33] Woodford (1990) surveyed the literature prior to 1990. Schmitt-Grohe and Uribe's chapter in this *Handbook* (Schmitt-Grohe &Uribe,(2010) asks if inflation targets of the magnitude commonly adopted by central banks can be reconciled with the optimal steady-state rate of inflation implied by theories of monetary non-neutrality. Because questions about the optimality of steady-state inflation rates is thoroughly covered we will focus mainly on the optimal volatility of inflation around its steady-state value. Doing so will require that we address optimal steady-state inflation, but we will generally do so only to the extent necessary for continuity and clarity.

[34] Lucas and Stokey (1983) showed that the Ramsey policy will satisfy the Friedman rule unless the utility function provides a reason for taxing cash goods at a higher rate than credit goods. With homotheticity, the two goods should be taxed at the same rate (Atkinson & Stiglitz, 1972). A tax on labor income implicitly taxes the two goods at the same rate so optimal policy uses only the tax on labor income and sets the nominal interest rate to zero.

long-standing advocacy of steady growth of the money supply, one might reasonably wonder how he would react to the characterization of the Ramsey policy in this model as following a "Friedman rule."[35]

Calvo and Guidotti (1993) consider a Brock-Sidrauski model in which the government must finance an exogenous level of transfer payments either through a tax on labor income or inflation. They obtain similar results on the optimal variability of inflation. Highly variable inflation converts nominal government debt into state-contingent real debt and is used optimally as a fiscal shock absorber. Because unexpected inflation has no substitution effects, optimal policy holds other taxes constant and uses unexpected inflation to absorb all unexpected developments in the government's budget.

Schmitt-Grohe and Uribe (2004a, 2005) note that the inflation volatility implied by Ramsey optimal policy in Chrari et al. (1991) contrasts sharply with the emphasis on price stability found in the literature on optimal monetary policy with imperfect competition and sticky prices.[36] They note that, in addition to considering sticky prices and imperfect competition, the models considered in that literature generally have a cursory treatment of fiscal policy. The fiscal authorities are assumed (perhaps implicitly) to have access to lump-sum taxes to balance their budget and subsidies to eliminate the distorting effects of firms' monopoly power. Therefore there is no need in those models to use inflation as a lump-sum tax on nominal asset holding.

Benigno and Woodford (2003) and Schmitt-Grohe and Uribe (2004a, 2005, 2007) compute the Ramsey solution in models with sticky prices and monopoly distortions that are not eliminated by a subsidy. The fiscal authority raises revenue either by taxing consumption (Benigno & Woodford, 2003) or by taxing profits and labor income (Schmitt-Grohe & Uribe, 2004a, 2005, 2007). As in Chari et al. (1991), the government issues only nominal debt that is not state contingent. The optimal policy problem involves a trade-off. Using unexpected inflation as a lump-sum tax/subsidy on nominal assets allows the fiscal authority to avoid the costs associated with variability of distorting taxes (as in Chari et al., 1991). But inflation variability increases the distortion and corresponding costs that arise because of sticky prices. They show that the trade-off is

[35] Friedman (1969) closed his essay with a section titled, "A Final Schizophrenic Note" in which he pointed out the discrepancy between the essay's conclusions and his long-standing advocacy for a rule providing for a constant 4 or 5% growth in the money supply. He noted that he had not previously worked out the analysis presented in the essay and "took it for granted, in line with a long tradition and near-consensus in the profession, that a stable level of prices was a desirable policy objective." He then pointed out that he had "always emphasized that a *steady* and known rate of increase in the quantity of money is more important than the precise numerical value of the rate of increase."

[36] For example, Goodfriend and King (1998, 2001), King and Wolman (1999), and Rotemberg and Woodford (1997). Khan, King, and Wolman (2003) consider a shopping time model with a monetary distortion and price rigidity but with no distortionary taxes. They find that optimal inflation is negative but very close to zero. Erceg, Henderson, and Levin (2000) show that when wages as well as prices are sticky, price stability is not optimal but optimal inflation volatility is close to zero in their calibrated model. Collard and Dellas (2005) find that introducing distortionary taxes does not alter the case for price stability — inflation volatility optimally remains low in their model when distortionary taxes are introduced.

resolved in favor of price stability even with small degrees of price stickiness. Introducing price stickiness implies that both average inflation and its volatility are very close to zero.[37] Lower inflation volatility comes at the expense of greater volatility of the tax rate on income because the fiscal authorities do not use surprise inflation to absorb the consequences of shocks to the budget. A little price stickiness is sufficient to overcome both the costs associated with greater variability in the distortionary tax rate and the effect of the monetary distortion, which would otherwise make the Friedman rule optimal. Schmitt-Grohe and Uribe (2004a) offered some simple intuition for why this happens. Because surprise inflation cannot affect the average level of government revenue, it cannot be used to reduce the average level of distorting taxes. It therefore only smooths the wage tax distortion, which is a second-order effect that is offset by the first-order costs of price adjustment.

Correia et al. (2008) reach the striking conclusion that, with a sufficiently rich menu of taxes, sticky prices are irrelevant to the optimal conduct of monetary policy.[38] They consider a model with cash goods and credit goods, monopolistically competitive firms and nominal, non-state-contingent debt. The fiscal authority optimally sets separate tax rates on labor income, dividends, and consumption. They show that the Ramsey allocation for an economy with sticky prices and a monopoly distortion is identical to that for an economy with flexible prices and perfect competition. Thus, in their model, the Friedman rule is optimal even when prices are sticky.

3.2 The cash and credit goods model

In each period t, one of a finite number of events, s_t, occurs. The history of events up to period t, $(s_0, s_1, \ldots, s_t)$, is denoted by s^t and the initial realization, s_0, is given. The probability of the occurrence of state s^t is $\rho(s^t)$. A continuum of monopolistically competitive firms produce intermediate goods using a technology linear in labor with an aggregate productivity shock, $z(s^t)$. Firm i's output is then $y_i(s^t) = z(s^t)\, n_i(s^t)$. Competitive retailers buy the intermediate goods and bundle them into the final good, y_t, using a CES aggregator (with elasticity η. The output of the final good is sold to households as either a cash good, a credit good, or to the government; $y(s^t) = c_x(s^t) + c_c(s^t) + g(s^t)$, where c_x is consumption of the cash good and c_c is consumption of the credit good. Government purchases, $g(s^t)$, are assumed to be exogenous and treated as a credit good.

[37] Benigno and Woodford (2003) do not include a monetary distortion and hence do not address the optimality of the Friedman rule — steady-state inflation is optimally zero in their model.

[38] Buiter (2004) reaches a similar conclusion in a model with lump-sum taxes. The striking feature of Corriea et al. (2008) is that they derive their result in a Ramsey framework with only distortionary taxes available to the fiscal authorities.

The utility of the representative household in our model is

$$U = E\sum_{t-0}^{\infty}\beta^c u\left[c_{x,t}, c_{c,t}, n_t\right] = \sum_{t=0}^{\infty}\sum_{s^t}\beta^c \rho(s^t)u[c_x(s^t), c_c(s^t), n(s^t)] \tag{31}$$

and we will illustrate our main points assuming that the period utility function is $\varphi\log(c_x(s^t)) + (1-\varphi)\log(c_c(s^1)) - (1+\chi)^{-1}n(s^t)^{1+\chi}$.[39] As the notation in Eq. (31) suggests, when convenient we will suppress the notation for state s^t by writing, for example, $c_x(s^t)$ as $c_{x,t}$.

The household enters period t with nominal assets, $A(s^t)$, and in the financial exchange acquires money balances, $M(s^t)$, nominal government bonds, $B(s^t)$, and a portfolio of state contingent nominal securities in zero net supply, $B^*(s^{t+1})$, that pay one dollar in state s^{t+1} and cost $Q(s^{t+1}|s^t)$. These asset purchases must satisfy

$$M(s^t) + B(s^t) + \sum_{s^{t+1}|s^t} Q(s^{t+1}|s^t)B^*(s^{t+1}) \le A(s^t)$$

In the subsequent goods exchange, the household purchases credit goods and cash goods, the latter subject to the cash in advance constraint:

$$M_t \ge (1+\tau_{c,t})P_t c_{x,t} \tag{32}$$

where $\tau_{c,t}$ is the consumption tax rate and P_t is the producer price of the final goods — the cash and credit goods sell for the same price; the only difference is the timing of the payment. Alternatively, we can write the cash in advance constraint as $M_t \ge P_t^c c_{x,t}$, where $P_t^c = (1+\tau_{c,t})P_t$ is the consumer price. The household receives labor income, $W_t n_t$, and dividends, Γ_t, and pays for credit goods in the next period's financial exchange. The evolution of nominal assets is governed by

$$\begin{aligned} A(s^{t+1}) = {} & I(s^t)B(s^t) + B^*(s^{t+1}) + (M(s^t) - P^c(s^t)c_x(s^t)) \\ & -P^c(s^t)c_c(s^t) + (1-\tau_n(s^t))W(s^t)n(s^t) + (1+\tau_\Gamma(s^t))\Gamma(s^t) \end{aligned} \tag{33}$$

where $\tau_{\Gamma,t}$ is the tax rate on dividends and $\tau_{n,t}$ is the tax rate on labor income.

The household's first-order conditions imply:

$$u_{x,t} = \frac{1}{I_t}u_{c,t} \tag{34}$$

Because the marginal rate of transformation between cash and credit goods is unity, a positive nominal interest rate distorts the household's consumption decision. To convert a credit good into a cash good, the household has to hold money to meet the cash in advance constraint. When $I_t > 1$, this is a tax (the seigniorage tax) on cash goods.

[39] We assume each household works at all of the firms; households will be identical in a symmetric equilibrium so we have no need to index households.

The household's first-order conditions also imply:

$$\frac{\left(1-\tau_{n,t}\right)W_t}{\left(1+\tau_{c,t}\right)P_t}u_{c,t}=-u_{n,t}=\frac{1}{I_t}\frac{\left(1-\tau_{n,t}\right)W_t}{\left(1+\tau_{c,t}\right)P_t}u_{x,t} \tag{35}$$

The labor and consumption taxes distort the labor–leisure decision. And in the case of the cash good, so does the seigniorage tax.

The prices of the state-contingent securities can be obtained from the first-order conditions,

$$Q\left(s^{t+1}|s^t\right)=\beta\rho\left(s^{t+1}|s^t\right)\frac{u_x\left(s^{t+1}\right)P^c\left(s^t\right)}{u_x\left(s^t\right)P^c\left(s^{t+1}\right)} \tag{36}$$

where $\rho(s^{t+1}|s^t)$ is the conditional probability of state s^{t+1} given state s^t. Summing over states s^{t+1} gives the price of a nominally riskless bond (i.e., one that pays one dollar in each state).

$$\frac{1}{I\left(s^t\right)}=\sum_{s^{+1}|s}Q\left(s^{t+1}|s^t\right) \tag{37}$$

Equations (36) and (37) imply the Euler equation,

$$\frac{1}{I_t}=\beta E_t\left[\frac{P_t\left(1+\tau_{c,t}\right)u_{x,t+1}}{P_{t+1}\left(1+\tau_{c,t+1}\right)u_{x,t}}\right]=\beta E_t\left[\frac{P_t^c u_{x,t+1}}{P_{t+1}^c u_{x,t}}\right] \tag{38}$$

Assuming that households face a no-Ponzi-game constraint (or that household borrowing is subject to a debt limit), the transversality condition,

$$\lim_{T\to\infty}\sum_{s^{t+1}|s}Q\left(s^{T+1}|s^t\right)\left[M\left(s^{T+1}\right)+B\left(s^{T+1}\right)\right]=0 \tag{39}$$

is also a necessary condition for optimality.

Labor markets are competitive, and there is no wage rigidity. However, intermediate goods producers engage in Calvo price-setting. In every period, each producer gets to reset its price with probability $1-\alpha$; otherwise, its price remains unchanged from the previous period. There is no indexation to lagged inflation or to steady-state inflation. Empirical work by Levin, Onatski, Williams, and Williams (2005) and Cogley and Sbordone (2008) does not find evidence of indexation of prices in aggregate U.S. data. Introducing sticky prices creates a case for price stability. Marginal cost is the same for all intermediate good producers. So when $\alpha>0$, there is a dispersion of intermediate good prices that distorts household consumption patterns and the efficient use of labor. When steady-state producer price inflation is nonzero and prices are not fully indexed, price dispersion arises in the steady state as well, which makes the case for price stability more compelling. When $\alpha = 0$, prices are flexible and there is no price dispersion; the only source of production inefficiency is the monopoly markup, $\eta/(1 - \eta)$.

There are four sources of distortions in the model. The first is the monopoly distortion, and second is the monetary distortion that arises if the interest rate is positive. As can be seen from Eq. (4), a positive nominal interest rate ($I_t > 1$) distorts the margin between the consumption of cash goods and credit goods. The third arises because of taxes. The authorities have access to three taxes in the model. The taxes on labor income and consumption enter the consumer's first-order conditions only as the ratio $(1 - \tau_{n,t})/(1 + \tau_{c,t})$. As can be seen from Eq. (35), that ratio of the tax rates distorts the margin between leisure and the consumption of the credit good and the product of that ratio and $1/I_t$ distorts the cash good–leisure margin. The tax on profits is not distorting because profits in this model are pure rents. The fourth source of distortion is inflation, which, because of our assumption of Calvo pricing, causes price dispersion and results in misallocation of labor across firms. And because we assume that prices are not indexed, nonzero steady-state inflation will cause misallocation of labor in the steady state. In addition, expected inflation will affect the nominal interest rate.

Optimal policy in this model will set tax rates and the inflation rate to minimize the welfare effects of these distortions while financing the exogenous level of government purchases. Some parts of optimal policy are clear. Because the profits tax is not distorting, profits will be fully taxed so other taxes can be set as low as possible. With flexible prices and profits fully taxed, the Friedman rule will be optimal. As we will see next, there will be no incentive to use the inflation tax to reduce either the consumption or wage taxes. Otherwise, optimal policy will involve trade-offs. With Calvo pricing, reducing the nominal interest rate to zero will equate the marginal rate of substitution between cash and credit goods with the marginal rate of transformation (unity), but the resulting deflation will create price dispersion both in and out of the steady state. Similarly, there will be a trade-off in the volatilities of the tax rates and inflation — using unexpected inflation as a nondistorting tax on nominal assets will reduce volatility of other taxes, reducing the welfare costs associated with tax rate variability, but will increase price dispersion and raise the costs associated with the misallocation of labor across firms.

3.3 Optimal monetary and fiscal policy in the cash and credit goods model

As noted above, Correia et al. (2008) show that with a sufficiently rich menu of taxes available to the fiscal authorities, sticky prices are irrelevant to optimal monetary policy. That is, they show that the Ramsey allocation for an economy with sticky prices and a monopoly distortion is identical to that for an economy with flexible prices and perfect competition.[40] The key to their result is that the menu of taxes is sufficiently rich that

[40] The set of implementable allocations is identical to that in Lucas and Stokey (1983) and Chari, Christiano, and Kehoe (1991).

state-contingent taxes keep producer prices constant and allow the monetary authority to ignore the distortions that arise because of price stickiness. Consumer prices can then be expected to fall to satisfy the Friedman rule. Unexpected inflation can be used as a lump-sum tax on nominal assets stabilizing other taxes.

Because Correia et al. (2008) proved that price rigidity does not affect optimal allocations, we can illustrate their main results by considering the Ramsey allocation obtained with flexible prices. Optimal policy will tax profits completely and use the revenue from the profits tax to subsidize labor and eliminate the monopoly distortion.[41] The resulting equilibrium will therefore be identical to that of a competitive economy. We will see that $\tau_{c,t}$ is not uniquely determined so there are many policies that can be used to implement the Ramsey allocation. One of these is to set $\tau_{c,t}$ to keep the producer price P_t constant. This policy can then be used with sticky prices to obtain an allocation identical to the Ramsey allocation with flexible prices.

The Ramsey problem for a flexible price competitive economy can be obtained as follows. Iterating the consumer's budget constraint forward and using the first-order conditions to eliminate prices and tax rates yields the implementability condition

$$E_0 \sum_{t=0}^{\infty} \beta^t [u_x(s^t)c_x(s^t) + u_c(s^t)c_c(s^t) + u_n(s^t)n(s^t)] = 0 \tag{40}$$

which, under our functional form assumption, reduces to

$$E_0 \sum_{t-0}^{\infty} \beta^t [1 - n(s^t)^{\pi}] = 0 \tag{40'}$$

A second implemetability condition requires that the nominal interest rate is non-negative

$$u_x(s^t) \geq u_c(s^t) \tag{41}$$

The Ramsey allocation must also satisfy the feasibility condition

$$c_x(s^t) + c_c(s^t) + g(s^t) = z(s^t)n(s^t) \tag{42}$$

The Ramsey planner maximizes utility Eq. (31), subject to Eqs.(40)–(42). The Lagrangian for this problem is[42]

$$\Im = \sum_{t=0}^{\infty} \sum_{s^t} \beta^t \rho(s^t) \left\{ \begin{array}{l} \phi \log(c_x(s^t)) + (1-\phi)\log(c_c(s^t)) - \dfrac{1}{1+\chi} n(s^t)^{1+\chi} \\ +\lambda[1 - n(s^t)^{1+\chi}] + \mu(s^t)[z(s^t)n(s^t) - c_x(s^t) - c_c(s^t) - g(s^t)] \end{array} \right\}$$

[41] More precisely, the tax on labor will be lower than it would otherwise be.
[42] We will verify that the solution to the Lagrange problem also satisfies the second implementability constraint (41).

The corresponding first-order conditions are

$$\begin{aligned}&\beta^t\rho(s^t)\left\{\frac{\phi}{c_x(s^t)}-\mu(s^t)\right\}=0\\&\beta^t\rho(s^t)\left\{\frac{1+\phi}{c_c(s^t)}-\mu(s^t)\right\}=0\\&\beta^t\rho(s^t)\{-n(s^t)^\chi-\lambda(1+\chi)n(s^t)^\chi+\mu(s^t)z(s^t)\}=0\end{aligned} \tag{43}$$

Combining Eqs. (43a) and (43b) yields

$$\frac{\phi}{c_x(s^t)}=\frac{1-\phi}{c_c(s^t)}$$

which, along with the consumer's first-order condition, (34), verifies Eq. (41) and shows that the Ramsey allocation implies the Friedman rule that the nominal interest rate is zero in every state. Next, combining Eqs.(43b) and (43c) yields

$$z(s^t)=\frac{[1+\lambda(1+\chi)]n(s^t)^\chi c_c(s^t)}{1+\phi} \tag{44}$$

To implement the allocation as a competitive equilibrium, the real wage must equal the marginal product of labor (recall that profits are taxed fully and the proceeds are used to eliminate the monopoly distortion), $z(s^t) = W(s^t)/P(s^t)$.

The consumer's optimality condition (35), which equates the marginal rate of substitution between labor and consumption of the credit good with the real product wage, is

$$\frac{1-\tau_n(s^t)}{1+\tau_c(s^t)}\frac{W((s^t))}{P(s^t)}\frac{1-\phi}{c_c(s^t)}=n(s^t)^\chi \tag{35$'$}$$

Substituting Eq. (44) into Eq. (35') and using $z(s^t) = W(s^t)/P(s^t)$ yields

$$\frac{1-\tau_n(s^t)}{1+\tau_c(s^t)}=\frac{1}{1+\lambda(1+\chi)} \tag{45}$$

The optimal distortion of the consumption-leisure margin (the ratio of the tax terms in Eq. 45) is constant across states and over time.[43] The Ramsey allocation for $c_x(s^t)$, $c_c(s^t)$, and $n(s^t)$ is then implemented with a unique path for the interest rate, $I(s^t)$, the real product wage, $W(s^t)/P(s^t)$ and the ratio $(1 - \tau_n(s^t))/(1 + \tau_c(s^t))$. The individual tax rates, τ_n and τ_c are not uniquely determined by the Ramsey allocation for the flexible price economy so there are multiple fiscal policies that can implement that allocation. One of these fiscal policies sets $\tau_c(s^t)$ so that the producer price $P(s^t)$ is constant.

[43] The Lagrange multipler, λ, is not state dependent because the implementability constraint (40) or (40′) is a present value constraint.

The intuition behind the main result in Correia et al. (2008) is that, because the Ramsey allocation for the flexible price economy can be implemented with constant producer prices, the degree and type of price stickiness is irrelevant. The Ramsey allocation for the flexible price economy is identical to that for an economy with sticky prices. The Friedman rule is optimal with sticky prices as well as with flexible prices. Moreover, although producer prices are constant, we will see that optimal consumer price volatility is substantial.

There are two potentially disturbing aspects of the Ramsey allocation with sticky prices that suggest substantial differences from observed fiscal policies. The first can be seen by considering the consumer's Euler equation (38), which, under our assumption about the functional form of utility, is

$$\frac{1}{I_t} = \beta E_t\left[\frac{P_t\left(1+\tau_{c,t}\right)u_{x,t+1}}{P_{t+1}\left(1+\tau_{c,t+1}\right)u_{x,t}}\right] = \beta E_t\frac{P_t(1+\tau_{ct})c_{x,t}}{P_{t+1}(1+\tau_{ct+1})c_{xt+1}} \tag{38'}$$

With $I_t = 1$ and producer prices constant

$$\frac{1}{\beta} = E_t\frac{\left(1+\tau_{c,t}\right)c_{x,t}}{\left(1+\tau_{c,t+1}\right)c_{x,t+1}}$$

so that $(1+\tau_{c,t})$ must be expected to fall over time on average at rate β.[44] The consumption tax rate is then declining over time to -1 — asymptotically consumption is fully subsidized. And because the ratio $(1-\tau_n(s^t))/(1+\tau_c(s^t))$ is constant, the labor tax must be expected to rise over time to 1 — asymptotically labor income is fully taxed.

The second potentially disturbing aspect of the Ramsey allocation with sticky prices is the extreme volatility of the tax rates. Because $P_t^c = \left(1+\tau_{c,t}\right)P_t$ and producer prices are constant, $\log(P_t^c)$ and $\tau_{c.t}$ have identical volatilities. Chari et al. (1991) calibrate a similar cash good/credit goods model and find that annual inflation volatility is about 20% under Ramsey policy. Because the Ramsey allocations are identical in the flexible price, perfectly competitive economy considered by Chari et al. (1991) and the sticky price, imperfectly competitive economy considered by Correia et al. (2008), the consumption tax rate's annual volatility is also 20%. Equation (45) implies that the tax rate on labor income must also have an annual volatility of about 20%.

Both features of the tax rates in this allocation — their trends (toward -1 for the consumption tax rate and 1 for the labor tax rate) and their high volatility — are substantially different from observed fiscal policies. A more realistic fiscal policy may require modeling frictions in the political decision-making process. To avoid these

[44] It is clear from Eqs. (43a)–(43c) that a trend decline in consumption of the two goods would imply a trend increase in labor supply, which would violate the resource constraint.

Table 2 Benchmark Parameter Values in the Calibrated Cash and Credit Goods Model

β	σ	χ	α	$\Psi_g = \Psi_z$	$g/(c+g)$	$b/(c+g)$	φ
0.99	7	1	0.75	0.9	0.25	2.0	0.4

implications of the Ramsey solution with sticky prices, we turn next to alternative versions of the model in which the menu of fiscal policies is restricted. In particular, we eliminate the consumption tax from the menu of taxes available to the fiscal authorities.

3.4 Optimal policy with no consumption tax

In this section we consider the Ramsey optimal monetary and fiscal policies in a calibrated cash and credit goods model. The model is essentially that of Correia et al. (2008) without a consumption tax. There are two sources of exogenous uncertainty in the model: productivity and government purchases. We assume that each follows an autoregressive process with parameters Ψ_z for productivity and Ψ_g for government purchases. The model's parameter values, which are summarized in Table 2, are fairly standard. The rate of time preference is roughly 1% per quarter, the markup is about 16%, the Frisch elasticity of labor supply, $1/\chi$, is 1.0. In our benchmark specification, the probability of not resetting prices in any quarter is 0.75, which implies that prices are reset once a year on average. The two autoregressive parameters are set at 0.9, which is roughly consistent with a number of estimates from U.S. data. The ratios of government purchases and government bonds held by the public to GDP (which, in this model is the sum of government purchases and consumption) are set to be consistent with U.S. data. The final parameter, the share of cash goods in overall consumption, is set to 0.4, which we infer from the work of Chari et al. (1991).

The fiscal authorities can tax wage income and profits (dividends) at separate rates. As profits are pure rents in this model, optimal policy taxes them fully. We therefore initially set the tax rate on profits to unity and compute the Ramsey optimal inflation rate and tax rate on wages.[45] We then suppose that profits are less than fully taxed and examine the effect of a lower profits tax rate on optimal inflation and wage taxes.[46]

Our focus is on the behavior of the interest rate, the inflation rate, the tax rate on wages or on income. We compute both the average and the standard deviation of these variables based on simulations of the model and report the averages from 1000 samples of 200 quarterly observations. We examine optimal policy with flexible prices ($\alpha = 0$) and with various degrees of price stickiness (α ranging from 0.01 to 0.90).

[45] We consider a profits tax rate of unity to be a limiting case, following Corriea et al. (2008).

[46] Schmitt-Grohe and Uribe (2004a) showed that with sticky prices the Ramsey problem cannot be written in terms of a single intertemporal implementability condition. Instead, the problem requires a sequence of intertemporal implementability conditions, one for each date and each state. For that reason we solve the model numerically using the Get Ramsey program of Levin and Lopez-Salido (2004) and Levin et al. (2005).

Three factors determine optimal inflation in the cash and credit goods model with the menu of taxes that we consider. The first is the monetary distortion, which pulls optimal inflation toward the Friedman rule. The second is price stickiness, which pulls optimal inflation toward zero. Without both consumption and wage taxes available to the fiscal authorities, the monetary authority cannot ignore price stability in setting its optimal policy. The absence of a consumption tax implies that consumer and producer prices are identical and optimal policy must trade off the Friedman and Calvo desiderata. Unlike these first two factors, the third "pull" on optimal inflation is not apparent from the preceding discussion. Inflation, by taxing nominal asset holdings, can provide an indirect tax on otherwise untaxed income. We will see the effects of this third pull on inflation when monopoly profits are less than fully taxed.[47]

The impact of these three "pulls" varies in our simulations, but three conclusions emerge. First, as is clear from the discussion, optimal monetary policy depends crucially on instruments available to the fiscal authorities. Second, price stickiness exerts a strong influence on optimal monetary policy. As Benigno and Woodford (2003) and Schmitt-Grohe and Uribe (2004a, 2005) find, even a relatively low degree of price stickiness restores the case for price stability. Both average inflation (or deflation) and inflation variability are optimally close to zero. Third, because taxing profits is not distortionary, the incentive to use inflation as an indirect tax on profits is surprisingly strong when τ_Γ, the tax rate on profits, is less than one.

Our aim in presenting these results is to illustrate the factors behind optimal policy, the interactions between monetary and fiscal policy, and the key results in the literature. We do not wish to emphasize particular quantitative results because the ultimate balance of the three pulls depends on details of model specification and auxiliary assumptions. For example, we use a cash and credit goods model as the source of the distortion arising from a nonzero interest rate, we assume the elasticity of substitution between the two goods is one, we adopt Calvo pricing with no indexation, and we do not include capital in our model so profits are pure rents.[48] None of these choices is innocuous and each is likely to affect our quantitative results.[49] Some of the results we present appear to be

[47] Here, as in Schmitt-Grohe and Uribe (2004a,b), the third pull arises from the Ramsey planner's incentive to use inflation to tax monopoly profits, which are a pure rent and would otherwise be untaxed. In Schmitt-Grohe and Uribe (2005), the incentive to use inflation to tax transfers, which are a rent to households, plays a similar role. In Schmitt-Grohe and Uribe (2010), foreign holdings of domestic money balances provide another target for the inflation tax.

[48] Schmitt-Grohe and Uribe (2005) include capital in their model and assume that profits and wage income are taxed at the same rate.

[49] For example, Burstein and Hellwig (2008) argue that models with Calvo pricing "substantially overstate" the welfare cost of price dispersion. According to their calibration of a menu cost model, relative price distortions do not contribute much (compared to the opportunity cost of holding money) when they quantify the welfare effects of inflation.

robust — most significantly the first two noted previously. Others are less so.[50] On the other hand, by using the same model, we are able to make consistent comparisons that are not otherwise possible because the existing literature uses a variety of models.

An additional reason for placing less emphasis on particular quantitative results is that we use a linear approximation to the model around a nonstochastic steady state. Chari, Christiano, and Kehoe (1995) provide examples of inaccuracies that can arise when doing so. Albanesi (2003) argues that concerns about the methods we use can be more serious because of the unit roots or near unit roots in the responses of key variable to shocks. On the other hand, both Benigno and Woodford (2006) and Schmitt-Grohe and Uribe (2004a) find that their log-linear approximations do not suffer from accuracy problems. Benigno and Woodford (2006) examine the model considered by Chari et al. (1995). They find that the numerical results they obtain using their linear-quadratic methods are quite close to those Chari et al. (1995) report based on more computationally intensive projection methods, but substantially different from those Chari et al. (1995) report based on log- linearization. Schmitt-Grohe and Uribe (2004a) address accuracy concerns by comparing the moments computed from exact solution of their model with flexible prices to those computed from a log-linear approximation. They find the differences are small, except that the approximate solution produces an inflation volatility that is about one percentage point too low. They cannot compute the exact solution of their model when prices are sticky but they compare the moments computed from a first-order approximation to the model with those computed from a second-order approximation in samples of 100 years. They argue that if the unit root behavior is a serious problem and over 100 years variables wander far from the point around which the model is approximated, then the errors are likely to be considerably larger in the moments computed from the second-order approximation. They find the results from the first- and second-order approximations are very close. Our reason for reporting moments computed from simulated samples of 200 quarterly observations is the hope of mitigating these problems.

We begin by considering the optimal choice of inflation and the tax rate on wage income when profits are fully taxed. The implications for optimal inflation and interest rates are summarized in Table 3 and Figures 7A and B. Not surprisingly, the Friedman rule is optimal when prices are flexible. The nominal interest rate is zero in every period so that both the average interest rate and its volatility are zero. Average inflation is approximately -1% per quarter, which is approximately minus one times the real interest rate (gross inflation in the nonstochastic steady state is equal to β). Unexpected

[50] For example, the incentive to use inflation to tax profits is robust, but the magnitude of steady-state inflation is not. We find positive inflation is optimal when profits are less than fully taxed. Schmitt-Grohe and Uribe (2004b) find that nominal interest rates are positive but that deflation (albeit less deflation than under the Friedman rule) is optimal unless the elasticity of substitution between the intermediate goods is lower than our benchmark value. When we consider a model similar to theirs, we replicate their results.

Table 3 Moments of policy variables in the cash and credit goods model

	Inflation	Nominal interest rate	Labor income tax rate	Debt/GDP
A. Benchmark specification				
Steady state	−0.002%	1.003%	14.83%	2.000
Volatility	0.0014%	0.361%	0.28%	0.071
B. Flexible prices				
Steady state	−1.005%	0.000%	15.183%	2.000
Volatility	1.976%	0.000%	0.000%	0.071

Notes: Inflation and nominal interest rates are in percent per quarter. The volatilities are standard deviations.

inflation is used actively as a tax on nominal assets when prices are flexible. As discussed above, the monetary authority uses surprise inflation as a lump-sum, state-contingent tax in response to adverse fiscal shocks. Inflation volatility is around 2%per quarter, which corresponds to about 8% annually because inflation is essentially serially uncorrelated.[51]

The Friedman rule is no longer optimal when prices are sticky. Deflation remains optimal, but introducing price stickiness raises the average inflation and interest rates above their Friedman rule values. As Benigno and Woodford (2003) and Schmitt-Grohe and Uribe (2004a, 2005) find, the pull toward price stability exerted by price stickiness is quite strong — a small degree of price stickiness is sufficient to bring both the average inflation rate and its volatility close to zero. For example, when α is 0.2, so that the average time between price changes is $1/0.8 = 1.25$ quarters, both average annual inflation and its volatility are essentially zero.[52]

Price stickiness also affects the optimal tax rate on labor income. The average wage tax rate (not shown) falls slightly as price stickiness increases. This effect is both unsurprising and small. As α rises, optimal inflation rises and greater use of the inflation tax corresponds to less reliance on wage taxes, but the change in the optimal tax rate on wages is small because the change in seigniorage is small. What is more striking, however, is the effect of α on the volatility of τ_w. When prices are flexible, optimal fiscal policy keeps both the interest rate and the tax rate on wages constant. As α increases,

[51] This volatility is consistent with the results in Schmitt-Grohe and Uribe (2004b) but is considerably smaller than the 20% volatility computed by Chari, Christiano, and Kehoe (1991). Schmitt-Grohe and Uribe (2004b) attribute this to differences in solution methods. Other differences in specification and calibration may also contribute to the difference.

[52] Chugh (2006) consideres a cash and credit goods model similar to ours and adds wage stickiness. He finds that when only wages are sticky, optimal price inflation volatility is similar to that when only prices are sticky. When wages are sticky, price volatility results in real wage volatility that has welfare costs that exceed the benefits of using surprise inflation as a fiscal shock absorber. Optimal policy then tries to keep real wages close to their equilibrium value.

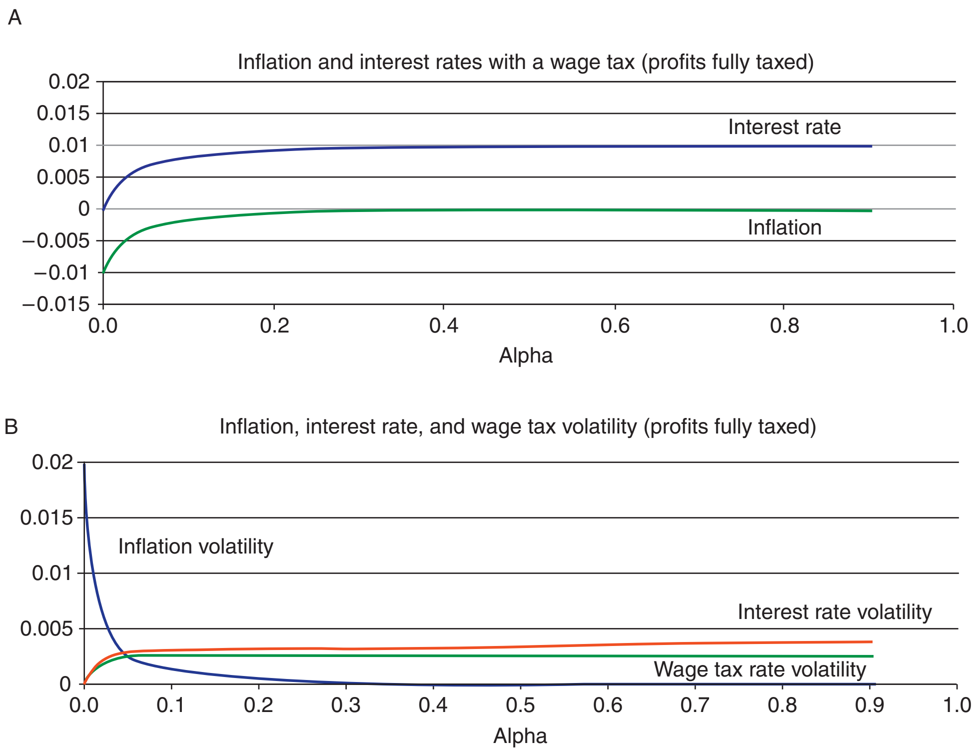

Figure 7 (A) Optimal inflation and interest rates in the cash and credit goods model, (B) optimal inflation and interest rate volatility in the cash and credit goods model.

optimal policy increases the volatility of both of these taxes as inflation volatility declines.

The results illustrate the trade-off (discussed earlier) between using surprise inflation as a fiscal shock absorber, which allows the authorities to stabilize the (distorting) tax rate on labor income, and price stability, which allows the authorities to reduce the costs of inflation associated with sticky prices. The results also show that the trade-off is clearly resolved in favor of price stability even with small values of α.[53]

When profits are not fully taxed, deflation is no longer optimal.[54] The incentive to use inflation to tax profits overcomes the pull toward the Friedman rule exerted by the

[53] These results are consistent with those in Schmitt-Grohe and Uribe (2004a, 2007).

[54] Changing the tax rate on profits changes average inflation but has essentially no effect on its volatility. Regardless of the tax rate, optimal inflation volatility quickly becomes negligible once even slight price stickiness is introduced. Optimal wage tax rate volatility is also essentially unaffected by changes in the tax rate on profits, rising quickly from zero with price flexibility to roughly 0.3% per quarter when price stickiness is introduced.

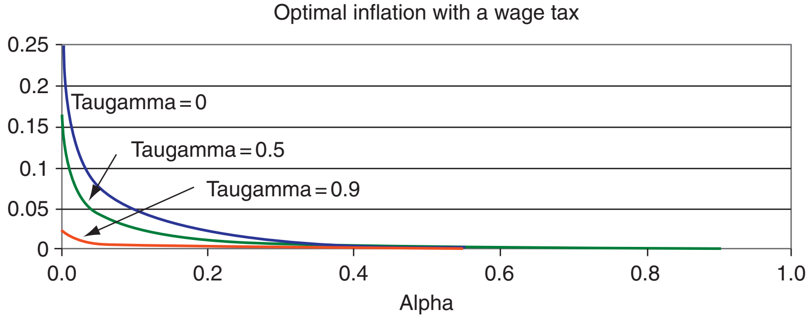

Figure 8 Optimal inflation in the cash and credit goods model when profits are not fully taxed.

interest rate distortion. The effects of the degree of price stickiness on optimal inflation are shown for three values of τ_Γ in Figure 8. When prices are flexible and profits are untaxed, the average inflation rate is extremely high (around 30% per quarter). Partially taxing profits brings the optimal inflation rate with flexible prices down significantly, but substantial inflation remains optimal. Even when τ_Γ is 90%, optimal annual inflation is about 10% when prices are flexible. Introducing price stickiness reduces optimal inflation. As α increases, price stability again becomes the clear goal of optimal monetary policy. Optimal inflation is positive but small and its volatility is near zero even with a moderate degree of price stickiness.[55]

The effect on optimal inflation of the incentive to tax profits is also apparent when we consider alternative values of the elasticity of substitution, σ. As we increase σ (decrease the markup over marginal cost), we reduce profits and the optimal inflation rate falls. For example, when prices are flexible and $\sigma = 100$, optimal annual inflation is just over 1%.

Another constraint on fiscal policy that we consider is that the fiscal authorities must tax all sources of income at the same rate; that is, we consider an income tax with $\tau_w = \tau_\Gamma = \tau_y$. This removes the incentive for the fiscal authority to use inflation to shift the burden of taxes from labor income to profits. Because profits and wages are received at the end of the period, inflation imposes a tax on both. The inflation tax and the income tax therefore have the same tax base. Relying on the inflation tax, however, would also distort the margin between cash and credit goods. As can be seem in Figure 9A and B, when prices are flexible the Friedman rule is optimal with an income tax.[56] As is the case with a wage tax, introducing even a small degree of price stickiness makes optimal

[55] Schmitt-Grohe and Uribe (2004b) discuss this effect with flexible prices. In their results, optimal inflation exceeds the Friedman rule but either deflation or inflation can be optimal, depending on the value of the markup. A similar effect arises in Schmitt-Grohe and Uribe (2005) where inflation is used as an indirect tax on transfers payments, which are pure rents in their model.

[56] Schmitt-Grohe and Uribe (2004b) note that the Friedman rule is optimal when the fiscal authorities must tax profits and wages at the same rate in their model with imperfect competition and flexible prices.

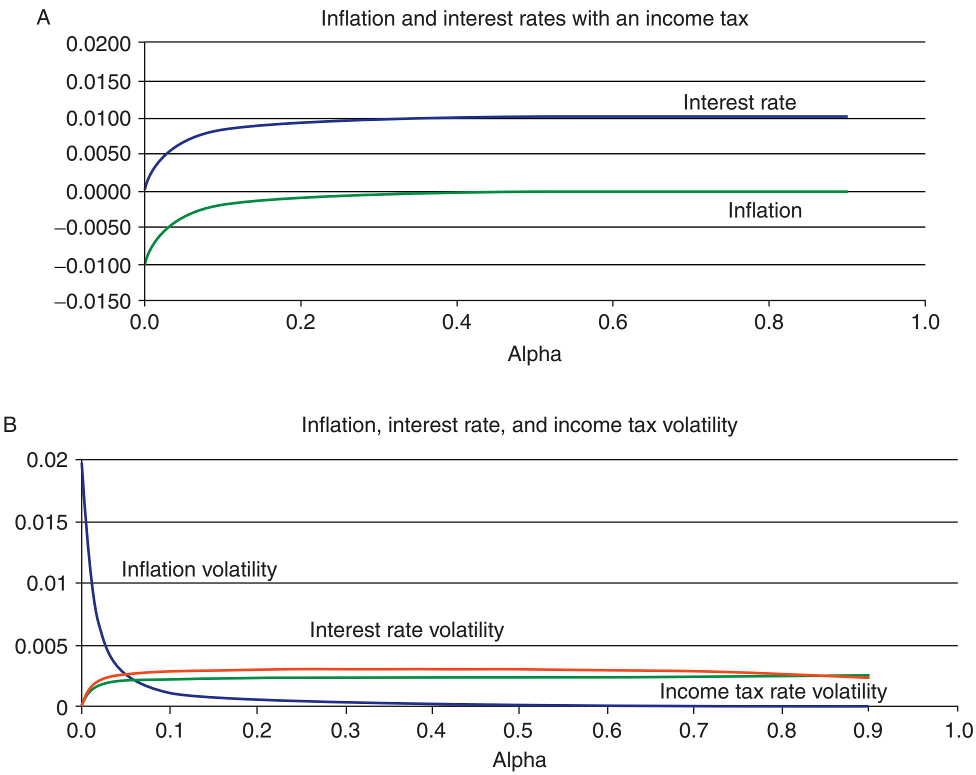

Figure 9 (A) Optimal inflation and interest rates in the cash and credit goods model, (B) optimal inflation and interest rate volatility in the cash and credit goods model.

inflation close to zero. As was the case when wages and profits were taxed at different rates, price stability emerges as the clear goal of optimal policy once price stickiness is introduced. Optimal inflation volatility declines sharply when price stickiness is introduced.[57]

3.5 Implementing optimal monetary and fiscal policy

The Ramsey solution to optimal policy problems does not provide a simple characterization of optimal policy. In the models we have considered, the optimal tax rate on labor income and the optimal interest rate are functions of all of the state variables of the model.[58] And some of these state variables; for example, lagged values of the

57 Tax rate volatility with an income tax is quite similar to that when wages and profits are taxed at different rates.

58 In our model with flexible prices and full taxation of profits, key parts of optimal policy can be stated simply: maintain a zero nominal interest rate and a constant labor tax rate at all dates and in all states. But that simple characterization is an incomplete description of optimal policy.

Lagrange multipliers associated with the constraints, are unobservable. The solutions therefore provide no specific advice to policy makers or answers to questions like whether optimal fiscal policy is Ricardian or non-Ricardian.

Schmitt-Grohe and Uribe (2007) optimize simple policy rules in a model with monopolistic competition, sticky prices, and capital accumulation; they introduce money into the model through CIA constraints for households and for firms' wage bill. They consider both an economy with lump-sum taxes and an economy in which the fiscal authorities levy distortionary taxes on labor income and capital income. The simple monetary and fiscal policy rules they examine differ from Eqs, (20) and (21) by including the deviation of output from its steady-state value in the interest rate rule

$$i_t = \rho m\ i_{t-1} + (1-\rho_m)[(\Pi^*/\beta) + \theta_m(\pi t - \pi^*) + \theta_y(y_t - \bar{y})] \qquad (20')$$

$$\tau_1 = \bar{\tau} + \theta_f(a_{t-1} - \bar{a}) \qquad (21')$$

where $a_t = (M_t + I_t Bt)/P_t$ is the real value of nominal government liabilities and τ_t is tax revenue. They compute the Ramsey solution as a benchmark to evaluate the solution to the model in which ρ_m, θ_m, θ_y, and θ_f are chosen to maximize welfare.

Several clear conclusions emerge:

1. Welfare under the optimized rules is virtually identical to welfare under the Ramsey solution.
2. Optimal fiscal policy is passive.
3. Interest rates should react strongly to inflation – the optimal value of θ_m is at the upper limit of their search. But, provided θ_m is sufficiently large to guarantee determinacy, welfare is relatively insensitive to θ_m.
4. Interest rates should not react to output – the optimal value of θ_y is either zero or very close to zero. Welfare is extremely sensitive to θ_y and strong reaction to the output gap is associated with significant welfare losses.

The intuition behind conclusion 4 is clear. In models like the one Schmitt-Grohe and Uribe (2007) consider, output fluctuations are driven largely by productivity shocks. The other source of uncertainty in their model is shocks to government purchases and these tend to account for relatively little of the variation in output.[59] Rotemberg and Woodford (1997) and others have shown that reducing deviations of output from its steady-state value are counterproductive when productivity shocks drive output fluctuations.

Schmitt-Grohe and Uribe (2007) offer useful intuition for why optimal fiscal policy is passive when the fiscal authority has access to lump-sum taxes. Under passive fiscal policy, the fiscal authorities adjust lump-sum taxes to assure fiscal solvency. Under an active fiscal rule, fiscal solvency is assured by unexpected variations in the price level that act as a lump-sum tax/subsidy on nominal asset holdings. With sticky prices, these

[59] See, for example, Canzoneri, Cumby, and Diba (2007).

price level movements result in distortions that reduce welfare. Because variations in lump-sum taxes do not result in welfare costs, optimal fiscal policy is passive.

The intuition with distorting taxes is less clear. Optimal policy trades off the distortions that arise from variations in the income tax against the distortions that arise from variations in the price level. The results discussed in Section 2.3 suggest that this trade-off is resoundingly resolved in favor of price stability so that optimal fiscal policy is passive even when taxes are distorting.

Schmitt-Grohe and Uribe (2005) use a larger model with additional frictions and compute optimal rules by minimizing the distance between the impulse responses generated by the model with the rules and those generated by the model with the Ramsey policies. Their results differ from those in Schmitt-Grohe and Uribe (2007) in several ways. Notably, monetary policy is passive. There are, however, some features of the results that we find disturbing. First, monetary policy reacts to wage inflation by reducing interest rates. Second, the value of θ_f is -0.06, so that taxes are reduced when liabilities exceed their steady-state value. As noted in Section 2, it is difficult to see why policymakers would seek actively to destabilize debt. The fiscal rule also includes a lagged tax term and the coefficient on that term is close to 2.0. Third, while the impulse responses of the endogenous variables to a productivity shock generated by the model with the optimized rules do a reasonable job in matching those generated by the model with Ramsey policies, the responses to the other shocks differ noticeably.

Benigno and Woodford (2003) take an alternative approach to determining optimal policy and optimal targeting rules for the authorities. Rather than searching for an instrument rule that yields outcomes close to those of the Ramsey policy, they consider a log-linear approximation to the Ramsey solution. They begin by deriving a quadratic loss function that approximates expected utility for the representative household. They then minimize that loss function subject to a set of linear constraints and obtain analytical rather than numerical results. In addition, they are able to use these analytical results to derive optimal targeting rules, that, when followed by the authorities, result in optimal responses to shocks. The rules are relationships among the target variables that do not depend on specific shocks. The targeting rules derived by Benigno and Woodford (2003) are

$$\begin{aligned} &\pi_t - a\pi_{t-1} + b(y_t - y_{t-1}) = 0 \\ &E_t\pi_{t+1} = 0 \end{aligned} \tag{46}$$

where a and b are functions of the model's parameters but do not depend on the specification of the disturbances. This pair of targeting rules does not directly imply a unique assignment of responsibilities for policymakers. Benigno and Woodford (2003) suggested one way that the monetary and fiscal authorities can be assigned separate responsibilities that lead to the two rules being satisfied. The assignment of responsibilities needs to be coordinated but the coordination of period-to-period policy actions do not need to be coordinated.[60]

3.6 Can Ramsey optimal policies be implemented?

The literature discussed thus far and the model we use for our calculations assume that the monetary and fiscal authorities can commit to the optimal policies.[61] Beginning with Lucas and Stokey (1983), a series of papers have asked if optimal policy can be implemented when the authorities are not assumed to be able to commit credibly to future policy actions. Lucas and Stokey (1983) consider the problem in an economy with neither capital nor money and with long-term, state-contingent real government debt. The dynamic consistency problem in their model arises because the government has an ex post incentive to manipulate the value of the existing debt through real interest rate changes. They show that a government can remove its successor's incentive to deviate from the previously optimal Ramsey policy using debt restructuring to leave its successor with the right maturity structure of the debt. Lucas and Stokey (1983) express doubt, however, that the dynamic consistency problem could be avoided in an economy with money. The incentive is to use inflation to tax existing nominal assets and avoid distorting taxes on labor income.

Persson, Persson, and Svensson (1987, 2006) extend Lucas and Stokey's (1983) analysis by offering a solution to the dynamic consistency problem with nonzero initial nominal government liabilities. Their solution involves the government holding nominal assets equal to the monetary base so that the government's net nominal liabilities are zero. The intuition behind this solution is that the net revenue gain to surprise inflation is zero, removing the incentive to deviate from the previously optimal Ramsey policy.

Calvo and Obstfeld (1990) point out that zero net nominal government liabilities is not sufficient to make the optimal policy under commitment dynamically consistent under discretion. They show that the government can use a combination of surprise interest rate change (which alters the balance of nominal assets and liabilities) and a surprise price level change to reduce distortionary taxes and raise welfare.

Alvarez, Kehoe, and Neumeyer (2004) and Persson et al. (2006) offer two alternative solutions to the problem raised by Calvo and Obstfeld (1990). Alvarez et al. (2004) restrict the utility function to make the Friedman rule optimal. With the nominal interest rate at zero in every state and every period, the incentive to use surprise interest rate changes is removed and the Persson et al. (1987) idea of offsetting nominal government liabilities with nominal government assets solves the dynamic consistency problem. Persson et al. (2006) introduce direct costs of unexpected inflation by assuming that

[60] Benigno and Woodford (2007) derive optimal monetary policy rules that are robust to alternative assumptions about the fiscal policy regime.

[61] Benigno and Woodford (2003) is a notable exception. Their approach requires limited commitment — the authorities need only one-period-ahead commitment to policies that influence expectations in order to implement Ramsey policies.

utility depends on beginning-of-period rather than end-of-period real balances but do not restrict preferences to make the Friedman rule optimal. They show that introducing this cost can result in an optimum in which the marginal cost of reducing real balances just equals the marginal benefit to the government of the revenue generated. Each government can then choose a structure of liabilities that provides its successor with the incentive to generate the surprise inflation consistent with the previously optimal Ramsey policy. The required structure of liabilities is, however, more complex than the simple rule of setting net nominal government liabilities to zero.

Albanesi (2005) also introduces direct costs of inflation. She introduces heterogenous agents into the cash and credit goods model in which agents with lower earning potential hold more cash as a fraction of expenditures than do agents with higher earning potential. Inflation then imposes a differential tax on the two types of agents. She shows that Ramsey policy will depart from the Friedman rule under commitment except for specific weights on the utilities of the two agents. Optimal policy can be made dynamically consistent in her model even when nominal debt is nonzero, but each government needs to leave its successor with the right distribution of nominal debt in addition to the right debt maturity structure.

3.7 Where are we now?

In the 40 years since Friedman's (1969) paper *Optimal Quantity of Money*, a substantial literature has developed viewing monetary policy in an optimal taxation framework. And since the contribution of Phelps (1973), characterizing optimal monetary policy has been viewed as a second-best problem in which inflation and other distorting taxes are jointly determined to fund government spending and to address other distortions in the economy, including the distortion that arises due to the holding of money balances. Optimal monetary policy, the choice of an optimal path for inflation, is inexorably tied to fiscal policy. The set of fiscal instruments available to the authorities along with the distortions in the economy determine optimal monetary policy.

Chari et al. (1991), using the Lucas-Stokey (1983) cash and credit goods model that became the workhorse model in this literature, show that when the government issues only nominal debt and prices are flexible, Friedman's rule (expected deflation and a zero nominal interest rate) is optimal. In addition, unexpected inflation is optimally used to absorb fiscal shocks, which stabilizes other tax rates. In a calibrated version of their model, they show that optimal inflation is extremely volatile.

Correia et al. (2008) show that, when the menu of taxes available to the fiscal authorities is sufficiently rich, introducing sticky prices into the cash and credit goods model is irrelevant for the conduct of monetary policy. By manipulating the tax rate on consumption goods, the fiscal authorities are able to keep producer prices constant (eliminating any costs of price changes) while consumer prices behave as they would with price flexibility, and with the downward trend required by the Friedman rule.

Taxes, however, exhibit two problematic features: consumption and wage taxes are highly volatile and asymptotically wages are fully taxed and consumption goods are fully subsidized. The trends in the tax rates are needed to accommodate the zero trend in producer prices and the negative trend in consumer prices.

The highly volatile inflation that characterizes Ramsey policy when prices are flexible or when the menu of taxes available to the fiscal authorities is sufficiently rich arises because the government is assumed to be unable to issue state-contingent debt and issues only nominal debt. Unexpected inflation is then used to offset this market incompleteness by making nominal debt state contingent in real terms. The assumption that the government cannot issue state-contingent debt is reasonable because of the difficulty in fully specifying contingencies — it is not surprising that we do not observe state-contingent government debt. But at the same time, one might ask whether it is reasonable to assume that governments can make tax rates and inflation state contingent. If governments are unable to write state-contingent debt contracts, why are they able to set state-contingent tax rates and inflation rates? Do political frictions render the kind of highly flexible use of fiscal tools that characterizes the Ramsey policy unfeasible? If so, what would optimal policy look like if it took account of those frictions? Our discussion has followed the literature by focusing on a limited menu of tax instruments. But this begs the question of why the authorities would not use both consumption and labor taxes. Would adding political frictionsprovide a way to allow authorities to use a broader range of tax instruments while avoiding the unappealing features previously discussed? Building political frictions into optimal taxation problems may yield significantly different optimal policies.

When a less complete menu of taxes is available to the fiscal authorities, the optimal policy problem involves a trade-off when prices are sticky. Using unexpected inflation as a lump-sum tax/subsidy on nominal assets allows the fiscal authority to avoid the costs associated with variability of the distorting tax on labor income. But inflation variability increases the distortion and corresponding costs that arise because of sticky prices. The trade-off is resolved in favor of price stability even with small degrees of price stickiness. Introducing price stickiness implies that both average inflation and its volatility are very close to zero. The primacy of price stability as the goal of monetary policy appears to be robust to model variations.

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