FLUCTUATING MACRO POLICIES AND THE FISCAL THEORY

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ABSTRACT. This paper estimates regime-switching rules for monetary policy and tax policy over the post-war period in the United States and imposes the estimated policy process on a calibrated dynamic stochastic general equilibrium model with nominal rigidities. Decision rules are locally unique and produce a stationary rational expectations equilibrium in which (lump-sum) tax shocks always affect output and inflation. Tax non-neutralities in the model arise solely through the mechanism articulated by the fiscal theory of the price level. The paper quantifies that mechanism and finds it to be important in U.S. data, reconciling a popular class of monetary models with the evidence that tax shocks have substantial impacts. Because long-run policy behavior determines existence and uniqueness of equilibrium, in a regime-switching environment more accurate qualitative inferences can be gleaned from full-sample information than by conditioning on policy regime.

1. INTRODUCTION

A popular approach to analyzing macroeconomic policy posits simple policy rules and characterizes how alternative policy specifications perform in dynamic stochastic general equilibrium models. This line of work has shown that simple rules seem to explain observed policy choices quite well and that those rules produce desirable outcomes in popular classes of dynamic monetary models. Most of the work makes convenient assumptions that allow monetary and fiscal rules to be studied separately. Because these assumptions are questionable, it has long been known that the resulting conclusions could be misleading. Recent work, particularly the fiscal theory of the price level, emphasizes that assumptions about how monetary and fiscal policies interaction can be important.

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Research on policy interactions has spawned a number of results that have become part of the standard reasoning about macroeconomic policy: (1) an active monetary policy that raises the nominal interest rate more than one-for-one with inflation—the "Taylor principle"—is necessary for stability of the economy [Taylor (1993)]; (2) the Taylor principle delivers good economic performance in widely used models [Rotemberg and Woodford (1997), Schmitt-Grohe and Uribe (2004)]; (3) high and variable inflation rates may be due to failure of central banks to obey the Taylor principle, leaving the price level undetermined and subject to self-fulfilling expectations [Clarida, Gali, and Gertler (2000), Lubik and Schorfheide (2003)]; (4) the combination of active monetary policy and passive tax policy insulates the economy from aggregate demand disturbances, such as those arising from tax-debt policies [Leeper (1991)].

As with earlier work that focused on monetary or fiscal rules separately, the derivation of these results rests on a number of assumptions of convenience that simplify the nature of monetary and fiscal policy interactions. The authors usually note that different sets of equally plausible assumptions may lead to qualitatively different outcomes. For example, there is now a growing literature providing counter-examples to the desirability of the Taylor principle [Benhabib and Farmer (2000), Benhabib, Schmitt-Grohe, and Uribe (2001a,b, 2002), Zanna (2003)].

Perhaps the least plausible assumption in this work is that policy regime is fixed. This implies that agents always expect the current policy regime to last forever; regime change, if it occurs, comes as a complete surprise. Of course, a major branch of the applied side of the literature consists of identifying periods of different policy regimes [Taylor (1999a, 2000), Clarida, Gali, and Gertler (2000), Auerbach (2002), Lubik and Schorfheide (2003), Sala (2004), Favero and Monacelli (2005)]. But, as Cooley, LeRoy, and Raymon (1984) argue, it makes little sense to assume policy makers are contemplating regime change when agents put zero probability on this event. Despite the empirical evidence and Cooley, LeRoy, and Raymon's compelling logic, there is little modeling of environments where recurring regime change is stochastic and the objects that change are the rules governing how policy authorities respond to the economy.[1]

Davig and Leeper (2005) show the consequences of regime switching for determinacy of equilibrium in a simpler context in which lump-sum taxes passively adjust to satisfy the government budget constraint. When coefficients of a Taylor (1993) rule

[1]Some work considers recurring regime switching in exogenous processes, including exogenously evolving policy variables [Andolfatto and Gomme (2003), Davig (2003, 2004), Leeper and Zha (2003), Schorfheide (2005)]. There have also been efforts to incorporate one-time regime changes into general equilibrium models of the fiscal theory [Sims (1997), Woodford (1998b), Loyo (1999), Mackowiak (2002), Daniel (2003), Weil (2003)].

evolve stochastically, the region of determinacy can expand dramatically relative to a constant-parameter specification. That paper also shows in analytically tractable environments that cross-regime spillovers can change the impacts of exogenous disturbances in quantitatively important ways.

This paper extends Davig and Leeper's (2005) analysis to consider fiscal as well as monetary regime switching. It aims to bring the applied and theoretical lines of this literature closer together by studying a model with a simple, but empirically plausible, specification of regime changes. We estimate Markov-switching rules for monetary and fiscal policy. Monetary policy obeys a Taylor rule that makes the nominal interest rate depend on inflation and the output gap; fiscal policy adjusts taxes as a function of government debt and other variables. All the parameters of the rules, including the error variances, evolve according to a Markov process. The estimated policy process leads to a locally unique and stationary equilibrium in a calibrated dynamic stochastic general equilibrium model with nominal rigidities.

There are five main findings.

First, the estimates uncover periods of active monetary/passive fiscal behavior, the policy mix typically assumed to prevail in monetary studies; there are also episodes of passive monetary/active fiscal behavior, the mix associated with the fiscal theory of the price level.[2] Remaining periods combine passive monetary with passive fiscal policy or active monetary with active fiscal behavior. Identification of estimated switching policy rules is corroborated by connecting estimated regime changes to narrative accounts of policy behavior.

Second, post-war U.S. data can be modeled as a single, locally unique equilibrium. While our empirical results are largely consistent with existing estimates from fixed-regime models, we avoid the necessary implication of those models that the economy lurched unexpectedly among periods of indeterminacy (passive/passive), nonexistence of equilibrium (active/active), or unique equilibria with completely different characteristics (active monetary/passive fiscal or passive monetary/active fiscal) [see, for example, Clarida, Gali, and Gertler (2000), Lubik and Schorfheide (2003), or Sala (2004) for such interpretations]. Instead, in a regime-switching setup those periods are merely alternative realizations of the state vector over which agents' decision rules are defined. Consequently, in a switching model the policy episodes have strikingly

[2]We apply the terminology in Leeper (1991). *Active monetary policy* arises when the response of the nominal interest rate is more than one-for-one to inflation and *passive monetary policy* occurs when that response is less than one-for-one. Analogously, *passive fiscal policy* occurs when the response of taxes to debt exceeds the real interest rate and *active fiscal policy* occurs when taxes do not respond sufficiently to debt to cover real interest payments. In many models, including the one studied below, a unique stationary equilibrium requires one active and one passive policy.

different implications. For example, an empirical finding that over some sub-period monetary policy has been active and fiscal policy has been passive is perfectly consistent with there being important impacts from (lump-sum) tax shocks. A finding that both monetary and fiscal behavior have been passive need not imply the equilibrium is indeterminate. And the economy can temporarily experience active/active policies without dire economic consequences.

Third, the fiscal theory of the price level is always operative. Shocks to (lump-sum) taxes always affect aggregate demand, even when the rules in place at a given moment would suggest that Ricardian equivalence should hold if regime were fixed. The fiscal theory is operating whenever economic agents believe it is possible for fiscal policy to become active. Then a cut in current taxes, financed by sales of nominal government debt, does not generate an expectation that future taxes will rise by at least enough to service the new debt. The tax reduction leaves households feeling wealthier, at initial prices and interest rates, and they perceive they can raise their consumption paths.[3] When nominal rigidities are present, the expansion in demand for goods raises output and inflation. Davig, Leeper, and Chung (2004) show that in a regime-switching environment, the fiscal theory is always at work, as long as agents believe there is a positive probability of moving to a regime with active fiscal policy.

Fourth, the fiscal theory mechanism is quantitatively significant in U.S. data, according to the model.[4] Through that mechanism alone, a surprise transitory tax cut of \$1 raises the discounted present value of output in the long run by between 76 cents and \$1.02, depending on which policy regime the simulation conditions. A temporary tax cut of 2 percent of output increases the long-run price level by between 1.2 percent and 6.7 percent, conditional on remaining in a given monetary-fiscal regime. Similar impacts arise from an anticipated cut in taxes. Stochastic simulations that draw from the estimated distribution for policy regime imply that the 80^{th} percentile for the output multiplier ranges from 43 cents to \$1.36 after 6 years, while a tax cut of 2 percent of output raises the price level between 0.53 to 2.27 percent after 6 years. These numbers suggest the fiscal theory mechanism may be quite potent in U.S. data, helping to reconcile a popular class of DSGE models for monetary policy with the empirical evidence that tax disturbances have important impacts [Blanchard and Perotti (2002), Mountford and Uhlig (2002), Perotti (2004)].

[3]See Leeper (1991), Woodford (1994, 1995), Sims (1994), and Cochrane (1999, 2001).

[4]Cochrane (1999) interprets U.S. inflation in light of the fiscal theory and Woodford (2001) points to particular historical episodes when the fiscal theory might have been relevant. But neither author claims to have found joint monetary-fiscal behavior consistent with the fiscal theory and neither author tries to quantify the fiscal theory mechanism.

Fifth, viewing time series as generated by recurring regime change alters how those time series should be interpreted. Many estimates of policy rules use *a priori* information about policy behavior in order to condition on sub-samples in which a particular regime prevailed. This procedure can obtain accurate estimates of policy parameters and the impacts of policy disturbances. But embedding the estimated rules in fixed-regime DSGE models can lead to seriously misleading qualitative inferences when a regime-switching environment generates the data. Because long-run policy behavior determines the qualitative features of data, more accurate inferences can be gleaned from full-sample information than by conditioning on regime.

Taken together, the paper's findings lead to a fundamental reassessment of results (1)-(4) that guide macro policy research. The findings also lead us to argue that to understand macroeconomic policy effects, it is essential to model policy regimes (or rules) as governed by a stochastic process over which agents form expectations. This argument puts on the table a new interpretation of macro policies and their impacts.[5]

2. Identification and Estimation of Policy Rules

We seek empirical characterizations of policy behavior that use simple rules of the kind appearing in the policy literature, but allow for recurring changes in regime. Monetary and tax regimes can switch independently of each other. This section reports maximum likelihood estimates of policy rules whose parameters evolve according to a hidden Markov chain, as in Hamilton (1989) and Kim and Nelson (1999).

Estimates of simple interest rate rules for monetary policy and tax rules for fiscal policy are plagued by identification problems because other omnipresent equilibrium conditions involve similar variables. An empirical relationship that links a short-term nominal interest rate to inflation and some measure of output might be capturing monetary policy behavior or it might simply reflect the correlations that a Fisher equation induces among the nominal rate, the real rate, and expected inflation. Similarly, a regression of taxes on lagged debt might describe how fiscal authorities raise taxes in response to increases in government indebtedness or it might arise from the positive correlation that the government budget constraint creates between the value of debt and expected future primary surpluses.

[5]The table is pretty full. Included among purely monetary interpretations are narratives [DeLong (1997), Mayer (1998), Romer and Romer (2004)], fixed regime [Orphanides (2003a)], permanent regime change [Clarida, Gali, and Gertler (2000), Lubik and Schorfheide (2003)], adaptive learning [Cogley and Sargent (2005b, 2002), Primiceri (2004), Sargent, Williams, and Zha (2004)], model uncertainty [Cogley and Sargent (2005a)], and regime-switching identified VARs [Sims and Zha (2006)]. Work that integrates monetary and fiscal policy includes Leeper and Sims (1994), Romer and Romer (1994), and Sala (2004).

These problems are particularly acute in single-equation regressions that assume policy follows simple rules with constant coefficients: nothing distinguishes a "policy rule" from some other equilibrium condition. Positing that policy behavior shifts discretely, as we do in our estimated policy rules and in the subsequent theory, can help to distinguish policy behavior from the other equilibrium conditions, which would not be expected to exhibit time variation that coincides with policy shifts.[6] A key step in identifying regime-switching policy rules corroborates the timing and nature of estimated regime changes with extra-sample evidence from other studies of policy behavior. This section also reports that evidence.

2.1. **Specifications.** For monetary policy, we estimate a standard Taylor (1993) specification, which Rotemberg and Woodford (1999) have shown is nearly optimal in the class of models we consider in section 3. The rule makes the nominal interest rate, r_t, depend only on inflation, π_t, and the output gap, x_t :

$$r_t = \alpha_0(S_t^M) + \alpha_\pi(S_t^M)\pi_t + \alpha_x(S_t^M)x_t + \sigma_R(S_t^M)\varepsilon_t^r, \tag{1}$$

where S_t^M is the monetary policy regime and $\varepsilon_t^r \sim N(0, \sigma_r^2)$. Regime evolves according to a Markov chain with transition matrix P^M. r and π are net rates. We allow for four states, with the parameters restricted to take only two sets of values, while the variance may take four different values. P^M is a 4×4 matrix.[7]

Unlike monetary policy, there is no widely accepted specification for fiscal policy.[8] We model some of the complexity of tax policy with a rule that allows for the revenue impacts of automatic stabilizers, some degree of pay-as-you-go spending, and a response to the state of government indebtedness. The rule links revenues net of transfer payments, τ_t, to current government purchases, g_t, the output gap, and debt held by the public, b_{t-1}. The specification is:

$$\tau_t = \gamma_0(S_t^F) + \gamma_b(S_t^F)b_{t-1} + \gamma_x(S_t^F)x_t + \gamma_g(S_t^F)g_t + \sigma_\tau(S_t^F)\varepsilon_t^\tau, \tag{2}$$

where S_t^F is the fiscal policy regime, which obeys a Markov chain with transition matrix P^F, for the two fiscal states, and $\varepsilon_t^\tau \sim N(0, \sigma_\tau^2)$. Both (1) and (2) allow for

[6] See Beyer and Farmer (2005) for a related discussion.

[7] Ireland (2001), Leeper and Zha (2001), Leeper and Roush (2003), and Sims and Zha (2006) argue that allowing money growth to enter the monetary policy rule is important for identifying policy behavior. To keep to a specification that is comparable to the Taylor rule literature, we exclude money growth.

[8] Examples of estimated fiscal rules include Bohn (1998), Taylor (2000), Fatas and Mihov (2001), Auerbach (2003), Cohen and Follette (2003), Ballabriga and Martinez-Mongay (2004), and Claeys (2004).

heteroskedastic errors, which Sims and Zha (2006) emphasize are essential for fitting U.S. time series.

Let $S_t = (S_t^M, S_t^F)$ denote the joint monetary/fiscal policy state. The joint distribution of policy regimes evolves according to a Markov chain with transition matrix $P = P^M \otimes P^F$, whose typical element is $p_{ij} = \Pr[S_t = j \,|S_{t-1} = i]$, where $\sum_j p_{ij} = 1$. With independent switching, the joint policy process has eight states.

2.2. **Estimation Results.** We use quarterly U.S. data from 1948:2 to 2004:1. To obtain estimates of (1) that resemble those from the Taylor rule literature, we define π_t to be the inflation rate over the past four quarters. Similarly, estimates of (2) use the average debt-output ratio over the previous four quarters as a measure of b_{t-1}.

The nominal interest rate is the three-month Treasury bill rate in the secondary market. Inflation is the log difference in the GDP deflator. The output gap is the log deviation of real GDP from the Congressional Budget Office's measure of potential real GDP. All fiscal variables are for the federal government only. τ is federal tax receipts net of total federal transfer payments as a share of GDP, b is the Federal Reserve Bank of Dallas' market value of gross marketable federal debt held by the public as a share of GDP, and g is federal government consumption plus investment expenditures as a share of GDP. All variables are converted to quarterly values.

Parameter estimates are reported in tables 1 and 2 (standard errors in parentheses) and estimated transition matrices are in table 3.[9]

Associated with each set of monetary policy parameters is a high- and a low-variance state.[10] Monetary policy behavior breaks into periods when it responds strongly to inflation (active policy) and periods when it does not (passive policy). In the active, volatile periods, the standard deviation is 3.7 times higher than in the active, docile periods; in passive periods, the standard deviations differ by a factor of seven. Passive regimes respond twice as strongly to the output gap, which is consistent with the Fed paying relatively less attention to inflation stabilization. There are also important differences in duration of regime. Active regimes last about 15 quarters each, on average, while the duration of the docile passive regime is over 22 quarters; the volatile passive regime is most transient, with a duration of 11.6 quarters.

[9]To follow existing empirical work on simple policy rules, the paper does not estimate the rules as parts of a fully specified model. We are reassured in doing this by the model-based estimates of Ireland (2001) and Lubik and Schorfheide (2003), which are very close to single-equation estimates of Taylor rules. It is noteworthy, though, that in an identified switching VAR, Sims and Zha (2006) conclude that monetary policy was consistently active since 1960; they do not consider fiscal behavior and their switching specification is more restricted than ours along some dimensions.

[10]We include a dummy variable to absorb the variability in interest rates induced by credit controls in the second and third quarters of 1980. See Schreft (1990) for a detailed account of those controls.

Tax policies fluctuate between responding by more than the quarterly real interest rate to debt (passive) and responding negatively to debt (active). The active policy is what one would expect over the business cycle, with revenues and debt covarying negatively. Active policy reacts strongly to government spending, though by less than one-to-one, while passive policy reacts more weakly. In both regimes taxes rise systematically and strongly with the output gap, as one would expect from built-in stabilizers in the tax system. A stronger response to output under passive policy is consistent with active policy pursuing countercyclical objectives more vigorously.

2.3. **Plausibility of Estimates.** We consider several checks on the plausibility of the estimated rules. First, are the estimates reasonable on *a priori* grounds? We think they are, as the rules fluctuate between theoretically interpretable regimes. Monetary policy fluctuates between periods when it is active, satisfying the Taylor principle ($\alpha_\pi > 1$), and periods when it is passive ($\alpha_\pi < 1$). Passive tax policy responds to debt by a coefficient that exceeds most estimates of the quarterly real interest rate (and by more than the calibrated real rate in the DSGE model below), while active tax policy lowers taxes when debt is high.

Second, how well do the estimated equations track the actual paths of the interest rate and taxes? We use the estimates of equations (1) and (2), weighted by the estimated regime probabilities, to predict the time paths of the short-term nominal interest rate, r, and the ratio of tax revenues to output, τ, treating all explanatory variables as evolving exogenously. The predicted—using smoothed and filtered probabilities—and actual paths of r and τ appear in figures 1 and 2. These fits are easily comparable to those reported by, for example, Taylor (1999a) for monetary policy.[11] The interest-rate equation goes off track in the 1950s, suggesting that that period might constitute a third distinct regime, but in three-regime specifications the response of policy to output was negative. The tax rule tracks the revenue-output ratio extremely well, except in the last year or so when revenues dropped precipitously.

2.4. **Corroborating Evidence: Individual Policy Processes.** A third check on the plausibility of the estimates, which is a critical step in identifying policy behavior, asks whether the periods estimated to be active and passive correspond with narrative

[11]Orphanides (2003b) argues that the poor U.S. inflation performance from 1965-1979 was due to a strong policy response to poor estimates of the output gap available at the time, rather than a weak response to inflation. Using real-time data on the gap and inflation, he claims the fit of a conventional Taylor rule specification is much improved when real-time data are used rather recent vintage data. Orphanides (2003a) extends this argument to the 1950s. The fit of our switching regression for monetary policy is far superior to Orphanides's over the 1960:2-1966:4 period, yet our results label this as a period of passive monetary policy.

accounts of policy history.[12] The estimated marginal probabilities of the monetary and fiscal states are plotted in figures 3 and 4. All probabilities reported are at time t, conditional on information available at $t-1$.

Figure 3 reports that, except for a brief active period in 1959-60, monetary policy was passive from 1948 until the Fed changed operating procedures October 1979 and policy became active. Monetary policy was consistently active except immediately after the two recessions in 1991 and 2001. For extended periods during the so-called "jobless recoveries," monetary policy continued to be less responsive to inflation for two or more years after the official troughs of the downturns. The passive episode in 1991 became active when the Fed launched its preemptive strike against inflation in 1994.

These results are broadly consistent with previous findings. From the beginning of the sample until the Treasury Accord of March 1951, Federal Reserve policy supported high bond prices to the exclusion of targeting inflation, an extreme form of passive monetary policy. Through the Korean War, monetary policy largely accommodated the financing needs of fiscal policy [Ohanian (1997) and Woodford (2001)]. Romer and Romer (2002) offer narrative evidence that Fed objectives and views about the economy in the 1950s were very much like those in the 1990s, particularly in its overarching concern about inflation. But Romer and Romer (2002, p. 123) quote Chairman William McChesney Martin's congressional testimony, in which he explained that "the 1957-58 recession was a direct result of letting inflation get substantially ahead of us." The Romers also mention that FOMC "members felt they had not reacted soon enough in 1955 [to offset the burst of inflation]" (p. 122). To buttress their narrative case, the Romers estimate a forward-looking Taylor rule from 1952:1-1958:4. They conclude that policy was active: the response of the interest rate to inflation was 1.178 with a standard error of 0.876. Our estimate of this response coefficient in passive regimes is 0.522, which is less than one standard error below the Romers' point estimate. The Fed might well have intended to be vigilant against inflation, but it appears not to have acted to prevent the 1955 inflation. The brief burst of active monetary policy late in 1959 and early in 1960 is consistent with the Romers' (2002) finding that the Fed raised the real interest rate in this period to combat inflation. From 1960-1979, monetary policy responded weakly to inflation, while since the mid-1980s the Fed has reacted strongly to inflation, a pattern found in many studies [Taylor (1999a), Clarida, Gali, and Gertler (2000), Romer and Romer (2002) and Lubik and Schorfheide (2003)].

[12]This draws on Pechman (1987), Poterba (1994), Stein (1996), Steuerle (2002), Romer and Romer (2004), and Yang (2004).

The estimates of passive monetary policy behavior following the 1991 and 2001 recessions are likely to conflict with some readers' priors. Other evidence, however, corroborates the estimates. As early as March 1993, after the federal funds rate had been at 3 percent for several months, during policy deliberations Governors Angell, LaWare, and Mullins expressed concern that the Fed was keeping the rate low for too long. Angell warned that "our progress to get inflation down low enough so it [isn't a factor affecting] any business decision is now in jeopardy" (p. 30) [Board of Governors of the Federal Reserve System, (1993b)]. At that March FOMC meeting, Governors Angell and Lindsey dissented on the vote to maintain the funds rate at 3 percent. Six months later, Mullins analogized 1993 to the 1970s as another "period in which perhaps short rates weren't appropriately set to track inflation" (p. 11) [Board of Governors of the Federal Reserve System, (1993a)].

More recently, close observers of the Fed have expressed similar concerns, citing the rapid growth in liquidity in 2003 and 2004 and the exceptionally low real interest rates since 2001 [Unsigned (2005a,b)]. Financial economists list unusually low interest rates as an important factor behind the spectacular growth in household and corporate debt in recent years [Unsigned (2002) and Roach (2004)]. These sentiments about monetary policy behavior in the early 1990s and 2000s are consistent with our estimates that the Fed responded only weakly to inflation in those periods.

Estimates of the tax rule in (2) reveal substantially more regime instability than for monetary policy. Over the post-war period, there were 12 fiscal regime changes, with tax policy spending 55 percent of the time in the active regime. Figure 4 shows that the model associates tax policy with regimes that accord well with narrative histories. Fiscal policy was active in the beginning of the sample. Despite an extremely high level of debt from World War Two expenditures, Congress overrode President Truman's veto in early 1948 and cut taxes. Although, as Stein (1996) recounts the history, legislators argued that cutting taxes would reduce the debt, the debt-GDP ratio rose while revenues as a share of GDP fell. In 1950 and 1951 policy became passive, as taxes were increased and excess profits taxes were extended into 1953 to finance the Korean War, consistent with the budget-balancing goals of both the Truman and the Eisenhower Administrations. From the mid-50s, through the Kennedy tax cut of 1964, and into the second half of the 1960s, fiscal policy was active, paying little attention to debt. There followed a period of about 15 years when fiscal policy fluctuated in its degree of concern about debt relative to economic conditions.

President Carter cut taxes to stimulate the economy in early 1979, initiating a period of active fiscal policy that extended through the Reagan Administration's Economic Recovery Plan of 1981. By the mid-1980s, the probability of passive tax policy

increased as legislation was passed in 1982 and 1984 to raise revenues in response to the rapidly increasing debt-output ratio. Following President Clinton's tax hike in 1993, fiscal policy switched to being passive through the 2001 tax cut. President Bush's tax reductions in 2002 and 2003 made fiscal policy active again.[13]

Favero and Monacelli (2005) estimate switching regressions similar to (1) and (2) and also find that monetary policy was passive from 1961 to 1979. In contrast to our results, they do not detect any tendency to return to passive policy following the 1991 and 2001 recessions, though they estimate one regime, which emerges from 1985:2-2000:4 and 2002:2-2002:4, in the monetary policy response to inflation is exactly unity. Their estimates of fiscal policy are not directly comparable to ours because Favero and Monacelli use the net-of-interest deficit as the policy variable, which confounds spending and tax policies. Like us, they find that fiscal policy is more unstable than monetary policy.[14] Our findings are also consistent with the time-varying monetary policy rule estimates of Kim and Nelson (2004). They find that the response of monetary policy to inflation is not different from unity in the 1970s and the 1990s.

2.5. **Corroborating Evidence: Joint Policy Process.** It is convenient, and does no violence to the qualitative predictions of the theory, to aggregate the four monetary states to two states. We aggregate the high- and low-variance states for both the active and the passive regimes, weighted by the regimes' ergodic probabilities. An analogous transformation is applied to the estimated variances. The resulting transition matrix is

$$P^M = \begin{bmatrix} .9505 & .0495 \\ .0175 & .9825 \end{bmatrix} \tag{3}$$

and variances are $\sigma_R^2(S_t = Active) = 4.0576e{-}6$ and $\sigma_R^2(S_t = Passive) = 1.8002e{-}5$. Combining this transition matrix with the one estimated for fiscal policy yields the

[13]The negative response of taxes to debt in the active fiscal regime might be regarded as perverse. A negative correlation arises naturally over the business cycle, as recessions automatically lower revenues and raise debt. Two active fiscal regimes, the late 1940s and 1973:4-1975:1, almost exactly coincide with the cycle. But there are extended periods of active behavior, which include but do not coincide with recessions [1955:4-1965:2 and 1978:4-1984:3]. There are also instances in which recessions occur during periods of passive fiscal policy [1990:3-1991:1 and 2001:1-2001:4]. Taken together these results suggest that the tax rule does more than simply identify active regimes with economic downturns.

[14]Favero and Monacelli (2005) estimate that through 2002, fiscal policy was active in 1961:1-1974:3, 1975:3-1995:1, and 2001:3-2002:4 and passive otherwise. Our estimates find more periods of passive behavior.

joint transition matrix

$$P = P^M \otimes P^F = \begin{bmatrix} .8908 & .0597 & .0464 & .0031 \\ .0494 & .9011 & .0026 & .0469 \\ .0164 & .0011 & .9208 & .0617 \\ .0009 & .0166 & .0511 & .9314 \end{bmatrix}. \tag{4}$$

Probabilities on the main diagonal are $P[AM/PF\,|AM/PF]$, $P[AM/AF\,|AM/AF]$, $P[PM/PF\,|PM/PF]$, and $P[PM/AF\,|PM/AF]$. The transition matrix implies that all states communicate and each state is recurring, so the economy visits each one infinitely often.

Figure 5 shows that the joint probabilities computed using (4) also correspond to periods that have been noted in the literature. Both policies were passive in the early 1950s, when the Fed supported bond prices (and gradually phased out that support) and fiscal policy was financing the Korean War. From the late 1960s through most of the 1970s, both policies were again passive. Arguing this, Clarida, Gali, and Gertler (2000) claim the policy mix left the equilibrium undetermined, allowing for bursts of inflation and output from self-fulfilling expectations. Using data only from 1960-1979, it is easy to see how one might reach this conclusion. The early-to-mid-1980s, when monetary policy was aggressively fighting inflation and fiscal policy was financing interest payments with new debt issuances, gets labeled as doubly active policies. Finally, the mid-1980s on is largely a period of active monetary and passive fiscal policies, as most models of monetary policy assume [for example, the papers in Bryant, Hooper, and Mann (1993) and Taylor (1999b)].

Taken together, the marginal and joint probabilities paint a picture of post-war monetary and fiscal policies that is broadly consistent with both narrative accounts and fixed-regime policy rule estimates.

A final check on the plausibility of the estimates asks if the policies make economic sense when they are embedded in a conventional DSGE model. Sections 6 and 7 answer this question in detail.

3. A Model with Nominal Rigidities

We employ a conventional model with monopolistic competition and sticky prices in goods markets, extended to include lump-sum taxes and nominal government debt.[15] Although the model is standard, because we intend to solve it in its full nonlinear form, it is worthwhile reviewing the specification.

[15]Detailed expositions appear in Yun (1996, 2004), Woodford (2003), and Schmitt-Grohe and Uribe (2004).

3.1. **Households.** The representative household chooses $\{C_t, N_t, M_t, B_t\}$ to maximize

$$E_t \sum_{i=0}^{\infty} \beta^i \left[\frac{C_{t+i}^{1-\sigma}}{1-\sigma} - \chi \frac{N_{t+i}^{1+\eta}}{1+\eta} + \delta \frac{(M_{t+i}/P_{t+i})^{1-\kappa}}{1-\kappa} \right] \tag{5}$$

with $0 < \beta < 1, \sigma > 0, \eta > 0$, $\kappa > 0, \chi > 0$ and $\delta > 0$. C_t is a composite consumption good that combines the demand for the differentiated goods, c_{jt}, using a Dixit and Stiglitz (1977) aggregator:

$$C_t = \left[\int_0^1 c_{jt}^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}}, \theta > 1. \tag{6}$$

The household chooses c_{jt} to minimize expenditure on the continuum of goods indexed by the unit interval, leading to the demand functions for each good j

$$c_{jt} = \left(\frac{p_{jt}}{P_t} \right)^{-\theta} C_t, \tag{7}$$

where $P_t \equiv \left[\int_0^1 p_{jt}^{1-\theta} dj \right]^{\frac{1}{1-\theta}}$ is the aggregate price level at t.

The household's budget constraint is

$$C_t + \frac{M_t}{P_t} + E_t \left(Q_{t,t+1} \frac{B_t}{P_t} \right) + \tau_t \leq \left(\frac{W_t}{P_t} \right) N_t + \frac{M_{t-1}}{P_t} + \frac{B_{t-1}}{P_t} + \Pi_t, \tag{8}$$

where τ_t is lump-sum taxes/transfers from the government to the household, B_t is one-period nominal bonds, $Q_{t,t+1}$ is the stochastic discount factor for the price at t of one dollar at $t+1$, and Π_t is profits from the firm, which the household owns. The household maximizes (5) subject to (8) to yield the first-order conditions

$$\chi \frac{N_t^{\eta}}{C_t^{-\sigma}} = \frac{W_t}{P_t} \tag{9}$$

$$Q_{t,t+1} = \beta \left(\frac{C_t}{C_{t+1}} \right)^{\sigma} \frac{P_t}{P_{t+1}}. \tag{10}$$

If R_t denotes the risk-free gross nominal interest rate between t and $t+1$, then absence of arbitrage implies the equilibrium condition

$$[E_t(Q_{t,t+1})]^{-1} = 1 + r_t, \tag{11}$$

so the first-order conditions imply that real money balances may be written as

$$\frac{M_t}{P_t} = \delta^{\kappa} \left(\frac{r_t}{1+r_t} \right)^{-1/\kappa} C_t^{\sigma/\kappa}. \tag{12}$$

The government demands goods in the same proportion that households do, so the government's demand is $g_{jt} = \left(\frac{p_{jt}}{P_t}\right)^{-\theta} G_t$, where $G_t = \left[\int_0^1 g_{jt}^{\frac{\theta-1}{\theta}} dj\right]^{\frac{\theta}{\theta-1}}$.

Necessary and sufficient conditions for household optimization are that (9)-(12) hold at all dates and that households exhaust their intertemporal budget constraints. The latter condition is equivalent to requiring that the present value of households' planned expenditure is finite and that wealth accumulation satisfies the transversality condition [Woodford (2001)]:

$$\lim_{T\to\infty} E_t\left[q_{t,T}\frac{A_T}{P_T}\right] = 0, \tag{13}$$

where $A_t = B_t + M_t$ and $q_{t,t+1} = Q_{t,t+1}P_{t+1}/P_t$.

3.2. **Firms.** A continuum of monopolistically competitive firms produce goods using labor. Production of good j is

$$y_{jt} = Z_t N_{jt}, \tag{14}$$

where Z_t is aggregate technology, common across firms and taken to be constant.

Aggregating consumers' and government's demand, firm j faces the demand curve

$$y_{jt} = \left(\frac{p_{jt}}{P_t}\right)^{-\theta} Y_t, \tag{15}$$

where Y_t is defined by

$$C_t + G_t = Y_t. \tag{16}$$

Equating supply and demand for individual goods,

$$Z_t N_{jt} = \left(\frac{p_{jt}}{P_t}\right)^{-\theta} Y_t. \tag{17}$$

Following Calvo (1983), a fraction $1-\varphi$ firms are permitted to adjust their prices each period, while the fraction φ are not permitted to adjust. If firms are permitted to adjust at t, they choose a new optimal price, p_t^*, to maximize the expected discounted sum of profits given by

$$E_t \sum_{i=0}^{\infty} \varphi^i q_{t,t+i}\left[\left(\frac{p_t^*}{P_{t+i}}\right)^{1-\theta} - \Psi_{t+i}\left(\frac{p_t^*}{P_{t+i}}\right)^{-\theta}\right] Y_{t+i}, \tag{18}$$

where the real profit flow of firm j at period t, $\Pi_{jt} = \left(\frac{p_{jt}}{P_t}\right)^{1-\theta} Y_t - \frac{W_t}{P_t} N_{jt}$, has been rewritten using (17). Ψ_t is real marginal cost, defined as

$$\Psi_t = \frac{W_t}{Z_t P_t}. \tag{19}$$

The first-order condition that determines p_t^* can be written as

$$\frac{p_t^*}{P_t} = \left(\frac{\theta}{\theta-1}\right) \frac{E_t \sum_{i=0}^{\infty} (\varphi\beta)^i (Y_{t+i} - G_{t+i})^{-\sigma} \left(\frac{P_{t+i}}{P_t}\right)^{\theta} \Psi_{t+i} Y_{t+i}}{E_t \sum_{i=0}^{\infty} (\varphi\beta)^i (Y_{t+i} - G_{t+i})^{-\sigma} \left(\frac{P_{t+i}}{P_t}\right)^{\theta-1} Y_{t+i}}, \tag{20}$$

which we denote by

$$\frac{p_t^*}{P_t} = \left(\frac{\theta}{\theta-1}\right) \frac{K_{1t}}{K_{2t}}, \tag{21}$$

where the numerator and the denominator have recursive representations:

$$K_{1t} = (Y_t - G_t)^{-\sigma} \Psi_t Y_t + \varphi\beta E_t K_{1t+1} \left(\frac{P_{t+1}}{P_t}\right)^{\theta} \tag{22}$$

and

$$K_{2t} = (Y_t - G_t)^{-\sigma} Y_t + \varphi\beta E_t K_{2t+1} \left(\frac{P_{t+1}}{P_t}\right)^{\theta-1}. \tag{23}$$

Solving (21) for p_t^* and using the result in the aggregate price index, $P_t^{1-\theta} = (1-\varphi)(p_t^*)^{1-\theta} + \varphi P_{t-1}^{1-\theta}$, yields

$$\pi_t^{\theta-1} = \frac{1}{\varphi} - \frac{1-\varphi}{\varphi} \left(\mu \frac{K_{1t}}{K_{2t}}\right)^{1-\theta}, \tag{24}$$

where $\mu \equiv \theta/(\theta-1)$ is the markup.

We assume that individual labor services may be aggregated linearly to produce aggregate labor, $N_t = \int_0^1 N_{jt} dj$. Linear aggregation of individual market clearing conditions implies $Z_t N_t = \Delta_t Y_t$, where Δ_t is a measure of relative price dispersion defined by

$$\Delta_t = \int_0^1 \left(\frac{p_{jt}}{P_t}\right)^{-\theta} dj. \tag{25}$$

Now the aggregate production function is given by

$$Y_t = \frac{Z_t}{\Delta_t} N_t. \tag{26}$$

It is natural to define aggregate profits as the sum of individual firm profits, $\Pi_t = \int_0^1 \Pi_{jt} dj$. Integrating over firms' profits and combining the household's and the government's budget constraints yields the aggregate resource constraint

$$\frac{Z_t}{\Delta_t} N_t = C_t + G_t. \tag{27}$$

From the definitions of price dispersion and the aggregate price index, relative price dispersion evolves according to

$$\Delta_t = (1-\varphi) \left(\frac{p_t^*}{P_t}\right)^{-\theta} + \varphi \pi_t^{\theta} \Delta_{t-1}, \tag{28}$$

where $\pi_t = P_t/P_{t-1}$.

3.3. **Policy Specification.** Monetary and tax policies follow (1) and (2), with error terms that are standard normal and *i.i.d.* The processes for $\{G_t, \tau_t, r_t, M_t, B_t\}$ must satisfy the government budget identity

$$G_t = \tau_t + \frac{M_t - M_{t-1}}{P_t} + E_t\left(Q_{t,t+1}\frac{B_t}{P_t}\right) - \frac{B_{t-1}}{P_t}. \tag{29}$$

given $M_{-1} > 0$ and $(1 + r_{-1})B_{-1}$. Government spending as a share of output is assumed to be constant.

3.4. **Information Assumptions.** Although in the empirical estimates in section 2 regime is a state variable hidden from the econometrician, we do not confront agents in the model with an inference problem. Instead, we assume agents observe at least current and past policy shocks and regimes. Under conventional information assumptions, the model is solved assuming that private agents base their decisions at date t on the information set $\Omega_t = \{\varepsilon^r_{t-j}, \varepsilon^\tau_{t-j}, S^M_{t-j}, S^F_{t-j}, j \geq 0\}$ plus the initial conditions $(M_{-1}, (1 + r_{-1})B_{-1})$. This conventional information structure enables us to quantify the impacts of unanticipated changes in taxes. We also seek to quantify the effects of anticipated changes in taxes. Those effects are computed by endowing agents with foreknowledge of tax disturbances, so the model is solved using the expanded information set $\Omega^*_t = \Omega_t \cup \{\varepsilon^\tau_{t+1}\}$.[16]

3.5. **Stationary Equilibria.** The algorithm used to solve this model finds decision rules that produce stationary equilibria, if they exist, given the estimated exogenous processes. Our focus on stationary equilibria is driven by empirical and theoretical considerations. On the empirical side, our aim is to understand post-war U.S. time series and those time series display no tendency for the debt-GDP ratio to explode. We take seriously Canzoneri, Cumby, and Diba's (2001) demonstration that if over time the response of government surplus to total government liabilities is bounded away from zero infinitely often, then there exist equilibria that exhibit Ricardian equivalence. But we question the relevance of this proposition for interpreting U.S. data because it depends on having debt grow without bound. Turning to theoretical considerations, Davig, Leeper, and Chung (2004) show that in a simple flexible-price endowment economy, regime-switching policies that satisfy the assumptions of Canzoneri, Cumby, and Diba's proposition deliver a non-Ricardian equilibrium that is unique within the set of equilibria with bounded debt-output ratios.

[16]See Leeper (1989) and Yang (2005) for further discussion of the implications of fiscal foresight.

4. The Fiscal Theory Mechanism

The economics underlying the fiscal theory mechanism potentially present in the model of section 3 relies on the existence of nominal government debt and particular combinations of monetary and fiscal policies. An equilibrium condition that is useful for heuristic purposes is derived by imposing the transversality condition, (13), on the present value form of the government's budget constraint to obtain:

$$\frac{A_{t-1}}{P_t} = \sum_{T=t}^{\infty} E_t \left[q_{t,T} \left(\tau_T - G_T + \frac{r_T}{1+r_T} \frac{M_T}{P_T} \right) \right]. \tag{30}$$

The expression states that in equilibrium the real value of nominal government liabilities must equal the expected present value of primary surpluses plus seigniorage. When this expression imposes restrictions on the stochastic process for the price level, it does so through the fiscal theory mechanism. In that case, Cochrane (1999, 2001) refers to (30) as a "debt valuation" equation because fluctuations in surpluses or seigniorage can induce jumps in P_t, which alter the real value of debt to keep it consistent with expected policies.[17] Conventional monetary analysis, in contrast, assumes that monetary policy is active and fiscal policy is passive, so (30) holds via adjustments in future surpluses, without imposing any restrictions on the $\{P_t\}$ process [for example, Woodford (2003)].

Consider the simple case of an exogenous process for the net-of-interest surplus (active fiscal policy) and a pegged nominal interest rate (passive monetary policy).[18] A debt-financed cut in taxes does not raise the present value of future taxes, so it is perceived by households as raising their wealth. Unlike when productivity or government purchases change, wealth effects from the fiscal theory do not necessarily stem from a change in the resources available to the economy.[19] Instead, a tax cut raises the present value of consumption the households believe they can afford at initial prices and interest rates. This wealth-induced increase in demand for goods raises output relative to potential, when nominal rigidities are present. But it must also cause inflation and/or real interest rates to adjust in order to satisfy (30). With a pegged nominal interest rate, the increase in inflation lowers the ex-ante real interest

[17] In the model all debt matures in one period. Cochrane (2001) emphasizes that with long-maturity debt, the inflation consequences of a fiscal expansion can be pushed into the future.

[18] This policy mix does not impose a boundary condition on the inflation process, but it does impose a boundary condition on the *real* debt process. With nominal liabilities predetermined, the price level is uniquely determined. This is the canonical fiscal theory specification [see Woodford (2001) or Gordon and Leeper (2006)].

[19] Taking a price-theoretic view of the fiscal theory, Leeper and Yun (2005) refer to this as the "asset revaluation effect," as distinct from conventional "wealth" and "substitution" effects.

rate, ensuring that the demand for goods expands. Condition (30) emphasizes that it is changes in the *present value* of primary surpluses and seigniorage that can trigger fluctuations in aggregate demand, suggesting that anticipated and unanticipated taxes have symmetric effects.

Equality between the value of government liabilities and the present value of surpluses plus seigniorage is achieved through three channels, as Woodford (1998a) explains. First, passive monetary policy endogenously expands the money stock to clear the money market at the targeted nominal interest rate, creating seigniorage revenue. Second, unexpectedly higher inflation revalues outstanding nominal debt. Third, lower real interest rates make it possible to service a higher level of debt with a given stream of primary surpluses.

If condition (30) imposes restrictions on the equilibrium price level, as it does in the fiscal theory, then higher expected seigniorage tends to lower the current price level, an association that seems perverse relative to conventional monetary theory. Of course, (30) is one of several conditions for equilibrium. But this informal analysis offers a preview of the possibility that monetary disturbances may have unconventional impacts in a fiscal theory equilibrium.

The logic of the fiscal theory mechanism carries over directly to a regime-switching environment. Davig, Leeper, and Chung (2004) show that in that environment the fiscal theory is always at work, regardless of the prevailing regime. As long as there is a positive probability of moving to a regime with active fiscal policy, agents' decision rules will reflect that probability and disturbances to current or expected future taxes will generate wealth effects that affect aggregate demand. This occurs even if in the current regime fiscal policy is passive and monetary policy is active. Whether this logic is practically relevant depends on whether the fiscal theory mechanism is quantitatively important. The paper now addresses this issue.

5. Calibration and Solution Method

Parameters describing preferences, technology and price adjustment for the model in section 3 are specified to be consistent with Rotemberg and Woodford (1997) and Woodford (2003). The model's frequency is quarterly. The markup of price over marginal cost is set to 15 percent, implying $\mu = \theta(1-\theta)^{-1} = 1.15$, and 66 percent of firms are unable to reset their price each period ($\varphi = .66$). The quarterly real interest rate is set to 1 percent ($\beta = .99$). Preferences over consumption and leisure are logarithmic ($\sigma = 1, \eta = -1$) and χ is chosen to make steady state employment 0.2. Each intermediate goods producing firm has access to a production function with

constant returns to labor. The technology parameter, A, is chosen to normalize the deterministic steady state level of output to be 1.

The preference parameter on real balances, δ, is set to ensure that velocity in the deterministic steady state, defined as cP/M, matches average U.S. monetary base velocity at 2.4. This value comes from the period 1959-2004 and uses the average real expenditure on non-durable consumption plus services. The parameter governing the interest elasticity of real money balances, κ, is set to 2.6 [Mankiw and Summers (1986), Lucas (1988), Chari, Kehoe, and McGrattan (2000)].

Reaction coefficients in the policy rules are taken from the estimates in tables 1 and 2 and the four-state joint transition matrix (4). The intercepts in the policy rules govern the deterministic steady state values of inflation and debt-output in the computational model. Intercepts are set so the deterministic steady state values of variables are common across regimes and match their sample means from 1948:2-2004:1. Those values, annualized, are $\pi = 3.43$ percent and $b = .3525$. Government purchases as a share of output are fixed in the model at their mean value of .115.

We compute the solution using the monotone map method, based on Coleman (1991). The algorithm uses a discretized state space and requires a set of initial decision rules that reduce the system to a set of non-linear expectational first-order difference equations. The complete model consists of the first-order necessary conditions from the households' and firms' optimization problems, constraints, specifications of policy, the price adjustment process, and the transversality condition. The solution is a set of functions that map the state, $\Theta_t = \{b_{t-1}, w_{t-1}, \Delta_{t-1}, \theta_t, \psi_t, S_t\}$, into values for the endogenous variables, where w is a wealth measure, defined as $w_t \equiv R_t b_t + M_t/P_t$.[20]

6. General Characteristics of Equilibrium

This section discusses the qualitative features of the computed equilibrium. In particular, we argue that the equilibrium is locally unique and stationary. An analytical demonstration of these features is not available, so we rely on numerical arguments.

6.1. **Uniqueness and Stationarity.**

Because monetary and fiscal regimes are free to change independently of one another, the model temporarily permits policy combinations with passive monetary and passive fiscal policies, as well as active monetary and active fiscal policies. A passive-passive policy combination leaves the equilibrium undetermined in fixed-regime versions of the model, admitting the possibility that sunspot shocks affect equilibrium allocations. An active-active policy combination implies either no equilibrium exists or, if it does exist, the equilibrium is

[20]Details appear in appendix A.

non-stationary. But when regimes obey a Markov process, an active-active mix does not necessarily violate the transversality condition because agents correctly impute positive probability to returning to a regime that prevents debt from growing too rapidly. Similarly, temporarily passive-passive policies do not necessary leave the equilibrium indeterminate. It is long-run policy behavior, not current behavior, that determines the qualitative properties of existence and uniqueness.

To establish local uniqueness of the equilibrium, we perturb the converged decision rules by a truncated normal random variable at every point in the state space and check that the algorithm converges back to the initial set of rules. We repeated this many times and the algorithm always converged to the initial converged decision rules, which we take to indicate the decision rules are locally unique.

We also checked how the monotone map algorithm behaves when it is known there are multiple equilibria or no equilibrium exists. Using the fixed-regime model with PM/PF policies, the algorithm diverges; under AM/AF policies, the algorithm converges, but implies a non-stationary path for debt. The regime-switching DSGE model converges and produces a stationary path for debt, providing further evidence that the equilibrium is locally unique and stationary.

Zero expected present value of debt, which the transversality condition implies, is equivalent to the intertemporal equilibrium condition

$$b_t = x_t + z_t, \tag{31}$$

where x and z are the expected discounted present values of future primary surpluses and seigniorage. We check whether (31) holds following an exogenous shock, conditioning on remaining in each of the three stationary regimes—AM/PF, PM/PF, PM/AF. We repeat this calculation with random realizations of regimes. The condition is always satisfied, confirming that the numerical solution is an equilibrium of the model.

To assess the long-run properties of the model, we compute distributions using a simulation of 250,000 periods (figure 6). The top four panels are unconditional distributions and the bottom four panels sort the sample by regime. The simulation randomly draws policy shocks and policy regimes from their estimated distributions.

All distributions have finite means and variances, as is apparent by inspection of the bottom four panels.[21] The estimated policy rules imply that debt diverges very slowly under AM/AF policies. Although debt temporarily follows a non-stationary

[21]Francq and Zakoian (2001) show that Markov-switching processes can have explosive regimes, yet the entire stochastic process can be stable. Davig (2005) shows that a properly restricted Markov-switching process for discounted debt can have an explosive regime, yet satisfy the transversality condition for debt.

path, the duration of the AM/AF regime is not sufficiently long nor is the growth rate of debt high enough to preclude stationary distributions for debt and other variables.

7. Quantifying the Fiscal Theory Mechanism

To quantify the effects of policy shocks, we report results based on two kinds of impulse response functions. The first conditions on regime to mimic responses functions usually reported from identified VARs. The second reflects the "typical" effect of a policy shock by computing the distribution of equilibrium time paths after a policy disturbance.

7.1. **Non-Linear Impulse Response Analysis.**

When conditioning on regime, we assume the initial state of the economy equals the regime-dependent mean. After perturbing the error term in a policy rule, we solve for equilibrium time paths, holding the prevailing regime fixed, and report paths of variables relative to the baseline of their regime-dependent means. For a policy shock at time t, the initial response of variable k is

$$\phi_t^k(\varepsilon_t^r, \varepsilon_t^\tau) = h^k(\overline{b^J}, \overline{w}^J, \overline{\Delta}^J, \varepsilon_t^r, \varepsilon_t^\tau, J) - h^k(\overline{b^J}, \overline{w}^J, \overline{\Delta}^J, 0, 0, J), \tag{32}$$

where h^k is the decision rule for variable k as a function of the state variables for regime J and the realizations of $i.i.d.$ policy disturbances, ε_t^r and ε_t^τ. $\bar{x}^J$ denotes the mean of x in regime J. Following initial impact, policy shocks equal their means of zero and the value of variable k in period $n > t$ is

$$\phi_n^k(\varepsilon_t^r, \varepsilon_t^\tau) = h^k(b_{n-1}, w_{n-1}, \Delta_{n-1}, 0, 0, J) - h^k(\overline{b^J}, \overline{w}^J, \overline{\Delta}^J, 0, 0, J), \tag{33}$$

ϕ_n^k is a function of the initial shocks because the impulse responses are history dependent.

Also of interest is the average ("typical") response of a variable, where the mean is computed over future realizations of regimes. In this case, the impact period is computed as above, but the generalized impulse response of variable k in period $n > t$ is given by

$$\hat{\phi}_n^k(\varepsilon_t^r, \varepsilon_t^\tau) = h^k(b_{n-1}, w_{n-1}, \Delta_{n-1}, 0, 0, S_n) - h^k(\overline{b^J}, \overline{w}^J, \overline{\Delta}^J, 0, 0, J), \tag{34}$$

where the realization of the decision rule depends on the current realization of regime, S_n. We report various summary measures of the random variable $\hat{\phi}_n^k$.

7.2. **A Fiscal Expansion.** In every regime, a cut in taxes is financed by new sales of nominal government debt and generates wealth effects that increase aggregate demand, inflation, and output.

Figure 7 reports paths following a surprise tax reduction of two percent of output in period 5, conditional on starting out and staying in each of the three stationary regimes—AM/PF, PM/AF, and PM/PF. Regardless of the prevailing regime, the fiscal theory mechanism is evident. A surprise tax cut raises inflation. Monetary policy prevents the nominal interest rate from rising as much as expected inflation, reducing the ex-ante real interest rate and raising output above potential. In all regimes, the one-period tax cut has persistent effects, lasting over 5 years when monetary policy is passive (thin solid and dashed lines) and for many more years when monetary policy is active (thick solid lines). Figure 7 illustrates the three sources of fiscal financing: inflation jumps unexpectedly on impact, revaluing debt; the real interest rate falls, raising the expected discounted present values of surpluses and seigniorage; future inflation and, therefore, seigniorage increases.

Active monetary policy appears to dramatically dampen the tax effects on output and inflation. In fact, a strong response of the nominal interest rate to inflation spreads the responses to taxes over many periods and actually results in larger long-run effects from fiscal disturbances. In a fixed-regime model, the Taylor principle creates explosive inflation dynamics following an *i.i.d.* shock, so it may seem anomalous that the inflation process is stationary in the AM/PF regime. Davig, Leeper, and Chung (2004) show, in an endowment version of this model, that an AM/PF regime creates wealth effects that make the forecast error in inflation serially correlated, depending negatively on past inflation and positively on past real debt. These surprises in inflation are a key feature of the fiscal theory mechanism, as they serve to revalue debt. Through the Taylor principle, higher π_t raises R_t, which increases future debt service. Because regimes can switch, agents expect some debt service to be met with future seigniorage. But the paths in figure 7 condition on remaining in the AM/PF regime, so taxes are unexpectedly high, which reduces aggregate demand and stabilizes inflation.

Generalized impulse response functions bring out the role that the evolution of regime plays in affecting economic agents' expectations and choices. Dynamic impacts of policy disturbances display important differences from their counterparts in figure 7. For the three stationary regimes, figure 8 plots the mean and one standard deviation bands of the generalized impulse responses following a fiscal expansion. The first four periods condition on the stationary mean in a given regime, period 5 imposes the shock and holds regime fixed, and draws of regimes are taken from period 6 on.

Factoring in future regime changes alters the predictions one makes about the dynamic path of the economy following a tax cut. A one-period fiscal expansion generates a hump-shaped response of inflation and output; the hump is more pronounced when the initial regime is AM/PF policies. The responses resemble those arising from identified VARs focusing on the effects of fiscal policy. When monetary policy is passive, the inflation and output responses are stronger in the short run, but die out more quickly. Generalized response functions also imply that when the initial regime entails passive fiscal policy, there is a substantial probability that a few years after the fiscal expansion both output and inflation will fall below their pre-shock levels.

7.3. **Tax Multipliers.** We compute several summary measures of tax effects, both conditional on the economy remaining in the current regime and unconditional, averaging across future realizations of regime. The measures quantify the impacts of a one-time exogenous change in taxes, either unanticipated or anticipated.

Table 4 reports tax multipliers, computed as the discounted present value of additional output generated by a tax cut. The multiplier is defined as $PV_n(\Delta y)/\Delta\tau_0 = \frac{1}{\Delta\tau_0}\sum_{s=0}^{n} q_{0,s}(y_s - \overline{y})$, where $q_{0,s}$ is the stochastic discount factor, computed for the horizons $n = 5, 10, 25$, and for the long run (∞).

A one-time \$1 surprise tax cut raises the discounted present value of future output in the long run by \$1.02 in the AM/PF regime, by 76 cents in the PM/PF regime, and by 98 cents in the PM/AF regime. The table highlights the stronger persistence of output under active monetary policy, where after 25 quarters the discounted present value of additional output is only 42 cents. Under passive monetary policy, the additional effects of the tax cut have largely dissipated after 25 quarters.

The fiscal theory does not sharply delineate between the impacts of unanticipated and anticipated changes in taxes. As expression (30) emphasizes, the fiscal theory focuses on how fluctuations in the expected discounted present value of taxes impact current aggregate demand. The lower panel of table 4 reports output multipliers when households anticipate a tax cut next period; multipliers are computed using the expanded information set Ω_t^*, defined in section 3.4. The multipliers under foreknowledge of taxes are similar to the multipliers from a tax surprise, confirming that it is the change in the expected discounted present value of primary surpluses that is central to the fiscal theory mechanism.

Table 4 shows the proportion of the marginal addition to debt arising from a tax cut that is backed by an increase in discounted primary surpluses. Under an AM/PF policy, two-thirds of new debt is backed by discounted primary surpluses, in contrast to fixed-regime models, where the proportion is 100 percent. The proportions under PM/PF and PM/AF are 59 percent and 49 percent. Consequently, the PM/AF

regime experiences the strongest wealth effect on impact from a tax cut, as figure 7 makes apparent. Much of this adjustment arises from the lower real interest rates that are used to discount future surpluses and seigniorage.

In the model, it is highly unusual for policy regime to remain unchanged, as the calculations in table 4 assume. Typically, after a policy disturbance, regimes evolve according to their estimated transition matrices. Table 5 reports 80th percentile ranges for the tax multipliers, computed from 10,000 draws of regimes, using the generalized impulse response function defined in (34). At the 80th percentile, a \$1 tax cut raises the discounted present value of output from 76 cents to \$1.36 after 6 years, depending on the initial regime.

Table 6 reports the price level effects of a one-period tax shock, conditional on regime. In the long run, a transitory tax cut of 2 percent of output raises the price level by 6.7 percent under AM/PF policies. At a little over 1 percent, the long-run price effects are substantially smaller when monetary policy is passive. At shorter horizons, taxes have larger price effects when monetary policy is passive than when it is active. Table 7 records typical price level impacts, accounting for possible future regimes. These impacts can be substantial, with the price level more than 2 percent higher 6 years after the tax cut. Uncertainty about realizations of future regimes creates a wide range of possible output and price level impacts from tax changes, as tables 5 and 7 attest.[22]

7.4. **A Monetary Expansion.** In the model's fiscal theory equilibrium, an expansionary monetary policy disturbance generates conventional short-run responses—lower real interest rate and higher output and inflation—but unconventional longer run impacts—higher real interest rate and lower output and inflation [figure 9]. Underlying the transitory monetary expansion is an open-market purchase of debt that leaves households holding less government debt. This negative wealth effect is not neutralized in the model, as it is with a fixed AM/PF regime, because the estimated policy process implies that future taxes do not fall in the long run by enough to counteract the decline in wealth from lower debt.

Although the longer run impacts of a monetary disturbance are unconventional by most criteria, the positive correlation between the nominal interest rate and future inflation that appears in figure 9 is a feature of many monetary VARs [Sims (1992)].

[22]Appendix B considers an alternative specification of the policy process that increases the duration of the active monetary policy regime by labeling as active the periods after the recessions in 1991 and 2001, which section 2 estimated as passive monetary policy. This reduces the quantitative impacts of tax shocks, though the fiscal theory mechanism remains important.

This "price puzzle," which is discussed in more detail in the next section, is a feature of the equilibrium generated by the fiscal theory mechanism.

8. Some Empirical Implications

Many studies of monetary policy condition on policy regime and then estimate policy rules. The estimates are interpreted by embedding them in a fixed-regime variant of the model in section 3. This section illustrates some pitfalls of this approach when data are generated by an environment with recurring changes in policy regimes.

We imagine that the calibrated model with the estimated switching process generated observed time series. Three sources of stochastic variation and the model's non-linearity are sufficient to ensure that a five-variable VAR fit to taxes, the nominal interest rate, the output gap, inflation, and the real value of debt is stochastically non-singular. In the identified VAR, only the policy rules are restricted. Output, inflation, and debt are treated as a triangular block which, as in the DSGE model, is permitted to respond contemporaneously to monetary and tax disturbances. The policy rules are specified as

$$r_t = \alpha_0 + \alpha_\pi \pi_t + \alpha_x x_t + \varepsilon_t^r \tag{35}$$

$$\tau_t = \gamma_0 + \gamma_x x_t + \gamma_b b_{t-1} + \varepsilon_t^\tau. \tag{36}$$

Following Blanchard and Perotti (2002), we impose the response of taxes to output, but freely estimate the response to debt. Counting only contemporaneous restrictions, the model is just identified if we estimate the response of monetary policy to inflation, but impose its response to output.

The econometrician estimates fixed-regime identified VARs with data generated by the DSGE model under two different assumptions about the econometrician's *a priori* information. In one case, the econometrician believes the full sample comes from a single policy regime; in other cases, the econometrician believes regime changes have occurred and has extra-sample information that identifies which regimes prevailed over various sub-samples. Simulated data in the first case draws both policy shocks and regime, while in the other cases the simulation conditions on regime and draws only policy shocks.[23] After estimating the VARs, the econometrician seeks to interpret the findings in the context of a fixed-regime DSGE model.

The identified VARs obtain accurate quantitative estimates of policy parameters and the impacts of policy shocks. Table 8 reports four sets of estimates of the feedback parameters α_π and γ_b. The "All Regimes" estimates come from the full sample and the other columns condition on the indicated regime. All the estimates that condition

[23]But the data are generated by decision rules based on the "true" regime-switching process.

on regime recover the correct policy parameters and the associated regimes. The "All Regimes" estimates suggest that a researcher using a long sample of data would infer that, on average, monetary policy is passive and fiscal policy is active.

Figure 10 shows estimates of the dynamic impacts of policy shocks from the identified VARs. Tax disturbances have important impacts on output and inflation, both conditional on regime and in the full sample. Active monetary policy diminishes the size of the period-by-period impacts, but induces such extreme serial correlation that the total impacts are substantial. Monetary contractions have conventional short-run effects (lower output and inflation), but unconventional longer run effects (higher output and inflation), owing to the resulting wealth effects engendered by the fiscal theory mechanism. The rise in future inflation resembles the price puzzle Sims (1992) discovered in monetary VARs. That puzzle is more pronounced when monetary policy is passive, consistent with Hanson's (2004) findings that in U.S. data the puzzle is more severe in samples that include data before 1979, a period that section 2 labels passive monetary policy. Both the parameter estimates and the impulse response functions the econometrician obtains are quantitatively consistent with those in the switching model underlying the simulated data (given that the econometrician knows α_x and γ_x *a priori*).

Connecting these quantitative results to fixed-regime theories can lead to qualitatively misleading inferences. Clarida, Gali, and Gertler (2000) and Lubik and Schorfheide (2003) use different econometric methods, but both condition on monetary policy regime and both conclude that since the early 1980s, U.S. monetary policy has been active, while from 1960-1979, monetary policy was passive. Both sets of authors maintain the assumption that fiscal policy was passive throughout, leading in their fixed-regime DSGE models to Ricardian equivalence in the recent sub-sample and indeterminacy in the earlier sub-sample. The results for AM/PF (thick solid lines) in figure 10 are difficult to reconcile with Ricardian equivalence. Similarly, in the sub-sample where the estimated rules imply PM/PF (thin solid lines), the econometrician would infer the equilibrium is indeterminate and be compelled to interpret the policy impacts as arising from correlations between sunspot shocks and policy shocks. But the simulated data were generated by locally unique decision rules.

Employing the full sample, the econometrician estimates the policy impacts shown by dashed lines in figure 10. Moreover, using the "All Regimes" parameter estimates in a fixed-regime version of the model in section 3, produces the policy impacts represented by lines in the figure punctuated with x's. In contrast to the estimates that condition on regime, the full sample estimates deliver qualitatively correct inferences about policy effects. Correct qualitative inferences require nailing down the correct

long-run behavior of policy. That long-run behavior is better gleaned from a long sample that includes the possible realizations of regimes than from sub-samples that condition on regime.[24]

9. Concluding Remarks

Existing work on policy rules is based on a logical inconsistency: it assumes regime cannot change and then proceeds to analyze the implications of alternative regimes. This paper takes a step toward resolving this inconsistency. A simple and plausible empirical specification of regime change finds that U.S. monetary and fiscal policies have fluctuated among active and passive rules. Treating that evidence of regime change in an internally consistent manner can significantly alter interpretations of the historical period and of monetary and fiscal policies more generally. Both the empirical specification and the economic model are very simple, leaving much room for improving fit to data. This is an important area for continued research.

This paper has not addressed why policy regimes change. This is a hard question, but it is the same hard question that can be asked of any model with a stochastic component to policy behavior. Although Sims (1987) offers a rationale for why optimal policy might include a component that is random to private agents, there is certainly no consensus on this issue. Lack of consensus, however, does not undermine the utility of simply postulating the existence of policy shocks and then tracing out their influence in data and in models. In this paper, we have followed the convention of assuming some part of policy behavior is random.

Under the working hypothesis of recurring regime change, this paper shows that when estimated Markov-switching rules for monetary and tax policies are embedded in a DSGE model calibrated to U.S. data, lump-sum taxes have quantitatively important effects on aggregate demand, output, and inflation. In the model, tax non-neutralities arise because the estimates imply that agents always place positive probability mass on an active fiscal regime in the future, a belief that makes the fiscal theory of the price level operative.

Of course, the fiscal theory is not the only source of tax non-neutralities in actual data. A full accounting of tax effects requires introducing some of the panoply of reasons offered for why taxes might be non-neutral—distortions, life-cycle considerations, and so forth. In any case, the quantitative predictions of this paper strongly suggest that the fiscal theory mechanism should be added to the list of usual suspects for the breakdown of Ricardian equivalence.

[24]Unless there is compelling evidence that agents believe the prevailing regime is permanent.

Appendix A. Solution Method

Implementation of the algorithm begins by conjecturing an initial set of rules, which we take to be the solution from the model's fixed-regime counterpart. Specifically, we take the solutions from the fixed-regime model with AM/PF and PM/AF policies as the initial rules for the corresponding regimes in the non-synchronous switching model. For the AM/AF and PM/PF regimes there are no stationary, unique fixed-regime counterparts, so we use the solution from the PM/AF fixed-regime model to initialize the algorithm. To ensure the solution is not sensitive to initial conditions, we also use the solution from the AM/PF regime and weighted averages of the two. Further perturbations of the initial rules have no effect on the final solution, suggesting the solution is locally unique.

Taking the initial rules for labor, $\widehat{h}^N(\Theta_t) = N_t$, and the functions determining the firm's optimal pricing decision, $\widehat{h}^{K_1}(\Theta_t) = K_{1,t}$ and $\widehat{h}^{K_2}(\Theta_t) = K_{2,t}$, we find values using a non-linear equation solver for N_t, $K_{1,t}$, $K_{2,t}$ such that

$$C_t^{-\sigma} = \beta R_t E_t \left[\pi_{t+1} \left(h^C(\Theta_{t+1})\right)^{-\sigma}\right], \tag{37}$$

$$K_{1,t} = C_t^{1-\sigma}\Psi_t + \varphi\beta E_t \widehat{h}^{K_1}(\Theta_{t+1}), \tag{38}$$

$$K_{2,t} = C_t^{1-\sigma} + \varphi\beta E_t \widehat{h}^{K_2}(\Theta_{t+1}), \tag{39}$$

where $h^C(\Theta_t) = (A/\Delta_t)\widehat{h}^N(\Theta_t) - g$. Given N_t, $K_{1,t}$, $K_{2,t}$, we compute the endogenous variables. Note that Δ_t, b_t and $w_t = R_t b_t + M_t/P_t$ are states at $t+1$. Gauss-Hermite integration is used over possible values for ε^r_{t+1}, ε^τ_{t+1} and S_{t+1}, yielding values for $E_t\left[\pi_{t+1}C_{t+1}^{-\sigma}\right]$, $E_t K_{1,t+1}$, $E_t K_{2,t+1}$, which reduces the above system to three equations in three unknowns. The (net) nominal interest rate is restricted to always be positive.

When solving the above system, the state vector and the decision rules are taken as given. The system is solved for every set of state variables defined over a discrete partition of the state space. This procedure is repeated until the iteration improves the current decision rules at any given state vector by less than some $\epsilon = 1e-12$.

Appendix B. An Alternative Policy Process

Many authors have argued that monetary policy has been active since around 1979. Since our empirical estimates indicate two brief episodes of passive monetary policy after 1979, this section conducts a sensitivity analysis that adjusts the transition matrix to be consistent with an active monetary regime for the entire post 1979 sample. This exercise highlights that the general message of the paper, namely that fiscal shocks have important real effects even under AM/PF policy, carries into an environment with a more persistent active monetary policy.

Our empirical estimates indicate that there are a total of 28 quarters of passive monetary policy after 1979. Relabeling these periods as active monetary policy results in 44.2 percent of all periods having active monetary policy. There is no unique way of adjusting the transition matrix so that 44.2 percent of periods are active. However, increasing the persistence of the active monetary regime, instead of decreasing the persistence of the passive regime, is more consistent with the priors of many researchers that the U.S. has had active monetary policy since 1979. So, we adjust the transition matrix by increasing the transition probability of staying in the active regime, conditioning on being in the active regime, from .9505 to .9779.

To summarize the effects of a more persistent active monetary regime, tables analogous to those reported in the paper are computed [tables 9-12].. The proportion of new debt backed by discounted surpluses increase in all regimes as the persistence of the active monetary regime increases. However, the primary differences that arise relative to the baseline specification occur under AM/PF policy. Across all time horizons, a more persistent active monetary regime diminishes the impacts fiscal shocks have on output and inflation. For example, the increase in all additional discounted output under AM/PF policy arising from a \$1 tax reduction is 61 cents, compared to \$1.02 under the baseline specification.

	Fraction of new debt	$\frac{PV(\Delta y)}{\Delta \tau}$ after			
Regime	backed by PV of taxes	5 quarter	10 quarters	25 quarters	∞
AM/PF	.801	−.053	−.099	−.213	−.607
PM/PF	.588	−.512	−.683	−.758	−.760
PM/AF	.490	−.619	−.853	−.976	−.981

TABLE 9. Output multipliers for taxes conditional on regime. Uses the alternative policy process that makes monetary policy active after the 1991 and 2001 recessions.

	$\frac{PV(\Delta y)}{\Delta \tau}$ after		
Initial Regime	5 quarters	10 quarters	25 quarters
AM/PF	$[-.062, -.066]$	$[-.107, -.667]$	$[-.218, -.959]$
PM/PF	$[-.172, -.174]$	$[-.192, -.512]$	$[-.249, -.655]$
PM/AF	$[-.314, -.317]$	$[-.447, -.799]$	$[-.802, -1.252]$

TABLE 10. Output multipliers for taxes, unconditional: 80th percentile bands based on 10,000 draws. Uses the alternative policy process that makes monetary policy active after the 1991 and 2001 recessions.

	$\%\Delta P$ after			
Regime	5 quarters	10 quarters	25 quarters	∞
AM/PF	.166	.331	.798	5.128
PM/PF	.765	1.073	1.231	1.236
PM/AF	.942	1.364	1.620	1.633

TABLE 11. Cumulative effect on price level of an *i.i.d.* unanticipated tax cut of 2 percent of output. Uses the alternative policy process that makes monetary policy active after the 1991 and 2001 recessions.

	$\%\Delta P$ after		
Initial Regime	5 quarters	10 quarters	25 quarters
AM/PF	$[.166, .180]$	$[.331, 1.206]$	$[.798, 1.906]$
PM/PF	$[.673, .765]$	$[.837, 1.073]$	$[.542, 1.231]$
PM/AF	$[.943, 1.001]$	$[1.292, 1.546]$	$[1.621, 2.233]$

TABLE 12. Cumulative effect on the price level of an *i.i.d.* tax cut of 2 percent of output, unconditional: 80th percentile bands based on 10,000 draws. Uses the alternative policy process that makes monetary policy active after the 1991 and 2001 recessions.

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	Active		Passive	
State	$S_t^M = 1$	$S_t^M = 2$	$S_t^M = 3$	$S_t^M = 4$
α_0	.0069	.0069	.0064	.0064
	(.00039)	(.00039)	(.00017)	(.00017)
α_π	1.3079	1.3079	.5220	.5220
	(.0527)	(.0527)	(.0175)	(.0175)
α_x	.0232	.0232	.0462	.0462
	(.0116)	(.0116)	(.0043)	(.0043)
σ_R^2	1.266e-5	9.184e-7	2.713e-5	5.434e-7
	(8.670e-6)	(1.960e-6)	(5.423e-6)	(1.512e-6)

TABLE 1. Monetary policy estimates. Log likelihood value = −1014.737.

State	$S_t^F = 1$	$S_t^F = 2$
γ_0	.0497	.0385
	(.0021)	(.0032)
γ_b	.0136	-.0094
	(.0012)	(.0013)
γ_x	.4596	.2754
	(.0326)	(.0330)
γ_g	.2671	.6563
	(.0174)	(.0230)
σ_τ^2	4.049e-5	5.752e-5
	(6.909e-6)	(8.472e-6)

TABLE 2. Tax policy estimates. Log likelihood value = −765.279.

$$P^M = \begin{bmatrix} .9349 & .0651 & .0000 & .0000 \\ .0000 & .9324 & .0444 & .0232 \\ .0093 & .0000 & .9552 & .0355 \\ .0000 & .0332 & .0529 & .9139 \end{bmatrix}, P^F = \begin{bmatrix} .9372 & .0628 \\ .0520 & .9480 \end{bmatrix}$$

TABLE 3. Monetary and fiscal policy transition matrices

Regime	Fraction of new debt backed by PV of taxes	$\frac{PV(\Delta y)}{\Delta \tau}$ after 5 quarters	10 quarters	25 quarters	∞
Conventional information set Ω_t					
AM/PF	.673	−.108	−.199	−.417	−1.019
PM/PF	.586	−.515	−.686	−.759	−.761
PM/AF	.488	−.623	−.855	−.976	−.981
Foreknowledge information set Ω_t^*					
AM/PF	-	−.106	−.195	−.410	−.997
PM/PF	-	−.460	−.612	−679	−.681
PM/AF	-	−.556	−.762	−.873	−.877

TABLE 4. Output multipliers for taxes conditional on regime

Initial Regime	$\frac{PV(\Delta y)}{\Delta \tau}$ after 5 quarters	10 quarters	25 quarters
AM/PF	$[-.126, -.400]$	$[-.213, -.754]$	$[-.430, -.922]$
PM/PF	$[-.215, -.401]$	$[-.271, -.623]$	$[-.414, -.764]$
PM/AF	$[-.365, -.568]$	$[-.537, -.928]$	$[-.993, -1.363]$

TABLE 5. Output multipliers for taxes, unconditional: 80th percentile bands based on 10,000 draws

Regime	$\%\Delta P$ after 5 quarters	10 quarters	25 quarters	∞
AM/PF	0.324	0.641	1.513	6.704
PM/PF	0.770	1.077	1.232	1.237
PM/AF	0.949	1.369	1.620	1.633

TABLE 6. Cumulative effect on price level of an *i.i.d.* unanticipated tax cut of 2 percent of output

		$\%\Delta P$ after	
Initial Regime	5 quarters	10 quarters	25 quarters
AM/PF	$[.324, .687]$	$[.641, 1.306]$	$[1.158, 2.160]$
PM/PF	$[.678, .770]$	$[.840, 1.077]$	$[.533, 1.232]$
PM/AF	$[.949, 1.008]$	$[1.325, 1.551]$	$[1.610, 2.269]$

TABLE 7. Cumulative effect on the price level of an *i.i.d.* tax cut of 2 percent of output, unconditional: 80th percentile bands based on 10,000 draws

	All Regimes	AM/PF	PM/PF	PM/AF
α_π	0.723	1.308	0.595	0.528
γ_b	0.002	0.016	0.018	-0.003

TABLE 8. Policy parameters from identified VAR estimated on simulated data. "All Regimes" from stochastic simulation drawing from regime; others are conditional on regime. Estimated equations are $\tau_t = \gamma_0 + \gamma_x x_t + \gamma_b b_{t-1} + \varepsilon_t^\tau$, $r_t = \alpha_0 + \alpha_\pi \pi_t + \alpha_x x_t + \varepsilon_t^R$, with γ_x and α_x restricted to values used to simulate model. Samples of length 10,000.

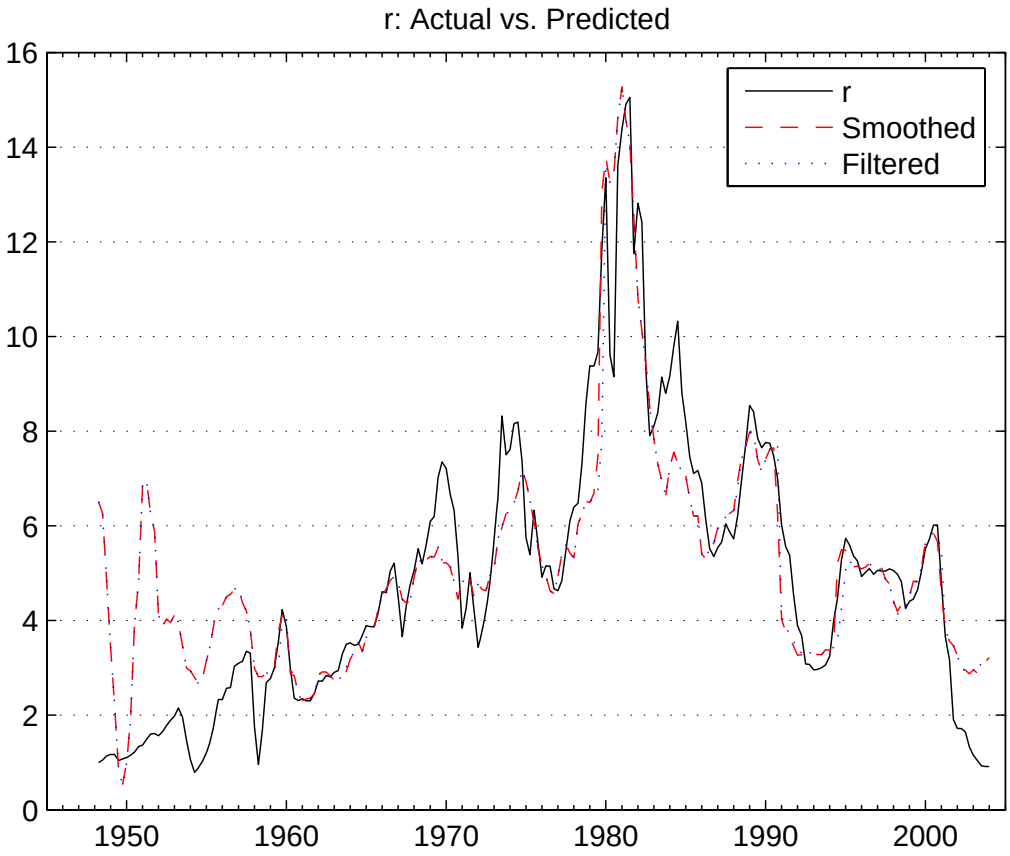


FIGURE 1. Actual and predicted paths of the nominal interest rate from estimates of the monetary policy rule, equation (1) using smoothed and filtered probabilities.

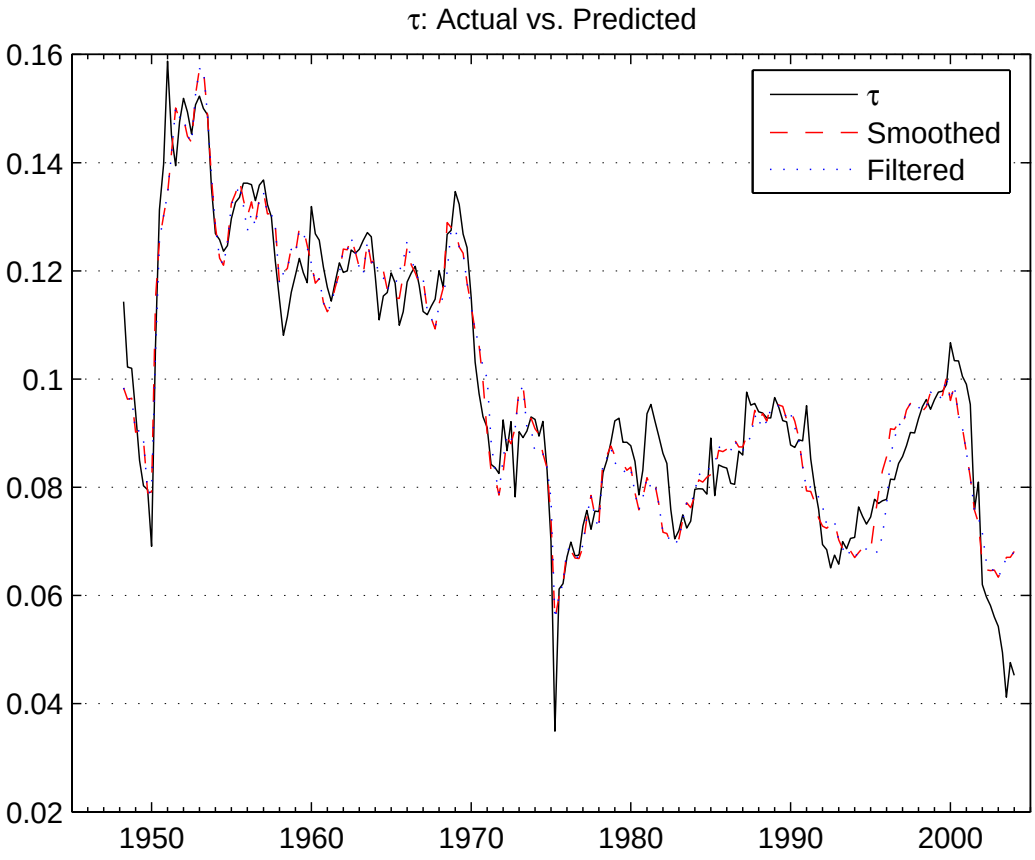


FIGURE 2. Actual and predicted paths of the tax-output ratio from estimates of the tax policy rule, equation (2), using smoothed and filtered probabilities.

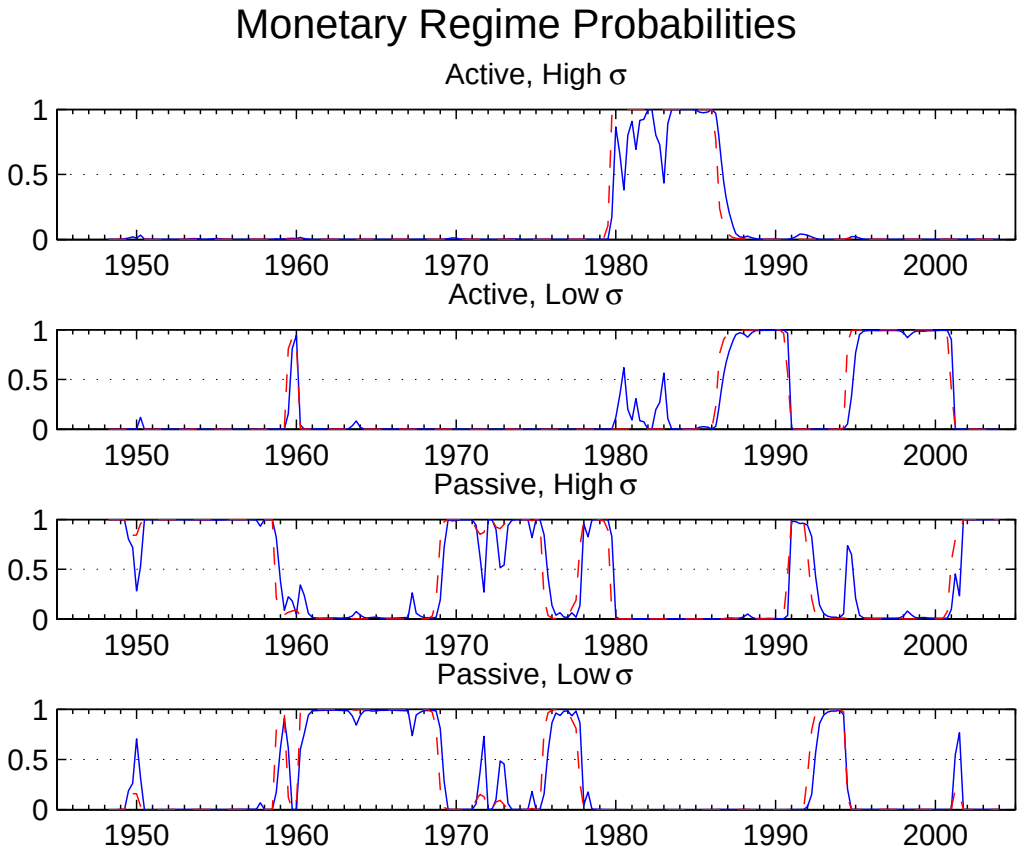


FIGURE 3. Smoothed (solid line) and filtered (dashed line) probabilities.

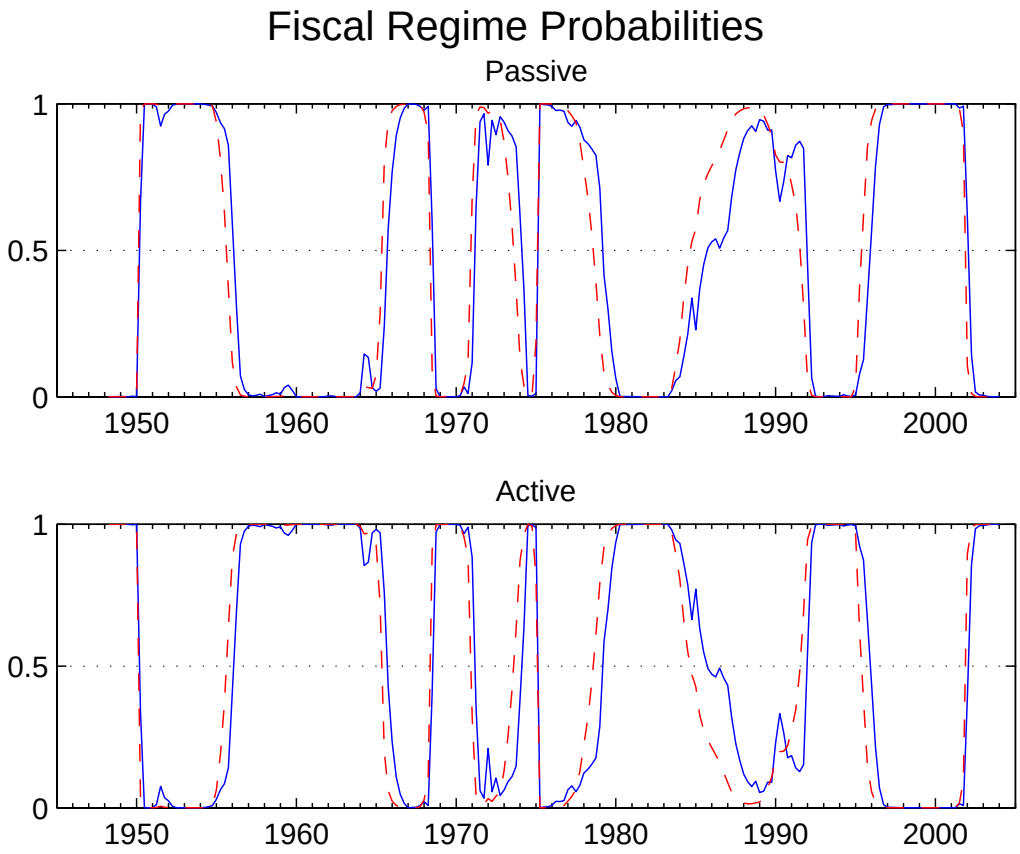


FIGURE 4. Smoothed (solid line) and filtered (dashed line) probabilities.

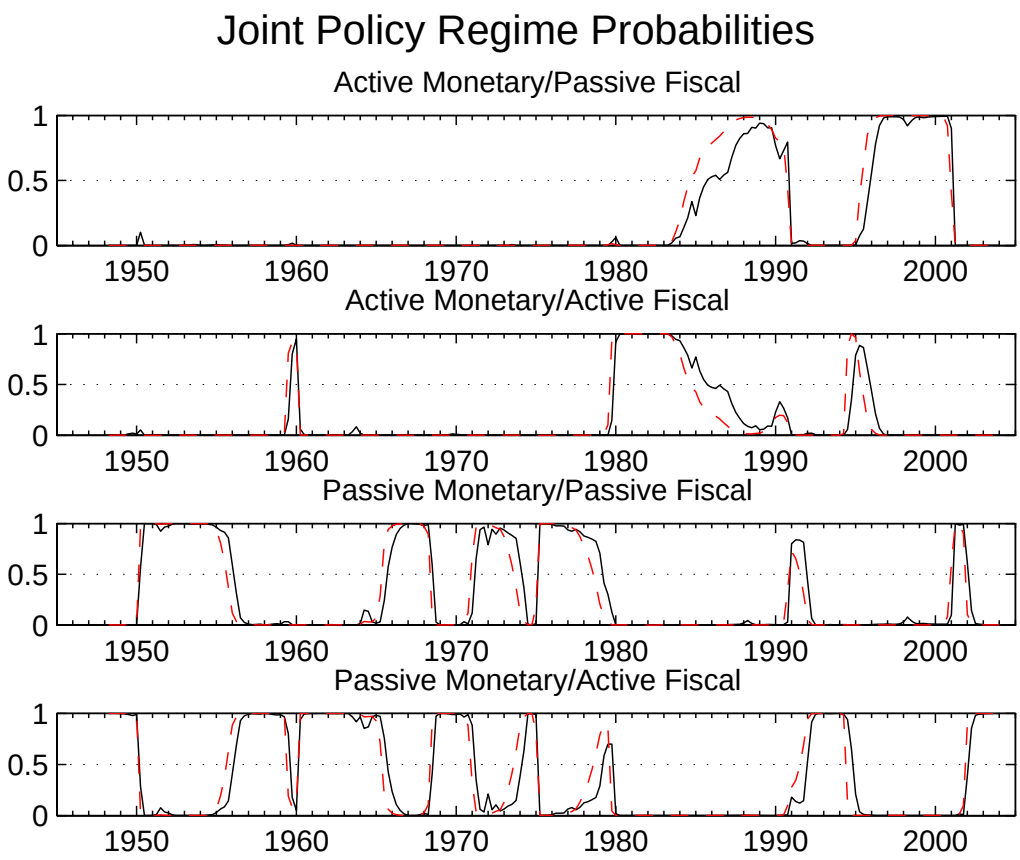


FIGURE 5. Smoothed (solid line) and filtered (dashed line) probabilities.

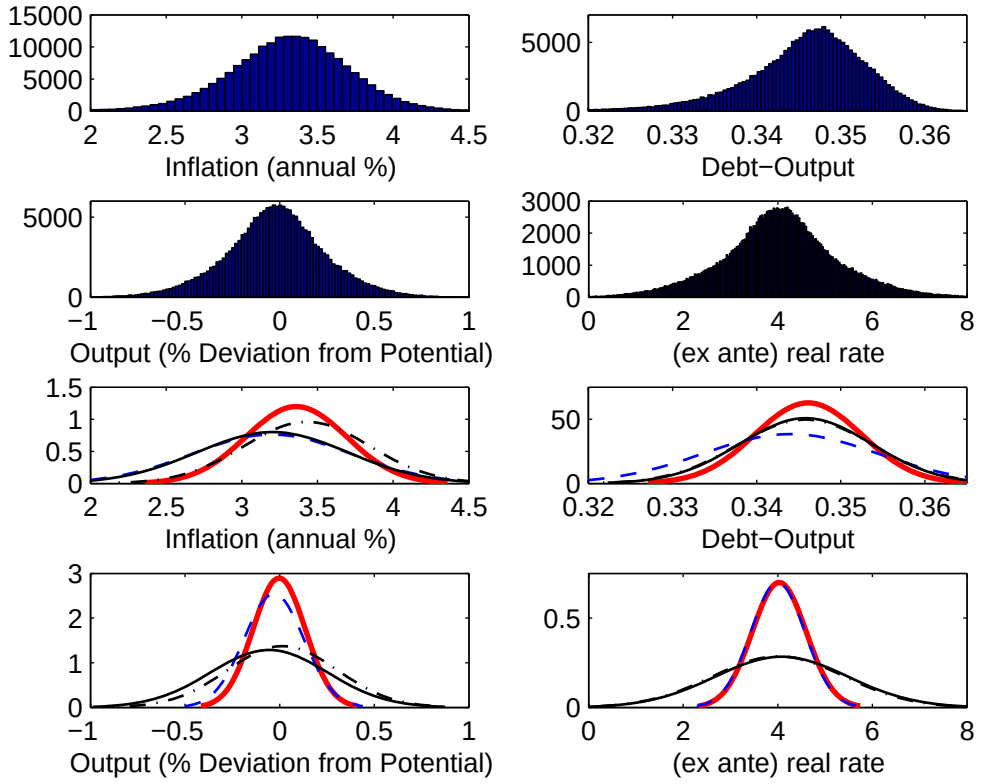


FIGURE 6. Distributions: unconditional and conditional. Top four panels are unconditional distributions, taking draws from policy shocks and regimes; bottom four panels are conditional on regime, sorting observations by designated regime. AM/PF (thick solid), AM/AF (dashed), PM/PF (dotted-dashed), PM/AF (thin solid).

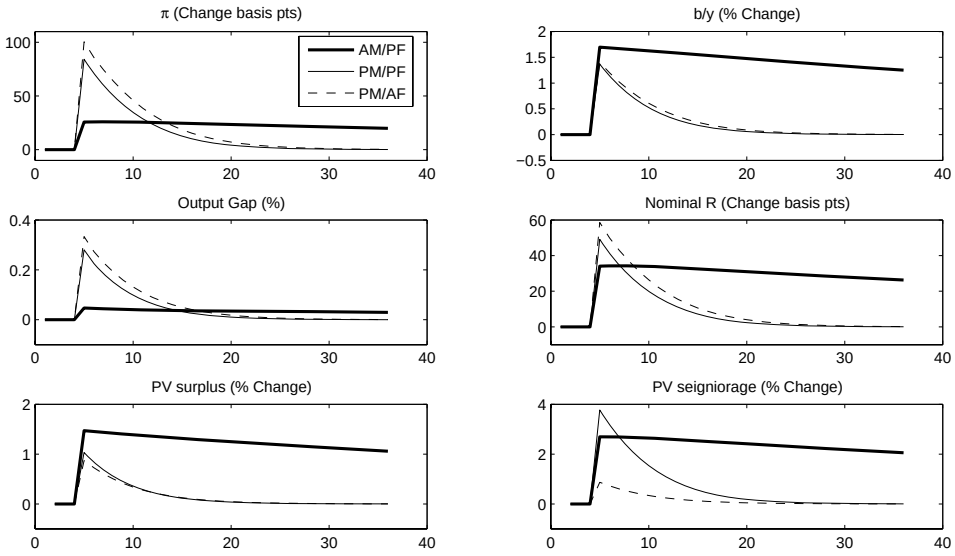


FIGURE 7. Responses to an *i.i.d.* tax cut of 2 percent of output, conditional on remaining in the prevailing regime.

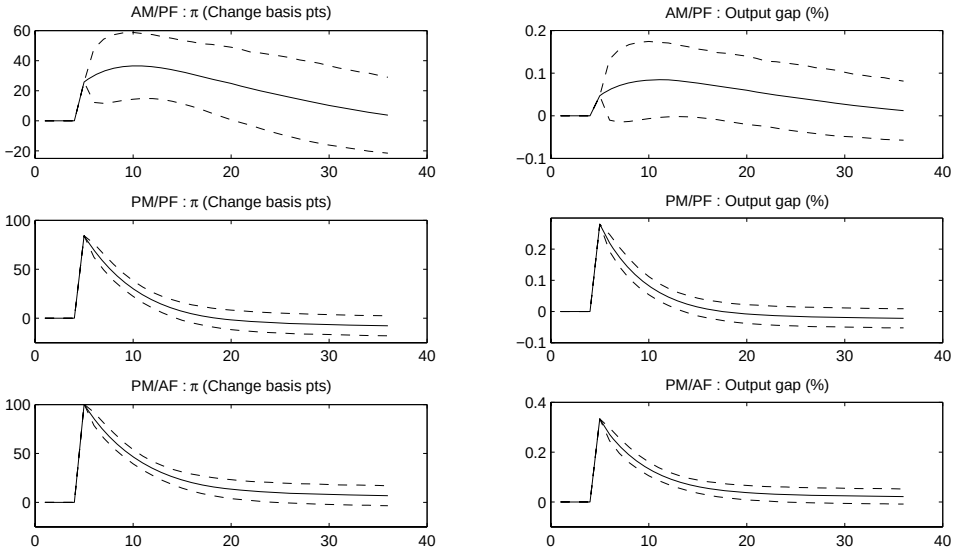


FIGURE 8. Responses to an *i.i.d.* tax cut, given the regime at the date of the shock and drawing from regime over the forecast horizon.

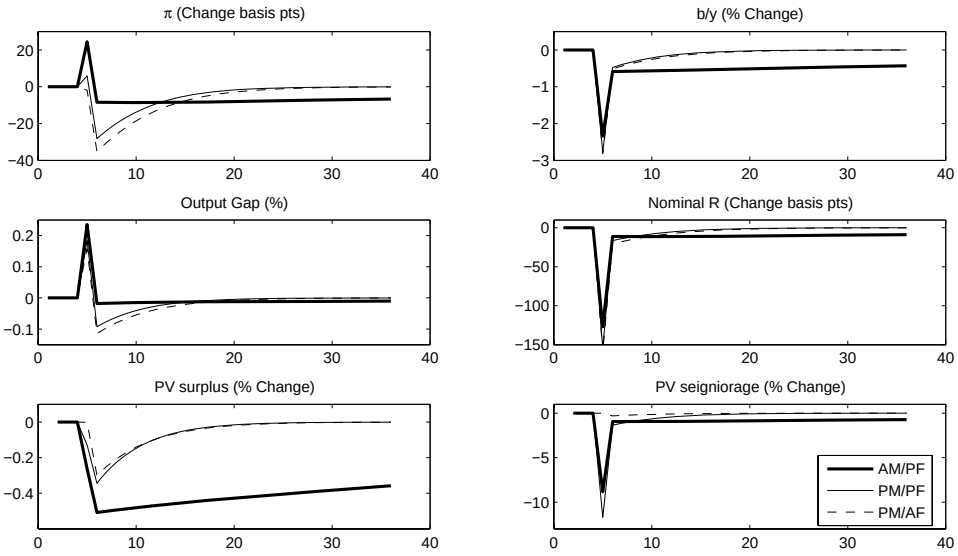


FIGURE 9. Responses to an *i.i.d.* monetary expansion, conditional on remaining in the prevailing regime.

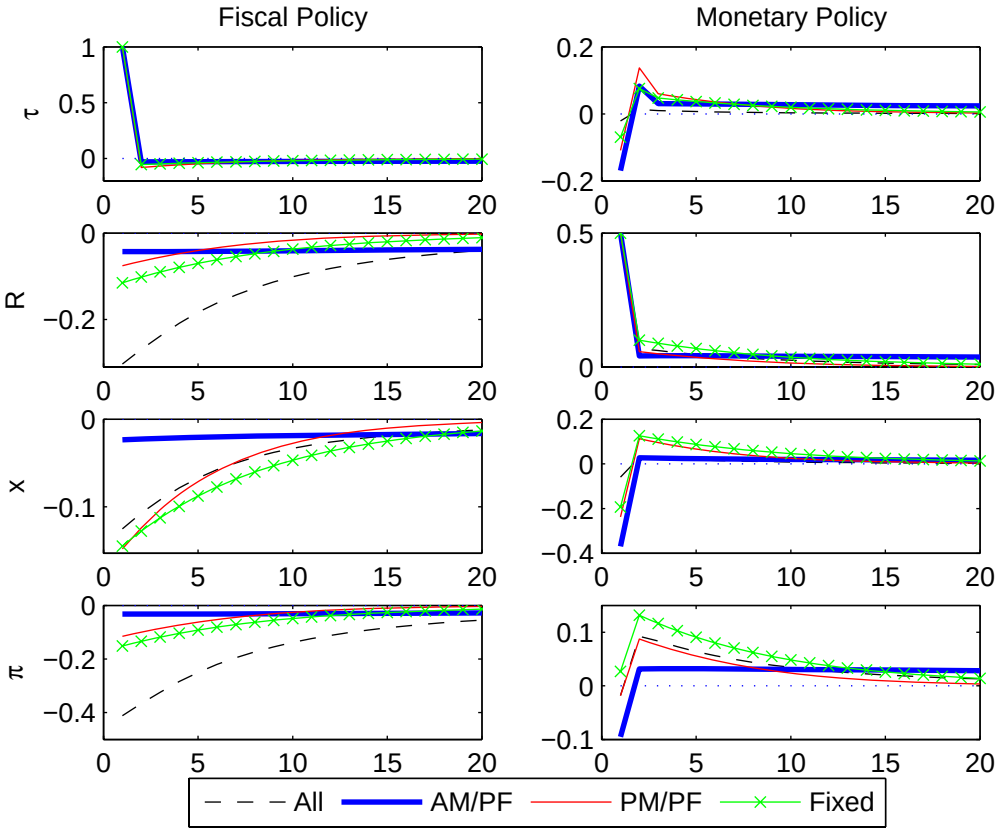


FIGURE 10. Impacts of policy shocks. Estimated from simulated data and produced by fixed-regime DSGE model.