GENERALIZING THE TAYLOR PRINCIPLE

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Abstract. Recurring change in a monetary policy function that maps endogenous variables into policy choices alters both the nature and the efficacy of the Taylor principle—the proposition that central banks can stabilize the macroeconomy by raising their interest rate instrument more than one-for-one in response to higher inflation. A monetary policy process is a set of policy rules and a probability distribution over the rules. We derive restrictions on that process that satisfy a long-run Taylor principle and deliver unique equilibria in two standard models. A process can satisfy the Taylor principle in the long run, but deviate from it in the short run. The paper examines three empirically plausible processes to show that predictions of conventional models are sensitive to even small deviations from the assumption of constant-parameter policy rules.

1. Introduction

Monetary policy making is complex. Central bankers examine a vast array of data, hear from a variety of advisors, use suites of models to interpret the data, and apply judgment to adjust the predictions of models. This process produces a monetary policy rule that is a complicated, probably non-linear, function of a large set of information about the state of the economy.

For both descriptive and prescriptive reasons, macroeconomists have sought a simple characterization of policy. Perhaps the most successful simplification is due to Taylor (1993). He finds that a very simple rule does a good job of describing Federal Reserve interest-rate decisions, particularly since 1982. Taylor's rule is

$$i_t = \alpha(\pi_t - \pi^*) + \gamma x_t + \varepsilon_t, \tag{1}$$

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where i is the central bank's policy interest rate, π is inflation, π^* is the central bank's inflation target, x is output, and ε is a possibly serially correlated random variable. With settings of $\alpha = 1.5$ and $\gamma = .5$ or 1, Taylor (1999a) uses this equation to interpret Federal Reserve behavior over several eras since 1960.

The Taylor principle—the proposition that central banks can stabilize the macroeconomy by adjusting their interest rate instrument more than one-for-one with inflation (setting $\alpha > 1$)—and the Taylor rule that embodies it have proven to be powerful devices to simplify the modeling of policy behavior. The rule appears to be a good approximation to Federal Reserve behavior since the early 1980s [Taylor (1993, 1999a), Clarida, Gali, and Gertler (2000)]. It has also been found to produce desirable outcomes in a class of models now in heavy use in policy research [Bryant, Hooper, and Mann (1993), Rotemberg and Woodford (1997), Taylor (1999b), Schmitt-Grohe and Uribe (2004)]. Some policy institutions publish the policy interest rate paths implied by Taylor-inspired simple rules, believing that these present useful benchmarks for policy evaluation [Bank for International Settlements (1998), Sveriges Riksbank (2001, 2002), Norges Bank (2005), Federal Reserve Bank of St. Louis (2005)]. In large part because it is a gross simplification of reality, the Taylor rule has been extraordinarily useful.

Gross simplification is both a strength and a weakness of a constant-parameter rule like (1). Because the rule compresses and reduces information about actual policy behavior, it can mask important aspects of that behavior. There are clearly states of the economy in which policy settings of the nominal interest rate deviate from the rule in substantial and serially correlated ways. This confronts researchers with a substantive modeling choice: it matters whether these deviations are shuffled into the ε's or modeled as time-varying feedback coefficients, α_t and γ_t. Positing that policy rules mapping endogenous variables into policy choices evolve according to some probability distribution can fundamentally change dynamics, including conditions that ensure a unique equilibrium, and substantially expand the set of unique, stationary rational expectations equilibria supported by conventional monetary models.

This paper generalizes Taylor's rule and principle by allowing the parameters of that rule to vary stochastically over time.[1] It examines how such time variation affects the nature of equilibrium in popular models of monetary policy. As a first step, in this paper we model parameters as evolving exogenously according to a Markov chain. The models admit analytical solutions that make transparent how time variation in policy

[1] In contrast to our approach, some papers consider changes in processes governing exogenous policy variables [Dotsey (1990), Kaminsky (1993), Ruge-Murcia (1995), Andolfatto and Gomme (2003), Davig (2003, 2004), and Leeper and Zha (2003)]. Each of these considers changes in exogenous processes for policy instruments like a tax rate, money growth rate, or government expenditures. Two other papers model policy switching as changes in endogenous policy functions [Davig, Leeper, and Chung (2004) and Davig and Leeper (2005)].

parameters changes the set of equilibria conventional monetary models support. Our modeling strategy springs from a desire to retain the simplicity of the Taylor rule and the Taylor principle while taking a step toward realism by recognizing that actual monetary policy behavior is complex and it does not strictly conform to a simple constant-coefficient rule.

In the Markov-switching literature, different possible realizations of policy parameters are referred to as "regimes" or "states" [Hamilton (1989) or Kim and Nelson (1999)]. Although we use these terms interchangeably with "rules," nothing rests on the terminology. Readers who believe the actual policy rule is time-invariant can interpret this paper as pointing out that introducing a particular form of non-linearity in policy rules can lead to important changes in the predictions of monetary models.

Our analysis starts with a simple model of inflation determination to illustrate the following general points:

(1) A unique equilibrium does not require the Taylor principle to hold in every period, but it does require that it hold for the ergodic distribution of policy. This leads to a *long-run Taylor principle*, which we derive explicitly.
(2) Monetary policy can experience substantial (but brief) or modest (and prolonged) departures from the Taylor principle and still deliver a unique equilibrium.
(3) If there are two possible policy rules—one that aggressively reacts to inflation ("more active") and one that reacts less aggressively ("less active" or "passive")—the prospect that future policy might be less active can spillover to the equilibrium under the more-active rule. The cross-regime spillover can be substantial, making the volatility of inflation under the more-active rule many times its level in a corresponding constant-parameter specification.

These themes extend to a conventional model of inflation and output determination in which price adjustment obeys Calvo's (1983) mechanism:

(4) The long-run Taylor principle can dramatically expand the region of determinacy relative to the constant-parameter setup.
(5) Cross-rule spillovers occur whenever rules differ. Those spillovers can change the responses of inflation and output to exogenous disturbances in quantitatively important ways.

Compelling empirical evidence points toward recurring regime change as a plausible working hypothesis to replace the convention of constant-coefficient policy rules. Based on that evidence, we calibrate the model to three empirically plausible policy scenarios that illustrate the potential spillovers that can arise. First, we consider Goodfriend's (1993) "inflation scares," in which policy is usually active but occasionally becomes very active, reacting more strongly to current inflation. Second, drawing on evidence from Marshall (2001) and Rabanal (2004), we examine episodes in which, because of worries about financial instability or slow recoveries from recessions, the central bank reduces the weight it places on inflation stabilization relative to output stabilization. The third scenario addresses a major branch of applied work, which finds evidence of time variation in monetary policy in the United States.[2] To model the idea that there is some probability that U.S. monetary policy can return to the policies of the 1970s, we posit two persistent policy rules—one active and the other passive—and show how the effects of aggregate disturbances differ from a constant policy parameter setup. Each of these scenarios underscores that deviations, even small ones, from the maintained assumption that policy parameters are fixed can drastically alter the models' predictions of the impacts of exogenous disturbances.

Results from the three scenarios illustrate potential pitfalls in studies of monetary policy. Many researchers insert estimated versions of (1) into dynamic stochastic general equilibrium models to study how the model economy performs [see papers in Bryant, Hooper, and Mann (1993), Taylor (1999b) and Faust, Orphanides, and Reifschneider (forthcoming)]. Those researchers face a substantive choice between modeling deviations from the constant-coefficient Taylor rule as serially correlated ε's or as time-varying feedback coefficients.[3] This modeling choice affects expectations formation. By assuming that parameters are fixed, deviations from the rule that are nonetheless *systematic* responses to the economy, are ruled out. Policy is not modeled as responding differently to inflation and output during business cycle expansions and contractions, dramatic run-ups of long-term interest rates, oil-price increases, stock market crashes, foreign financial crises, or "jobless recoveries." Instead, these systematic and predictable deviations appear as serially correlated errors that do not affect solutions or the qualitative nature of equilibrium.

This paper pursues the alternative choice—modeling deviations from a simple Taylor rule as time-varying systematic responses of policy to the economy—and shows the implications of that choice for the predictions of two standard monetary models.

[2]For example, Judd and Trehan (1995), Taylor (1999a), Clarida, Gali, and Gertler (2000), Kim and Nelson (2004), Lubik and Schorfheide (2004), Rabanal (2004), Davig and Leeper (2005), Favero and Monacelli (2005), Boivin and Giannoni (forthcoming), Boivin (forthcoming), and Sims and Zha (forthcoming).

[3]Taylor (1993) acknowledges that the rule shuffles into ε much of the detail about how monetary policy responds to the myriad exogenous disturbances that buffet the economy. He provides some illustrations of circumstances in which a central bank would decide *not* to follow (1) rigidly. In Taylor (1999a), he characterizes substantial and persistent departures from the rule in the early 1960s, from the mid-1960s through the 1970s, and in the early 1980s as "policy mistakes."

2. A Model of Inflation Determination

An especially simple model of inflation determination emerges from using Lucas's (1978) asset-pricing framework to price nominal government bonds. The setup is rich enough to highlight general features that arise in a rational expectations environment with regime change in monetary policy, but simple enough to admit analytical solutions that make transparent the mechanisms at work.

We adopt a two-step procedure to solve the models in this paper. First, we derive the evolution equations for endogenous variables, from which we derive analytical conditions on the model parameters, which ensure there exists a unique equilibrium. Next, we derive a stationary equilibrium using the method of undetermined coefficients to obtain solutions as functions of the minimum set of state variables. Conditions from step one are employed to guarantee the solution in step two is unique. Throughout the paper, fiscal policy is in the background, passively adjusting lump-sum taxes and transfers to ensure fiscal solvency.

2.1. **The Setup.** Consider a nominal bond that costs \$1 at date t and pays off $\$(1+i_t)$ at date $t+1$. The asset-pricing equation for this bond can be written in log-linearized form as:

$$i_t = E_t\pi_{t+1} + E_t r_{t+1}, \tag{2}$$

where $E_t r_{t+1}$, the expected real interest rate, is the conditional expectation at t of the stochastic discount factor. For simplicity, the real interest rate is exogenous and evolves according to

$$r_t = \rho r_{t-1} + \upsilon_t, \tag{3}$$

with $|\rho| < 1$ and υ is an $i.i.d.$ random variable.

Monetary policy follows a simplified Taylor rule, adjusting the nominal interest rate in response to inflation, where the reaction to inflation evolves stochastically between regimes:[4]

$$i_t = \alpha(s_t)\pi_t. \tag{4}$$

s_t is the observed policy regime, which takes realized values of 1 or 2. Two regimes are sufficient for our purposes, though the methods employed immediately generalize to many regimes. Regime follows a Markov chain with transition probabilities $p_{ij} = P[s_t = j\,|s_{t-1} = i]$, where $i, j = 1, 2$. We assume

$$\alpha(s_t) = \begin{cases} \alpha_1 \text{ for } s_t = 1 \\ \alpha_2 \text{ for } s_t = 2 \end{cases}.$$

We assume the processes for s and υ are independent.

[4]Although this rule is clearly sub-optimal in this model, its use is motivated by the fact that it produces effects that carry over to a richer model, like the one in section 3, in which Taylor rules are nearly optimal.

A *monetary policy regime* is a distinct realization of the random variable $\alpha(s_t)$ and a *monetary policy process* consists of all possible α_i's and the transition probabilities of the Markov chain, $(\alpha_1, \alpha_2, p_{11}, p_{22})$. In this model, monetary policy is *active* in regime i if $\alpha_i > 1$ and *passive* if $\alpha_i < 1$, following the terminology of Leeper (1991). If $\alpha_1 > \alpha_2$, then the monetary policy process becomes *more active* if α_1, α_2, or p_{11} increase or p_{22} decreases.

Substituting (4) into (2) and using (3), the system reduces to the single state-dependent equation:

$$\alpha(s_t)\pi_t = E_t\pi_{t+1} + \rho r_t. \tag{5}$$

Realizations of the real interest rate at t can affect current inflation only if they are informative about the future path of r; that is, only if $\rho \neq 0$. The serial correlation of r, therefore, plays the role of a propagation mechanism in this model, which otherwise contains no source of propagation.

If only a single, fixed regime were possible, then $\alpha_i = \alpha$ and the expected path of policy depends on the constant α. A unique equilibrium requires active policy behavior ($\alpha > 1$) and the solution to (5) would be

$$\pi_t = \frac{\rho}{\alpha - \rho} r_t.$$

Stronger responses of policy to inflation (larger values of α) reduce the variability of inflation. The Taylor principle says that $\alpha > 1$ is necessary and sufficient for a unique equilibrium.

When $\alpha < 1$ and regime is fixed, the equilibrium is not unique and self-fulfilling sunspot equilibria are possible. In this case, the difference equation for inflation is stable and the "forward solution" is non-stationary. Stationary solutions for inflation make π_t a function of (π_{t-1}, r_t) and possibly a sunspot shock.

2.2. **The Long-Run Taylor Principle.** With regime change, the difference equation in (5) can be expressed as a system, with an equation for each possible date t regime. Let $\Omega_t^{-s} = \{r_t, r_{t-1}, \ldots, s_{t-1}, s_{t-2}, \ldots\}$ denote the representative agent's information set at t, not including the current regime, and let $\Omega_t = \Omega_t^{-s} \cup \{s_t\}$. All expectations are formed conditional on Ω_t.

In general, the expectation of inflation in (5) is given by

$$E[\pi_{t+1}(s_{t+1} = i, s_t = j) \,|\Omega_t],$$

for $i, j = 1, 2$. Integrating out the current regime, s_t, and writing (5) for $s_t = 1$ and $s_t = 2$,

$$\begin{aligned} \alpha(s_t = 1)\pi_t(s_t = 1) = p_{11}E[\pi_{t+1}(s_{t+1} = 1, s_t = 1) \,\big|\Omega_t^{-s}] \\ +(1 - p_{11})E[\pi_{t+1}(s_{t+1} = 2, s_t = 1) \,\big|\Omega_t^{-s}] + \rho r_t \end{aligned} \tag{6}$$

and

$$\alpha(s_t = 2)\pi_t(s_t = 2) = (1 - p_{22})E[\pi_{t+1}(s_{t+1} = 1, s_t = 2) \,\big|\Omega_t^{-s}] \\ + p_{22}E[\pi_{t+1}(s_{t+1} = 2, s_t = 2) \,\big|\Omega_t^{-s}] + \rho r_t. \quad (7)$$

These equations are derived assuming that current regime enters the agent's information set. This assumption contrasts with the usual econometric treatment of regime as an unobserved state variable [Hamilton (1989) or Kim and Nelson (1999)]. Future regimes, however, are not known.[5]

Appendix A shows how to convert these equations into a system in realized state-dependent inflation rates, whose dynamics are governed by the eigenvalues of

$$\begin{bmatrix} p_{11} & 1-p_{11} \\ 1-p_{22} & p_{22} \end{bmatrix}^{-1} \begin{bmatrix} \alpha_1 & 0 \\ 0 & \alpha_2 \end{bmatrix}.$$

Those eigenvalues are

$$\lambda_k = \frac{p_{11}\alpha_2 + p_{22}\alpha_1 \pm \sqrt{(p_{11}\alpha_2 + p_{22}\alpha_1)^2 + 4\alpha_1\alpha_2(1 - p_{11} - p_{22})}}{2(p_{11} + p_{22} - 1)}, \qquad k = 1, 2. \quad (8)$$

A unique equilibrium requires that the absolute values of both roots exceed unity, leading to a generalization of the Taylor principle. A monetary policy process satisfies the *long-run Taylor principle* if and only if

$$\lambda_k > 1 \text{ for } k = 1, 2.$$

Two unstable eigenvalues imply two linear restrictions that uniquely determine the regime-dependent expectations of inflation in (6) and (7). This is quite different from fixed regimes because now it is possible for both roots to be unstable, even if $\alpha_i < 1$ in one regime. With regime switching, when there is a unique equilibrium, the solutions always come from "solving forward," even in regimes where monetary policy behavior is passive ($\alpha_i < 1$). This delivers solutions that are qualitatively different from those obtained with fixed regimes. The roots are highly non-linear functions of all the parameters of the monetary policy process, including the feedback coefficients in the rule and the transition probabilities for regimes.

A necessary condition for uniqueness is that policy be active in at least one regime, so $\alpha_i > 1$ for some i. When this necessary condition is satisfied, the long-run Taylor principle simplifies to:

$$p_{11}(1 - \alpha_2) + p_{22}(1 - \alpha_1) + \alpha_1\alpha_2 > 1. \quad (9)$$

[5] Some theoretical work treats agents as having to infer the current regime [Andolfatto and Gomme (2003), Leeper and Zha (2003), and Davig (2004)]. Concentrating all uncertainty about policy on future regimes, as we do, makes clearer how expectations formation, as opposed to inference problems, affect the regime-switching equilibrium.

This determinacy condition implies that a range of monetary policy behavior is consistent with a unique equilibrium: monetary policy can be mildly passive most of the time or very passive some of the time. To see this, suppose that regime 1 is active and regime 2 is passive and consider the limiting case that arises as α_1 becomes arbitrarily large. Driving $\alpha_1 \to \infty$ in (9) implies that $\alpha_2 > p_{22}$ is the lower bound for α_2 in a determinate equilibrium. For α_1 sufficiently large, a unique equilibrium can have α_2 arbitrarily close to 0 (a pegged nominal interest rate), so long as the regime in which this passive policy is realized is sufficiently short-lived ($p_{22} \to 0$). When regime 1 is an absorbing state ($p_{11} = 1$), the eigenvalues are α_1 and α_2/p_{22}. A unique equilibrium requires that that $\alpha_1 > 1$ and $\alpha_2 > p_{22}$.[6] The general principle is that an active regime that is either very aggressive ($\alpha_1 \to \infty$) or very persistent ($p_{11} = 1$) imposes the weakest condition on behavior in the passive regime.

Alternatively, the passive regime can be extremely persistent ($p_{22} \to 1$), so long as α_2 is sufficiently close to, but still less than, 1. In this case, if the active regime has short duration, it is possible for the ergodic probability of the passive regime to be close to 1 (but less than 1), yet still deliver a unique equilibrium.

An interesting special case arises when both regimes are reflecting states. With $p_{11} = p_{22} = 0$, the eigenvalues reduce to $\lambda_k = \pm\sqrt{\alpha_1\alpha_2}$. When the α's are both positive and regime 1 is active, the lower bound on the passive policy (α_2) for a unique equilibrium is $\alpha_2 > 1/\alpha_1$. In this case, the economy spends equal amounts of time in the two regimes, but it changes regime every period with probability 1. This inequality reinforces the general principle that the more aggressive monetary policy is in active regimes, the more passive it can be in other regimes and still deliver uniqueness.

Figure 1 uses the eigenvalues in (8) to plot combinations of the policy-rule coefficients, α_1 and α_2, that deliver unique equilibria for given transition probabilities. Light-shaded areas mark regions of the parameter space that deliver unique equilibria when regime is fixed. When regime can change, those regions expand to include the dark-shaded areas. The top two panels show that as the mean duration, given by $1/(1 - p_{ii})$, of each regime declines, the determinacy region expands. Asymmetric mean duration expands the determinacy region in favor of the parameter drawn from the more transient regime (α_2 in the southwest panel of the figure). As the mean durations of both regimes approach 1 period, the determinacy region expands dramatically along both the α_1 and α_2 dimensions, as the southeast panel shows.

[6] As the system derived in appendix A makes clear, $p_{11} = 1$ makes the system recursive, so the difference equation for inflation in state 1 is independent of state 2 and yields the usual fixed-regime solution for inflation. The second equation reduces to a difference equation in inflation in state 2 and a unique, stationary solution to that equation requires $\alpha_2 > p_{22}$.

2.3. **Solutions.** To solve the model, define the state of the economy at time t to be (r_t, s_t). We are interested only in unique, stationary equilibria. We find the model's minimum state variable (MSV) solution by positing regime-dependent linear solutions of the form:

$$\pi_t = a(s_t) r_t,$$

where

$$a(s_t) = \begin{cases} a_1 \text{ for } s_t = 1 \\ a_2 \text{ for } s_t = 2 \end{cases}.$$

Within the class of solutions that are functions of (r_t, s_t), the MSV solution is unique. Of course, there may be other solutions that are functions of an expanded state vector, so the question of whether the MSV solution is the *only* solution remains to be answered. We use (8) to check that all the solutions we report are unique.

Expected inflation one step ahead depends on this period's realizations of regime and real interest rate, as well as on next period's expected solution:

$$\begin{aligned} E_t \pi_{t+1} &= E[\pi_{t+1} \,|s_t, r_t] \\ &= \rho r_t E[a(s_{t+1}) \,|s_t, r_t], \end{aligned} \tag{10}$$

where we have used the independence of the processes governing r and s. The posited solutions, together with (10), imply the following regime-dependent expectations:

$$E[\pi_{t+1} \,|s_t = 1, r_t] = [p_{11} a_1 + (1 - p_{11}) a_2] \rho r_t, \tag{11}$$

$$E[\pi_{t+1} \,|s_t = 2, r_t] = [(1 - p_{22}) a_1 + p_{22} a_2] \rho r_t. \tag{12}$$

Substituting (11) and (12) into (5) for each $s_t = 1, 2$, we obtain a linear system in the unknown coefficients, (a_1, a_2) :

$$A \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} = b,$$

where

$$A = \begin{bmatrix} \alpha_1 - \rho p_{11} & -\rho(1 - p_{11}) \\ -\rho(1 - p_{22}) & \alpha_2 - \rho p_{22} \end{bmatrix}, \qquad b = \begin{bmatrix} \rho \\ \rho \end{bmatrix}.$$

The solutions are:

$$a_1 = a_1^F \left(\frac{1 + p_{12} a_2^F}{1 - p_{12} a_2^F p_{21} a_1^F} \right), \tag{13}$$

and

$$a_2 = a_2^F \left(\frac{1 + p_{21} a_1^F}{1 - p_{12} a_2^F p_{21} a_1^F} \right), \tag{14}$$

where we have used the facts that $p_{12} = 1 - p_{11}$ and $p_{21} = 1 - p_{22}$, and we have defined the "fixed-regime" coefficients to be[7]

$$a_i^F = \frac{\rho}{\alpha_i - \rho p_{ii}}, \qquad i = 1, 2.$$

The limiting arguments applied to (9), together with the stationarity of the real interest rate process, imply that in a unique equilibrium, $\alpha_i > \rho p_{ii}$, so $a_i^F \geq 0$. a_i^F is strictly increasing in ρ (for $\alpha_i > 0$), strictly decreasing in α_i (for $\rho > 0$), and strictly increasing in p_{ii} (for $\rho > 0$). It is straightforward to show that the volatility of inflation is smaller in the regime where policy is more active; that is, $a_1 < a_2$ if $\alpha_1 > \alpha_2$.

Notice that if $\alpha_2 < 1$, nothing like solution (14) can emerge from a fixed-regime setup. In a fixed-regime model, $\alpha < 1$ creates a stable root which, following Sargent's (1987) dictum to "solve unstable roots forward and stable roots backward," makes a stationary solution for π_t depend on π_{t-1} (and shocks). With recurring regime change, in contrast, the "forward solution" is stationary even when $\alpha_2 < 1$. This has the effect of expanding the set of unique, stationary rational expectations equilibria relative to those available under fixed regimes.

In general, all policy parameters enter the solution. Policy behavior in regime 2 affects the equilibrium in regime 1 and vice versa. Let $D = 1 - p_{12} a_2^F p_{21} a_1^F$ denote the denominator common to (13) and (14). $D \in (0, 1]$ and reaches its upper bound whenever regimes are absorbing states ($p_{12} = 0$ or $p_{21} = 0$). Values of D less than 1 scale up the coefficients relative to their "fixed-regime" counterparts. D achieves its minimum when regimes are reflecting states ($p_{12} = p_{21} = 1$). In that case, $D = 1 - \rho^2/\alpha_1\alpha_2$, raising the variability of inflation by its maximum amount (given values for α_1 and α_2).

The numerators in the solutions report the two distinct effects that news about future real interest rates has on current inflation. Suppose the economy is in regime 1 and a higher real interest rate is realized. One effect is direct and raises inflation by an amount inversely related to α_1, just as it would if regime were fixed. A second effect works through expected inflation, $E[\pi_{t+1} | s_t = 1, r_t]$, which is the function given by (11), $(p_{11} a_1 + p_{12} a_2)\rho r_t$. The term $p_{12} a_2^F$ in (13) arises from the expectation that regime can change, with p_{12} the probability of changing from regime 1 to regime 2. The size of this effect is also inversely related α_1 through the coefficient a_1^F. Both of these effects are tempered when the current policy regime is active ($\alpha_1 > 1$) or amplified when current policy is passive ($\alpha_1 < 1$).

The a_1 and a_2 coefficients have the intuitive properties that they are strictly decreasing in both α_1 and α_2 and strictly increasing in ρ. More active monetary policy

[7] When regime is fixed at i, $p_{ii} = 1, p_{jj} = 0, i \neq j, i, j = 1, 2$ and the coefficients reduce to $a_i^F = \rho/(\alpha_i - \rho)$.

raises the α's and decreases the inflation impacts of real interest rate shocks. Greater persistence in real interest rates amplifies the magnitude and therefore the impact of real-rate shocks on inflation. If $\alpha_1 > \alpha_2$, then as p_{11} rises (holding p_{22} fixed), the persistence of the more-active regime and the fraction of time the economy spends in the more-active regime both rise. This reduces the reaction of inflation to real-rate disturbances in both regimes.[8]

How strongly regime 2 behavior affects the equilibrium in regime 1 depends on the probability of transitioning from regime 1 to regime 2, p_{12}, and on the policy behavior in and the persistence of regime 2, which are determined by α_2 and p_{22}. Cross-regime spillovers to regime 1 can be large if p_{12} is large, p_{22} is large, or α_2 is small. The only way to eliminate spillover is for regime 1 to be an absorbing state. In that case, $p_{11} = 1$ and the solution in that regime is $\pi_t = [\rho/(\alpha_1 - \rho)]r_t$, exactly the fixed-regime rule.

2.4. **Implications of Regime Switching.** Solutions (13) and (14) suggest the potential for spillovers from regime 2 to regime 1 and to the ergodic distribution of inflation. We now show that in this setup those spillovers can be quantitatively important. We restrict attention to regions of the policy parameter space for which a unique equilibrium exists.

Results in this section focus on how regime change alters the variability of inflation relative to a fixed-regime policy that always satisfies the Taylor principle. Throughout these examples, we assume that policy is more active in regime 1 than in regime 2 ($\alpha_1 > \alpha_2$) and that policy may be passive in regime 2 ($\alpha_2 < 1$). We show how in the switching setup the standard deviation of inflation conditional on regime 1 compares to its fixed-regime counterpart. For most of the results, we assume that in the active regime, whether fixed or switching, policy reacts to inflation with a coefficient of 1.5, as in Taylor's (1993) original formulation. If policy is less active (or passive) in regime 2, inflation can be appreciably more volatile even in the active regime, compared to fixed-regime policy.

2.4.1. *Mildly Passive Most of the Time.* Figure 2 illustrates the implications for inflation volatility of a policy process that is slightly passive most of the time, yet the equilibrium is unique. Active policy is transitory, lasting only one period before switching back to passive behavior ($p_{11} = 0$). The top panel indicates the ergodic probability of the active regime that is associated with each plot of relative standard deviations as a function of regime 2 policy (α_2). For a given α_2, the smaller the ergodic probability of the active regime, the more volatile inflation is in both regimes. In this example, that ergodic probability is given by $(1 - p_{22})/(2 - p_{22})$, so it is completely determined by the persistence of regime 2. Here the distinction between inflation

[8] Of course, if $\alpha_1 > \alpha_2$ and p_{22} rises (holding p_{11} fixed), then both a_1 and a_2 rise.

behavior in the two regimes is not very pronounced because the high probability of transitioning from regime 1 to 2 maximizes the spillovers. These spillovers are substantial, with inflation more than five times more volatile in the active regime than in its fixed-regime counterpart.

This example creates difficulties for empirical efforts to infer whether observed time series were generated by a determinate or an indeterminate equilibrium [Clarida, Gali, and Gertler (2000) and Lubik and Schorfheide (2004)]. Samples of the lengths typically employed—20 to 40 years—can with high probability never realize active monetary policy or realize very few observations of active policy. Parameter estimates based on such samples will inevitably conclude that policy was passive throughout and that the equilibrium is indeterminate.

2.4.2. *Spectacular Spillovers from Extremely Passive Policy.* A purely transitory passive regime can generate spectacular spillovers to the active regime. When $p_{22} = 0$, the lower bound for uniqueness on policy in the passive regime is given by $\alpha_2 > (1 - p_{11})/(\alpha_1 - p_{11})$. This bound falls as active policy becomes more aggressive (α_1 rises) or more persistent ($p_{11} \to 1$). In both cases the lower bound on α_2 approaches $p_{22} = 0$, representing a pegged nominal interest rate of the form the Federal Reserve adopted during World War II until the Treasury Accord in 1953.

Table 1 reports the same relative standard deviations of inflation shown in the figures, but for select values of p_{11} and α_2. Scanning down the column titled "Regime 1," the numbers outside the parentheses give the standard deviation in regime 1 with $\alpha_1 = 1.5$ relative to a fixed regime with $\alpha = 1.5$. When the probability of passing from the active to the passive regime is .01 ($p_{11} = .99$), the relative standard deviation rises from 1.3 to 7.5 as α_2 falls from .10 to .02. Even when the probability of switching to passive policy is .001, over this range of α_2's the relative standard deviation of inflation varies from 2 percent higher to 14 percent higher than in the fixed regime.

Monetary policy in the active regime can offset the spillovers from the passive regime by leaning more strongly against the wind. Numbers in parentheses reflect the standard deviations of inflation when the active regime sets $\alpha_1 = 2$ relative to a fixed regime with $\alpha = 1.5$. Of course, more aggressive active behavior lowers the determinacy bound for α_2. Setting $\alpha_1 = 2$ allows α_2 to move closer to zero, drastically raising the volatility in regime 2 and spilling over strongly to regime 1.

This spectacular example resembles a peso problem. A small probability (.001) of extremely passive policy behavior ($\alpha_2 = .001$) can cause substantially higher volatility in the active regime. Moreover, time series generated by this policy process are quite likely never to exhibit the passive policy, making it problematic to identify the source of the volatility.

3. A Model of Inflation and Output Determination

This section and the next report the implications of a regime-switching monetary policy process for determinacy and equilibrium dynamics in a bare-bones model from the class of models with nominal rigidities now in wide use for monetary policy analysis. Ours is a textbook version, as in Walsh (2003) and Woodford (2003), but the general insights extend to the variants being fit to data [Smets and Wouters (2003) and Adolfson, Laseen, Linde, and Villani (2004)]. There are several reasons to examine regime change in a more complex model: it brings the analysis closer to models now being used to confront data, compute optimal policy, and conduct actual policy analysis at central banks; the model contains an explicit transmission mechanism for monetary policy—an endogenous real interest rate—which tempers some of the spectacular spillovers found in the simple model; it allows us to track how the possibility of regime change influences the dynamic impacts of aggregate demand and aggregate supply shocks on inflation and output.

3.1. **The Model.** The linearized equations describing private sector behavior are the consumption-Euler equation and aggregate supply relations

$$x_t = E_t x_{t+1} - \sigma^{-1}(i_t - E_t \pi_{t+1}) + u_t^D, \tag{15}$$
$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t + u_t^S, \tag{16}$$

where x_t is the output gap, u_t^D is an aggregate demand shock, and u_t^S is an aggregate supply shock. σ^{-1} represents the intertemporal elasticity of substitution, κ is a function of how frequently price adjustments occur, as in Calvo (1983), and of β, the discount factor. The slope of the supply curve is determined by $\kappa = (1-\omega)(1-\beta\omega)/\omega$, where $1-\omega$ is the randomly selected fraction of firms that adjust prices. Prices are more flexible as $\omega \to 0$, which makes $\kappa \to \infty$. Most of our examples use a benchmark calibration of $\beta = .99, \sigma = 1, \rho = .9, \omega = 2/3$, so $\kappa = .18$. We interpret a model period as one quarter in calendar time.

Exogenous disturbances are autoregressive and mutually uncorrelated:

$$u_t^D = \rho_D u_{t-1}^D + \varepsilon_t^D,$$
$$u_t^S = \rho_S u_{t-1}^S + \varepsilon_t^S,$$

where $|\rho_D| < 1$, $|\rho_S| < 1$, $\varepsilon_t^D \sim N(0, \sigma_D^2)$, $\varepsilon_t^S \sim N(0, \sigma_S^2)$ and $E[\varepsilon_t^D \varepsilon_s^S] = 0$ for all t and s. If shocks are *i.i.d.*, then regime switching is irrelevant to the dynamics, but not the determinacy properties of the equilibrium.

As before, monetary policy is the source of regime switching and we assume a simplified Taylor rule that sets the nominal interest rate according to

$$i_t = \alpha(s_t)\pi_t + \gamma(s_t)x_t, \tag{17}$$

where s_t evolves according to a Markov chain with transition matrix Π, with typical element $p_{ij} = \Pr[s_t = j | s_{t-1} = i]$ for $i, j = 1, 2$. s_t is independent of u_t^D and u_t^S. As before, $\alpha(s_t)$ equals α_1 or α_2 and $\gamma(s_t)$ equals γ_1 or γ_2. We assume the steady state does not change across regimes.

3.2. **Fixed-Regime Equilibrium.** Intuition from the fixed-regime equilibrium carries over to a switching environment. Solutions are given by:

$$\pi_t = \frac{\kappa}{\Delta^D} u_t^D + \frac{\sigma^{-1}\gamma + 1 - \rho_S}{\Delta^S} u_t^S,$$

$$x_t = \frac{1 - \beta\rho_D}{\Delta^D} u_t^D - \frac{\sigma^{-1}(\alpha - \rho_S)}{\Delta^S} u_t^S,$$

where $\Delta^Z = 1 + \sigma^{-1}(\alpha\kappa + \gamma) - \rho_Z[1 + \sigma^{-1}(\kappa + \beta\gamma) + \beta(1 - \rho_Z)]$, $Z = S, D$.

More-active monetary policy (higher α) reduces the elasticities of inflation and output to demand shocks. Supply shocks, however, present the monetary authority with a well-known tradeoff: a more-active policy stance reduces the elasticity of inflation with respect to supply shocks, but it raises the responsiveness of output. A stronger reaction of monetary policy to output (higher γ) reduces the elasticities of inflation and output to demand shocks. Higher γ reduces the elasticity of output to supply shocks and raises the responsiveness of inflation to supply shocks.

3.3. **The Long-Run Taylor Principle.** Turning back to the setup with regime change, this section describes how to derive restrictions on the monetary policy process that ensure the long-run Taylor principle is satisfied. Substituting the policy rule, (17) , into (15) yields

$$x_t = E_t x_{t+1} - \sigma^{-1}(\alpha(s_t)\pi_t + \gamma(s_t)x_t - E_t\pi_{t+1}) + u_t^D. \tag{18}$$

The system to be solved consists of (16) and (18).

To specify the system whose eigenvalues determine whether there exists a unique equilibrium, we follow the procedure in section 2.2. Let $\pi_{it} = \pi_t(s_t = i)$ and $x_{it} = x_t(s_t = i)$, $i = 1, 2$, denote state-specific inflation and output. As appendix B describes, after defining the forecast errors

$$\begin{aligned} \eta_{1t+1}^{\pi} &= \pi_{1t+1} - E_t\pi_{1t+1}, \qquad \eta_{2t+1}^{\pi} = \pi_{2t+1} - E_t\pi_{2t+1}, \\ \eta_{1t+1}^{x} &= x_{1t+1} - E_t x_{1t+1}, \qquad \eta_{2t+1}^{x} = x_{2t+1} - E_t x_{2t+1}, \end{aligned}$$

the model is cast in the form

$$AY_t = BY_{t-1} + A\eta_t - Cu_t, \tag{19}$$

where

$$Y_t = \begin{bmatrix} \pi_{1t} \\ \pi_{2t} \\ x_{1t} \\ x_{2t} \end{bmatrix}, \qquad \eta_t = \begin{bmatrix} \eta^{\pi}_{1t} \\ \eta^{\pi}_{2t} \\ \eta^{x}_{1t} \\ \eta^{x}_{2t} \end{bmatrix}, \qquad u_t = \begin{bmatrix} u^S_t \\ u^D_t \end{bmatrix},$$

and the matrices are defined in the appendix. A unique equilibrium requires four unstable roots to generate four linear restrictions that determine the regime-dependent forecast errors for inflation and output. The eigenvalues of this system determine whether the monetary policy process satisfies the long-run Taylor principle.

Analytical expressions for the eigenvalues are available, but do not yield compact expressions for the restrictions that guarantee a unique equilibrium. We nonetheless use those analytical expressions to calculate the eigenvalues to check whether a given monetary policy process satisfies the long-run Taylor principle.[9] Figure 3 illustrates that recurring regime change can dramatically expand the set of policy parameters that deliver a unique equilibrium.[10] As long as one regime is active, the less persistent the other regime is, the smaller is the lower bound on the response of monetary policy to inflation. The bottom panels of the figure indicate that when regimes are transitory, a large negative response of policy to inflation is consistent with determinacy. As in the simple model, a unique equilibrium can be produced by a policy process that is mildly passive most of the time or very passive some of the time.

In contrast to fixed regimes, recurring regime change makes determinacy of equilibrium depend on the policy process and all the parameters describing private behavior, (β, σ, κ), even when the Taylor rule does not respond to output. Because the current regime is not expected to prevail forever, parameters that affect intertemporal margins interact with expected policies to influence determinacy [figure 4]. Greater willingness of households to substitute intertemporally (lower σ) or greater ability of firms to adjust prices (lower ω) enhance substitution away from expected inflation, which gives expected regime change a smaller role in decisions. This shrinks the determinacy region toward the flexible-price region in section 2.

3.4. **Solutions.** To solve the model, define the state of the economy at t as $\left(u^D_t, u^S_t, s_t\right)$. The method of undetermined coefficients delivers solutions as functions of this smallest set of state variables—the MSV solution. We posit solutions of the form

$$\begin{aligned} \pi_t &= a^D(s_t)u^D_t + a^S(s_t)u^S_t, \\ x_t &= b^D(s_t)u^D_t + b^S(s_t)u^S_t, \end{aligned}$$

[9]We also compute the generalized eigenvalues for system (19) and check the spanning criteria used by Sims's (2001) gensys program to confirm existence and uniqueness of a solution.

[10]For simplicity, figures 3 and 4 are drawn setting $\gamma(s_t) = 0$, $s_t = 1, 2$, so in fixed regimes, the Taylor principle is $\alpha_1 > 1$ and $\alpha_2 > 1$.

where

$$a^Z(s_t) = \begin{cases} a_1^Z \text{ for } s_t = 1 \\ a_2^Z \text{ for } s_t = 2 \end{cases}, \qquad b^Z(s_t) = \begin{cases} b_1^Z \text{ for } s_t = 1 \\ b_2^Z \text{ for } s_t = 2 \end{cases}, \qquad Z = D, S.$$

These posited solutions, along with their one-step-ahead expectations,

$$\begin{aligned} E\left[\pi_{t+1} \,|s_t = i\right] &= p_{ii}\left(a_i^D \rho_D u_t^D + a_i^S \rho_S u_t^S\right) + p_{ij}\left(a_j^D \rho_D u_t^D + a_j^S \rho_S u_t^S\right), \\ E\left[x_{t+1} \,|s_t = i\right] &= p_{ii}\left(b_i^D \rho_D u_t^D + b_i^S \rho_S u_t^S\right) + p_{ij}\left(b_j^D \rho_D u_t^D + b_j^S \rho_S u_t^S\right), \end{aligned}$$

for $i, j = 1, 2$, are substituted into (16) and (18) to form a system whose solution yields expressions for π and x as functions of the model parameters and the monetary policy process. Appendix B describes the systems of equations that are solved.

4. Three Empirically Plausible Policy Processes

We turn now to study the implications of three monetary policy processes that empirical evidence suggests are relevant. The first process pursues the idea that modeling recurring regime change can be important even if the policy process is switching between two active regimes. There is evidence that over the past decade or so, U.S. monetary policy has fluctuated between aggressive and less-aggressive stances against inflation. We illustrate this idea by interpreting Goodfriend's (1993) "inflation scares" episodes.

The second process examines instances when central banks abandon their "business-as-usual" rule and do something different. Examples include the October 1987 stock market crash, Asian and Russian financial crises in the 1990s, credit controls in 1980, sluggish job-market recoveries from recessions, and currency crises. These are events with small probability mass that recur and can entail a substantial deviation from the usual rule. We model these events as relatively short-lived excursions into passive policy behavior, though we recognize that this is, at best, a crude representation of the diversity of examples listed above.

The final process addresses the consequences of private agents believing there is a small probability of returning to a persistent regime like the one that prevailed in the 1970s. This process reflects empirical work that finds U.S. monetary policy followed very different rules from 1960 to 1979 and after 1982 and it captures some of the drive in favor of inflation targeting.

4.1. **Inflation Scares.** Goodfriend (1993) coined the term "inflation scares" to describe instances when long-term interest rates rise, even when contemporaneous measures of inflation are not rising. For example, Fed tightening during the 1983-1984 inflation scare increased the real short-term rate by 3 percentage points, even though inflation was steady at 4 percent. Goodfriend (2005) argues that inflation scares occur at times when the Federal Reserve's commitment to act aggressively against inflation is in question. Scares have recurred over the past 25 years—Chairman Paul Volcker faced four and Chairman Alan Greenspan two. Inflation scares are also prone to occur during transitions between Fed chairs—the 1987 scare coincided with Greenspan's appointment.

Constant-parameter Taylor rules, which do not include long rates as arguments, categorize a sharp rise in the interest rate instrument as a "shock"—the unsystematic part of policy behavior. But Goodfriend argues that Fed behavior during inflation scares *is* systematic and specifically designed to affect agents' beliefs about the Fed's commitment to fight inflation. During a scare, the Fed systematically responds more strongly to inflation than in normal times. One way to model this, which maintains the simplicity of a Taylor-rule specification, is to treat policy as moderately active most of the time, responding to inflation with a coefficient of 1.5, but occasionally—and only briefly—very active, raising the interest rate by 2.5 times the change in inflation.[11]

Consider a monetary policy process with $\alpha_1 = 2.5$, $\alpha_2 = 1.5$, $p_{11} = .5$, and $p_{22} = .975$.[12] Policy is moderately active 95 percent of the time and very active the rest of the time; the expected duration of the more-active regime is 2 quarters.

In the inflation-scare state, a demand shock can raise inflation and *lower* output on impact, just as an aggregate supply shock usually does. Figure 5 plots the expected paths in the very active regime and in a fixed regime.[13] More aggressive policy tempers the impact of the shock on current and expected inflation by sharply raising the real interest rate. Lower inflation is achieved, however, through lower output. In the assumed policy process, the real rate rises enough to more than offset the positive output effects of the demand shock, and output can fall on impact.[14] In subsequent periods, the real interest rate essentially follows the path it would if regime were fixed, so output exhibits a hump-shaped response, as it does in many empirical studies that identify aggregate demand shocks [Blanchard and Quah (1989), Leeper, Sims, and Zha (1996)].

4.2. **Financial Crises and Business Cycles.** Periodically, monetary policy shifts its focus from price stability to other concerns. Two other concerns that recurrently come into the central bank's focus are financial stability and job creation. Episodes

[11]This policy process might also describe the Fed's preemptive strike against inflation in 1994, which Leeper and Zha (2003) model as an intervention on policy shocks.

[12]We set $\gamma_1 = \gamma_2 = 0$.

[13]Expected paths are computed from 50,000 simulated paths in which regime is randomly drawn for periods $t \geq 2$; the demand shock is 1 at $t = 1$ and 0 for $t \geq 2$, and the supply shock is 0 for $t \geq 1$.

[14]Lower values for the intertemporal elasticity of substitution, such as .16 as in Woodford (2003), do not alter the qualitative conclusions.

in which price stability is de-emphasized in favor of other objectives can last a few months or more than a year. Distinctive features of these episodes are that they recur fairly often and they represent an important shift away from monetary policy's usual reaction to inflation and output. In the United States, since Greenspan became chairman of the Fed in the summer of 1987, the episodes include at least two stock market crashes, two foreign financial crises, and two "jobless recoveries"—an episode every three years, on average.[15]

Marshall (2001) carefully documents the financial crisis in late summer and fall of 1998. In August the Russian government devalued the rouble, defaulted on debt, and suspended payments by financial institutions to foreign creditors. These actions precipitated the near collapse of Long-Term Capital Management, a large hedge fund. The Fed reacted swiftly by cutting the federal funds rate by a total of 75 basis points over three moves. One of the policy moves arose from an unusual intermeeting conference call on October 15 and all the moves occurred against a backdrop of concern by Federal Open Market Committee members about inflation. In fact, until the August 18 FOMC meeting, which left the funds rate unchanged, the Committee concluded the risks to the outlook were tilted toward rising inflation. Marshall argues that the Fed's unusually rapid response signalled that the "policy rule had changed," with the purpose of discretely shifting private-sector beliefs to a lower likelihood of a liquidity crisis in the United States.

Rabanal (2004) presents a variety of evidence on time variation in Taylor rules. First, he reports estimates of Taylor rules with parameter drift that buttress Marshall's claim: during periods that Rabanal calls "high risk in the economy," the Fed's response to inflation declines appreciably. High-risk periods include financial crises.

Rabanal also estimates a two-state—recessions and expansions—Taylor rule to find that during recessions the Fed's reaction to inflation is weaker and its reaction to output is stronger than during expansions. Davig and Leeper's (2005) estimates of (17) identify the "jobless recoveries" from the recessions of 1990-91 and 2000 as episodes of passive Fed behavior, with a weaker response to inflation and a stronger response to output than in the surrounding active episodes. Whereas Rabanal estimates the economy is three times more likely to be in an expansion than a recession, Davig and Leeper, using data beginning in the late 1940s, estimate that active and passive regimes are almost equally likely.

Table 2 reports that spillovers from a passive regime can substantially raise the standard deviations of inflation and output in an active regime relative to their values in a fixed regime. The probabilities of transitioning to the passive regime are 5 percent

[15]We do not include the terrorist attacks of September 11, 2001 in this list because, although the Fed reacted sharply by pumping liquidity into the market and lowering the federal funds rate, within two months it had just as sharply withdrawn the liquidity. This event is probably best modeled as a sequence of additive shocks to the policy rule.

and 2.5 percent ($p_{11} = .95$ and $p_{11} = .975$), which correspond to a financial crisis or stronger concern about job growth occurring every 5 or 10 years, on average. In the active and the fixed regimes, $\alpha_1 = \alpha = 1.5$ and $\gamma_1 = .25$. Passive policy responds more strongly to output ($\gamma_2 = .5$), while both its response to inflation, α_2, and its persistence, p_{22}, take different values in the table.[16]

When the passive regime always lasts only one period ($p_{22} = 0$), spillovers are relatively small and intuition from fixed regimes directly applies: when regime 2 is more passive (lower α_2), spillovers raise the volatility of inflation and output from demand shocks, raise the volatility of inflation from supply shocks, and lower the volatility of output from supply shocks. Fixed-regime intuition carries over because when the passive regime lasts only one period, it has only a minor impact on expected inflation.

As the passive regime becomes more persistent (p_{22} rises), the monetary policy process becomes less active and the relative volatility of inflation rises monotonically across both types of shocks. Even when the expected duration of passive policy is only 2 quarters ($p_{22} = .5$), as it might be during some financial crises, if policy is very passive, inflation volatility can be 20 percent or more higher in the active state than in a fixed-regime setup. When the duration is one year ($p_{22} = .75$), as when the Fed kept interest rates low for extended periods during the two recent recoveries from recession, inflation can be 50 percent more volatile than in a fixed regime [see columns for $p_{11} = .95$].

Persistence in the passive regime changes the effects of increases in the degree to which policy is passive on relative output variability. The prospect of moving to a passive regime raises current and expected inflation in the active regime relative to a fixed regime. Although it starts at a higher level, in the long run the ergodic mean of inflation in the switching environment converges to the mean when regime is constant. With inflation expected to fall more rapidly in the active regime, the real interest rate rises more sharply. A higher real rate offsets the effects of a demand shock on output, but it reinforces the impacts of a supply shock. This shows up in table 2 as declining relative output variability in the demand columns and rising relative output variability in the supply columns, as the monetary policy process becomes more passive.

4.3. **A Return to the 1970s?** Many observers of U.S. monetary policy fear that the Fed could revert to the policies of the 1970s. Such a fear is often behind arguments for adopting inflation targeting in the United States [Bernanke and Mishkin (1997), Bernanke, Laubach, Mishkin, and Posen (1999a), Mishkin (2004), Goodfriend

[16]In the case of pure inflation targeting, $\gamma_1 = \gamma_2 = \gamma = 0$, the relative standard deviations in the table are amplified, but the patterns are identical to those in the table.

(2005)]. The United States seems particularly susceptible to this kind of policy reversal because, in the absence of institutional reforms, the Fed relies on what Bernanke, Laubach, Mishkin, and Posen (1999b) call the "just trust us" approach, which relies more on the personal credibility of policy makers than on the credibility of the policy institution or the policymaking process.[17]

Three widely cited empirical studies report constant-coefficient estimates of Taylor rules for the United States [Clarida, Gali, and Gertler (2000), Taylor (1999a), Lubik and Schorfheide (2004)]. Each of these reports that U.S. monetary policy was passive through the 1960s and 1970s and active since 1982. Efforts to estimate Markov-switching versions of these rules frequently find analogous results [Favero and Monacelli (2003), Davig and Leeper (2005)].[18] A literal interpretation of the switching results is that agents place substantial probability mass on a return to the inflationary times of the 1970s.

4.3.1. *Determinacy Regions for Previous Studies.* Lubik and Schorfheide (2004) emphasize that in a model with a fixed policy rule, their estimate of Fed behavior from 1960-1979 leaves the model undetermined and subject to self-fulfilling sunspot equilibria.[19] Since the early 1980s, however, Lubik and Schorfheide infer their estimates imply a unique equilibrium. For the latter period, they estimate $\alpha_1 = 2.19$ and $\gamma_1 = .17$, while for the earlier period the estimates are $\alpha_2 = .77$ and $\gamma_2 = .3$. Their maximum likelihood estimates contrast the fit of determinate to indeterminate equilibria under the maintained assumption that policy rules cannot change.

Figure 6 reports combinations of the transition probabilities, (p_{11}, p_{22}), that yield a unique equilibrium given the Lubik-Schorfheide estimates of policy parameters (light-shaded plus dark-shaded regions). For reference, the figure also reports determinacy regions for Taylor's (1999a) estimates—$\alpha_1 = 1.5, \gamma_1 = .75$ (post-1987) and $\alpha_2 = .8, \gamma_2 = .25$ (1960-1979). A larger set of transition probabilities is consistent with determinacy under the Lubik-Schorfheide estimates because their active regime is substantially more active than is Taylor's (2.19 compared to 1.5).

[17]Fiscal policy represents a possible impetus for a change from an active to a passive monetary policy stance. In 2005, in the face of growing federal government budget deficits, the talk in Washington is of making President Bush's earlier tax cuts permanent, not of how spending and taxes can be adjusted to balance the budget. Demographic shifts in the United States and elsewhere have created projected fiscal deficits for the foreseeable future [Kotlikoff and Burns (2004)]. As fiscal pressures build, it may be reasonable to expect some erosion of the much-vaunted independence of the Federal Reserve. A possible outcome is a shift to a policy that accommodates inflation as a source of fiscal financing. Sargent's (1999) learning environment offers a different rationale for how a return to the 1970s might arise. In his setup, time inconsistency and constant-gain learning combine to create incentives for policy to optimally choose to revert to an accommodative stance.

[18]Sims and Zha (forthcoming), in contrast, find that the best fit is achieved from an identified VAR with constant coefficients and eight distinct variance states.

[19]Clarida, Gali, and Gertler (2000) also suggest this possibility.

On the surface, the figure seems to support Lubik and Schorfheide's inference. After all, if the passive regime has an expected duration of more than 5 years ($p_{22} > .95$), as switching estimates consistently find, then Lubik and Schorfheide's policy parameter estimates imply indeterminacy. Carrying this argument forward, however, reveals an unappealing implication. Unless one is willing to maintain the extreme assumption that the post-1982 regime is an absorbing state ($p_{11} = 1$), the U.S. economy must still be in an indeterminate equilibrium.[20] Without assuming people place no probability mass on future passive policy, it is difficult to reconcile Lubik and Schorfheide's conclusions with an environment of recurring regime change.

4.3.2. *Impacts of Demand and Supply Shocks.* To illustrate the potential spillovers of a belief that policy might return to its passive behavior in the 1970s, we impose Lubik and Schorfheide's policy parameter estimates, along with the transition probabilities $p_{11} = .95$ and $p_{22} = .93$, on the model of inflation and output determination. These probabilities mean there is a 5 percent chance of returning to a passive policy rule. The active regime is expected to last 20 quarters, while the passive regime lasts 14 quarters, on average. We gauge the extent of spillovers to the active regime by contrasting responses of inflation and output to demand and supply disturbances in the active regime to those in an equivalently active fixed regime.

Cross-regime spillovers from this policy process are substantial. Figure 7 shows that researchers predicting the impacts of exogenous disturbances assuming the policy rule is fixed will consistently underpredict inflation.[21] The underprediction can be as much as 40 basis points following demand shocks and nearly 1 percentage point following supply disturbances. Output predictions depend on the source of the shock. A hump-shaped response of output in the switching environment means the fixed-regime model initially overpredicts and then underpredicts output. With supply shocks, the prediction errors are quite large. A constant-coefficient policy rule misses the initial decline in output by nearly 1 percentage point; the errors change sign after several periods when constant-coefficient predictions are about .3 percentage points too pessimistic.

5. Concluding Remarks

This paper offers a broader perspective on the Taylor principle and the range of unique equilibria it supports by allowing policy regime to vary over time. Examples show that endowing conventional models with empirically relevant monetary policy switching processes can generate important cross-regime spillovers. These spillovers can alter the qualitative and quantitative predictions of standard models. Along

[20]The reasoning is identical to that contained in footnote 6.

[21]As in figure 5, these are expected paths, computed taking draws from regime after the initial period. See footnote 13.

the way, the paper develops a two-step solution method that obtains determinacy conditions and solutions for a rational expectations equilibrium. This method can be extended to a broad class of linear rational expectations models with exogenous Markov switching in parameters and many discrete regimes.

The paper's results should be useful for both researchers and policy analysts using constant-coefficient policy rules in DSGE models. The choice of how to model deviations from such rules is potentially quite important. Under prevailing practice, that choice is made implicitly. That choice should be explicit, with careful consideration given to the characteristics of the deviation—how likely is it to recur? how long is it likely to last? what is the nature of policy behavior during the period of deviation? Some deviations are more naturally modeled as additive, exogenous errors to the policy rule. Some might be better modeled as systematic responses to an expanded information set for the policy authority. Others are best treated as recurring changes in rules mapping endogenous variables to policy choices, as in this paper.

Modeling policy as we do in this paper requires no more heroic assumptions than those routinely made in policy research. Largely as a matter of convenience, nearly all theoretical models assume—rather heroically—that future policy *is* current policy. When the current regime is an absorbing state, this assumption is reasonable. If, as seems more likely, alternative future policies are possible, then rational agents must have a probability distribution over those policies, and the properties of observed equilibria will depend critically agents' beliefs about those policies and their probabilities.

Appendix A. Inflation Model: Determinacy

Let $\Omega_t^{-s} = \{r_t, r_{t-1}, \ldots, s_{t-1}, s_{t-2}, \ldots\}$ denote the agents' information set at t, not including the current regime, and let $\Omega_t = \Omega_t^{-s} \cup \{s_t\}$. All expectations are formed conditional on Ω_t. We have the equation

$$\alpha(s_t)\pi_t = E_t\pi_{t+1} + \rho r_t. \tag{20}$$

Recall that the processes for s and r are independent.

In general, the expectation of inflation is given by

$$E[\pi_{t+1}(s_{t+1} = i, s_t = j)\,|\Omega_t], \tag{21}$$

for $i, j = 1, 2$. Integrating out the current regime, s_t, and writing (20) for $s_t = 1$ and $s_t = 2$,

$$\begin{aligned}\alpha(s_t = 1)\pi_t(s_t = 1) &= p_{11}E[\pi_{t+1}(s_{t+1} = 1, s_t = 1)\,\big|\Omega_t^{-s}]\\ &+(1-p_{11})E[\pi_{t+1}(s_{t+1} = 2, s_t = 1)\,\big|\Omega_t^{-s}] + \rho r_t\end{aligned} \tag{22}$$

and

$$\begin{aligned}\alpha(s_t = 2)\pi_t(s_t = 2) &= (1-p_{22})E[\pi_{t+1}(s_{t+1} = 1, s_t = 2)\,\big|\Omega_t^{-s}]\\ &+p_{22}E[\pi_{t+1}(s_{t+1} = 2, s_t = 2)\,\big|\Omega_t^{-s}] + \rho r_t.\end{aligned} \tag{23}$$

Several remarks about (22) and (23) are in order. First, by using the transition probabilities as weights on the respective expectations, the current state, s_t, is no longer in the conditioning set for the expectations. Second, at any given date t, the realization of s_t determines which of the two equations determines the current equilibrium.[22] Third, the structure of the model—being forward-looking and containing no lagged endogenous variables—together with the assumption that the Markov process is first-order, imply that π_{t+1} will not be a function of s_t, allowing the equations to be written as

$$\begin{aligned}\alpha(s_t = 1)\pi_t(s_t = 1) &= p_{11}E[\pi_{t+1}(s_{t+1} = 1)\,\big|\Omega_t^{-s}]\\ &+(1-p_{11})E[\pi_{t+1}(s_{t+1} = 2)\,\big|\Omega_t^{-s}] + \rho r_t\end{aligned}$$

and

$$\begin{aligned}\alpha(s_t = 2)\pi_t(s_t = 2) &= (1-p_{22})E[\pi_{t+1}(s_{t+1} = 1)\,\big|\Omega_t^{-s}]\\ &+p_{22}E[\pi_{t+1}(s_{t+1} = 2)\,\big|\Omega_t^{-s}] + \rho r_t.\end{aligned}$$

Introduce the notation that $\pi_{it} = \pi_t(s_t = i)$ and let

$$E_t\pi_{1t+1} = p_{11}E[\pi_{t+1}(s_{t+1} = 1)\,\big|\Omega_t^{-s}] + (1-p_{11})E[\pi_{t+1}(s_{t+1} = 2)\,\big|\Omega_t^{-s}]$$

[22] By analogy to the reasoning underlying contingent-claims pricing, these expressions define inflation in the different states as different "goods."

$$E_t\pi_{2t+1} = (1-p_{22})E[\pi_{t+1}(s_{t+1}=1)\,|\Omega_t^{-s}] + p_{22}E[\pi_{t+1}(s_{t+1}=2)\,|\Omega_t^{-s}].$$

Define the forecast errors

$$\eta_{1t+1} = \pi_{1t+1} - E_t[\pi_{1t+1}]$$
$$\eta_{2t+1} = \pi_{2t+1} - E_t[\pi_{2t+1}].$$

Because the forecast errors are functions of s_{t+1}, but not of s_t, we can write the model as the system

$$\begin{bmatrix} \alpha_1 & 0 \\ 0 & \alpha_2 \end{bmatrix}\begin{bmatrix} \pi_{1t} \\ \pi_{2t} \end{bmatrix} = \begin{bmatrix} p_{11} & 1-p_{11} \\ 1-p_{22} & p_{22} \end{bmatrix}\begin{bmatrix} \pi_{1t+1} \\ \pi_{2t+1} \end{bmatrix} + \begin{bmatrix} \rho \\ \rho \end{bmatrix} r_t - \begin{bmatrix} p_{11} & 1-p_{11} \\ 1-p_{22} & p_{22} \end{bmatrix}\begin{bmatrix} \eta_{1t+1} \\ \eta_{2t+1} \end{bmatrix}.$$

The roots of the system are the eigenvalues of

$$\begin{bmatrix} p_{11} & 1-p_{11} \\ 1-p_{22} & p_{22} \end{bmatrix}^{-1}\begin{bmatrix} \alpha_1 & 0 \\ 0 & \alpha_2 \end{bmatrix},$$

and a unique equilibrium requires that both roots exceed 1 in absolute value.

Appendix B. Output and Inflation Model: Solution Method

Define the information set $\Omega_t^{-s} = \{u_t^S, u_{t-1}^S, \ldots, u_t^D, u_{t-1}^D, \ldots s_{t-1}, s_{t-2}, \ldots\}$ denote the agents' information set at t, not including the current regime, and let $\Omega_t = \Omega_t^{-s} \cup \{s_t\}$. All expectations are formed conditional on Ω_t. The equations of the model are

$$\pi_t = \beta E_t\pi_{t+1} + \kappa x_t + u_t^S$$
$$x_t = E_t x_{t+1} - \sigma^{-1}(\alpha(s_t)\pi_t + \gamma(s_t)x_t - E_t\pi_{t+1}) + u_t^D$$

B.1. **Conditions for Uniqueness.** Following the procedure in appendix A, write these equations out as

$$\pi_t(s_t=1) = \beta\left\{p_{11}E[\pi_{t+1}(s_{t+1}=1)\,|\Omega_t^{-s}] + (1-p_{11})E[\pi_{t+1}(s_t=2)\,|\Omega_t^{-s}]\right\} + \kappa x_t(s_t=1) + u_t^S \tag{24}$$

$$\pi_t(s_t=2) = \beta\left\{(1-p_{22})E[\pi_{t+1}(s_{t+1}=1)\,|\Omega_t^{-s}] + p_{22}E[\pi_{t+1}(s_t=2)\,|\Omega_t^{-s}]\right\} + \kappa x_t(s_t=2) + u_t^S \tag{25}$$

$$x_t(s_t=1) = p_{11}E[x_{t+1}(s_{t+1}=1)\,|\Omega_t^{-s}] + (1-p_{11})E[x_{t+1}(s_{t+1}=2)\,|\Omega_t^{-s}] - \sigma^{-1}[\alpha(s_t=1)\pi_t(s_t=1) + \gamma(s_t=1)x_t(s_t=1)] + \sigma^{-1}\left\{p_{11}E[\pi_{t+1}(s_{t+1}=1)\,|\Omega_t^{-s}] + (1-p_{11})E[\pi_{t+1}(s_t=2)\,|\Omega_t^{-s}]\right\} + u_t^D \tag{26}$$

$$\begin{aligned} x_t(s_t=2) = (1-p_{22})E[x_{t+1}(s_{t+1}=1)\,\big|\Omega_t^{-s}] + p_{22}E[x_{t+1}(s_{t+1}=2)\,\big|\Omega_t^{-s}] \\ -\sigma^{-1}[\alpha(s_t=2)\pi_t(s_t=2)+\gamma(s_t=2)x_t(s_t=2)] \\ +\sigma^{-1}\left\{(1-p_{22})E[\pi_{t+1}(s_{t+1}=1)\,\big|\Omega_t^{-s}] + p_{22}E[\pi_{t+1}(s_t=2)\,\big|\Omega_t^{-s}]\right\} + u_t^D \end{aligned} \tag{27}$$

As before, define $\pi_{1t}, \pi_{2t}, x_{1t}, x_{2t}$ to represent inflation and output when the current state is 1 or 2. And define the forecast errors

$$\begin{aligned} \eta^{\pi}_{1t+1} &= \pi_{1t+1} - E_t\pi_{1t+1}, \qquad \eta^{\pi}_{2t+1} = \pi_{2t+1} - E_t\pi_{2t+1}, \\ \eta^{x}_{1t+1} &= x_{1t+1} - E_t x_{1t+1}, \qquad \eta^{x}_{2t+1} = x_{2t+1} - E_t x_{2t+1}. \end{aligned}$$

Using these forecast errors to eliminate the conditional expectations in (24)-(27) yields the system

$$AY_t = BY_{t-1} + A\eta_t - Cu_t$$

where

$$Y_t = \begin{bmatrix} \pi_{1t} \\ \pi_{2t} \\ x_{1t} \\ x_{2t} \end{bmatrix}, \qquad \eta_t = \begin{bmatrix} \eta^{\pi}_{1t} \\ \eta^{\pi}_{2t} \\ \eta^{x}_{1t} \\ \eta^{x}_{2t} \end{bmatrix}, \qquad u_t = \begin{bmatrix} u_t^S \\ u_t^D \end{bmatrix},$$

$$A = \begin{bmatrix} \beta \otimes \Pi & 0_{2\times 2} \\ \sigma^{-1} \otimes \Pi & \Pi \end{bmatrix},$$

$$B = \left[\begin{array}{cc|cc} \multicolumn{2}{c|}{I_{2\times 2}} & \multicolumn{2}{c}{-\kappa I_{2\times 2}} \\ \hline \sigma^{-1}\alpha_1 & 0 & 1+\sigma^{-1}\gamma_1 & 0 \\ 0 & \sigma^{-1}\alpha_2 & 0 & 1+\sigma^{-1}\gamma_2 \end{array}\right],$$

$$C = \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 1 \end{bmatrix}.$$

The roots of the system are the generalized eigenvalues of (A, B). A unique equilibrium requires that all four eigenvalues exceed 1 in absolute value. The eigenvectors associated with those unstable eigenvalues constitute four linear restrictions that determine the four endogenous forecast errors.

B.2. **Solutions.** Solutions for the model are derived using the method of undetermined coefficients, just as for the simple model in section 2. Supply and demand shocks are uncorrelated, so the coefficients on the demand shocks and those on the supply shocks can be solved separately. Coefficients on the supply shock come from solving

$$\begin{bmatrix} 1-\beta p_{11}\rho_S & -\beta\rho_S\left(1-p_{11}\right) & -\kappa & 0 \\ -\beta\rho_S\left(1-p_{22}\right) & 1-\beta p_{22}\rho_S & 0 & -\kappa \\ \frac{1}{\sigma}(\alpha_1-\rho_S p_{11}) & -\frac{\rho_S}{\sigma}(1-p_{11}) & 1+\sigma^{-1}\gamma_1-p_{11}\rho_S & -\rho_S\left(1-p_{11}\right) \\ -\frac{\rho_S}{\sigma}\left(1-p_{22}\right) & \frac{1}{\sigma}\left(\alpha_2-p_{22}\rho_S\right) & -\rho_S\left(1-p_{22}\right) & 1+\sigma^{-1}\gamma_2-p_{22}\rho_S \end{bmatrix} \begin{bmatrix} a_1^S \\ a_2^S \\ b_1^S \\ b_2^S \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 0 \\ 0 \end{bmatrix}$$

and those on demand shocks from solving

$$\begin{bmatrix} 1-\beta p_{11}\rho_D & -\beta\rho_D\left(1-p_{11}\right) & -\kappa & 0 \\ -\beta\rho_D\left(1-p_{22}\right) & 1-\beta p_{22}\rho_D & 0 & -\kappa \\ \frac{1}{\sigma}\left(\alpha_1-\rho_D p_{11}\right) & -\frac{\rho_D}{\sigma}\left(1-p_{11}\right) & 1+\sigma^{-1}\gamma_1-\rho_D p_{11} & -\rho_D\left(1-p_{11}\right) \\ -\frac{\rho_D}{\sigma}\left(1-p_{22}\right) & \frac{1}{\sigma}\left(\alpha_2-p_{22}\rho_D\right) & -\rho_D\left(1-p_{22}\right) & 1+\sigma^{-1}\gamma_2-p_{22}\rho_D \end{bmatrix} \begin{bmatrix} a_1^D \\ a_2^D \\ b_1^D \\ b_2^D \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 1 \\ 1 \end{bmatrix}.$$

Analytic expressions for the coefficients are not easy to interpret, but are straightforward to compute. These coefficients are the impact elasticities of the various shocks.

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	α_2	**Regime 1**	**Regime 2**
		(Active)	(Passive)
$p_{11} = .95$			
	.10	5.55 (1.26)	58.20 (17.43)
$p_{11} = .975$			
	.10	1.96 (0.80)	24.07 (13.12)
	.05	6.62 (1.30)	136.83 (35.76)
$p_{11} = .99$			
	.10	1.28 (0.62)	17.69 (11.40)
	.05	1.73 (0.75)	43.81 (25.15)
	.025	3.82 (1.09)	167.30 (63.29)
	.02	7.49 (1.33)	383.48 (90.85)
$p_{11} = .995$			
	.10	1.13 (0.57)	16.24 (10.92)
	.05	1.30 (0.62)	35.64 (22.86)
	.025	1.75 (0.75)	88.46 (50.45)
	.02	2.07 (0.82)	125.73 (66.49)
$p_{11} = .999$			
	.10	1.03 (0.53)	15.23 (10.56)
	.05	1.05 (0.54)	30.98 (21.31)
	.025	1.11 (0.56)	64.14 (43.38)
	.02	1.14 (0.57)	81.60 (54.71)
Addendum			
$p_{11} = .999$			
$\alpha_1 = 2$	.001	7.23	7413.4

Table 1. **Standard Deviation in Active Regime 1 Relative to Fixed Regime.** Active and fixed regimes set $\alpha_1 = \alpha = 1.5$, passive regime is purely transitory ($p_{22} = 0$). Numbers in parentheses are standard deviations when policy in the active regime is more aggressive, $\alpha_1 = 2$, relative to the fixed regime with $\alpha = 1.5$. p_{11} approximately equals the ergodic probability of regime 1, active monetary policy.

	$p_{11} = .95$				$p_{11} = .975$			
	Demand		**Supply**		**Demand**		**Supply**	
	Inflation	Output	Inflation	Output	Inflation	Output	Inflation	Output
$p_{22} = 0$								
$\alpha_2 = .5$	1.044	1.008	1.075	.995	1.022	1.004	1.037	.998
$\alpha_2 = .25$	1.060	1.011	1.092	.994	1.030	1.005	1.045	.997
$\alpha_2 = 0$	1.073	1.014	1.110	.992	1.037	1.007	1.054	.997
$p_{22} = .5$								
$\alpha_2 = .5$	1.084	.988	1.143	1.008	1.042	.993	1.071	1.004
$\alpha_2 = .25$	1.120	.983	1.185	1.010	1.059	.990	1.091	1.006
$\alpha_2 = 0$	1.165	.977	1.238	1.013	1.080	.987	1.115	1.007
$p_{22} = 2/3$								
$\alpha_2 = .5$	1.123	.961	1.209	1.025	1.061	.979	1.104	1.014
$\alpha_2 = .25$	1.188	.940	1.290	1.034	1.092	.968	1.142	1.018
$\alpha_2 = 0$	1.283	.910	1.408	1.048	1.135	.953	1.194	1.025
$p_{22} = .75$								
$\alpha_2 = .5$	1.162	.931	1.275	1.044	1.080	.963	1.137	1.024
$\alpha_2 = .25$	1.268	.886	1.412	1.066	1.129	.940	1.199	1.034
$\alpha_2 = 0$	1.454	.807	1.653	1.104	1.210	.903	1.302	1.052

TABLE 2. **Standard Deviation in Active Regime 1 Relative to Fixed Regime.** Active and fixed regimes set $\alpha_1 = \alpha = 1.5$ and $\gamma_1 = \gamma = .25$. Passive regime sets $\gamma_2 = .5$. Ergodic probability of active regime ranges from .83 ($p_{11} = .95, p_{22} = .75$) to .98 ($p_{11} = .975, p_{22} = 0$).

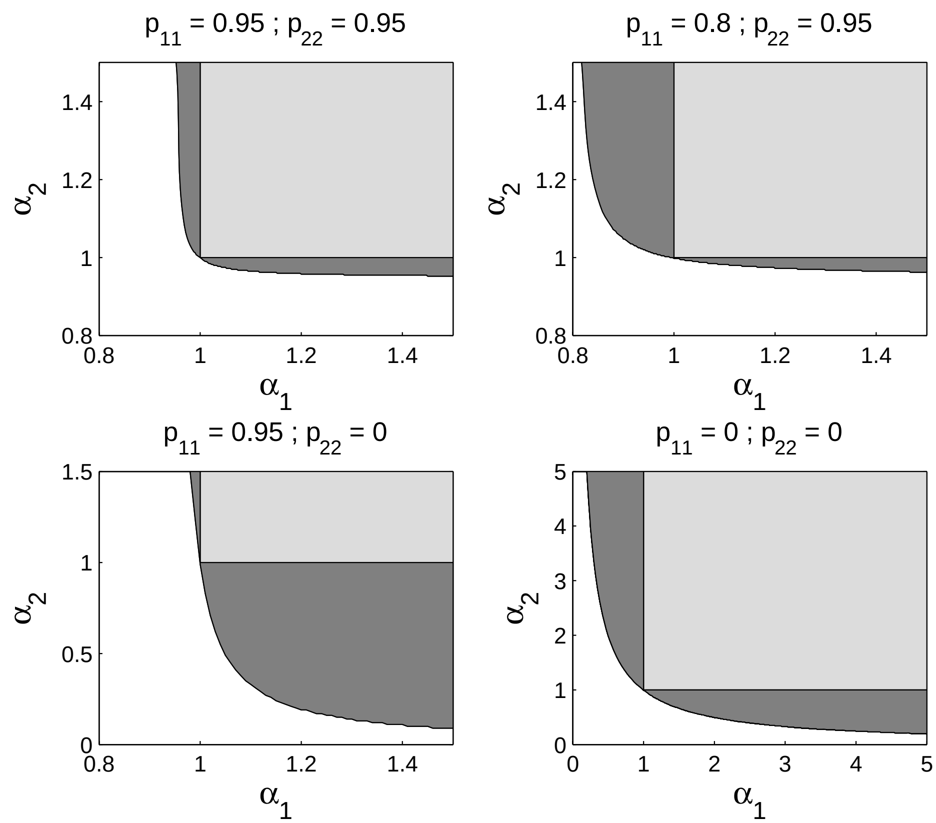

FIGURE 1. **Determinacy Frontiers: Model of Inflation Determination.** Parameter combinations in the light-shaded regions imply a unique equilibrium in fixed-regime model; combinations in dark-shaded plus light-shaded regions imply a unique equilibrium in regime-switching model.

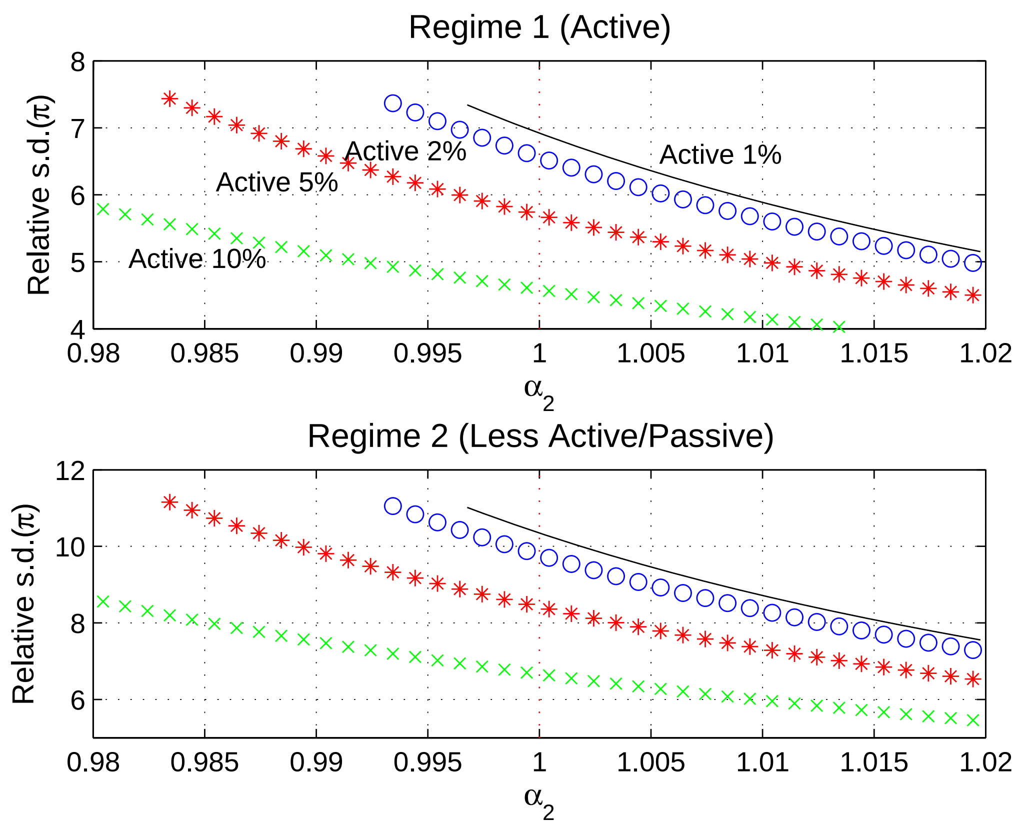

FIGURE 2. **Variability of Inflation: Mildly Passive Most of the Time.** Standard deviation of inflation with regime-switching policy relative to fixed-regime policy (with $\alpha = 1.5$). Active policy regime, with $\alpha_1 = 1.5$ and $p_{11} = 0$. Labels in the top panel report the associated ergodic probability of active policy.

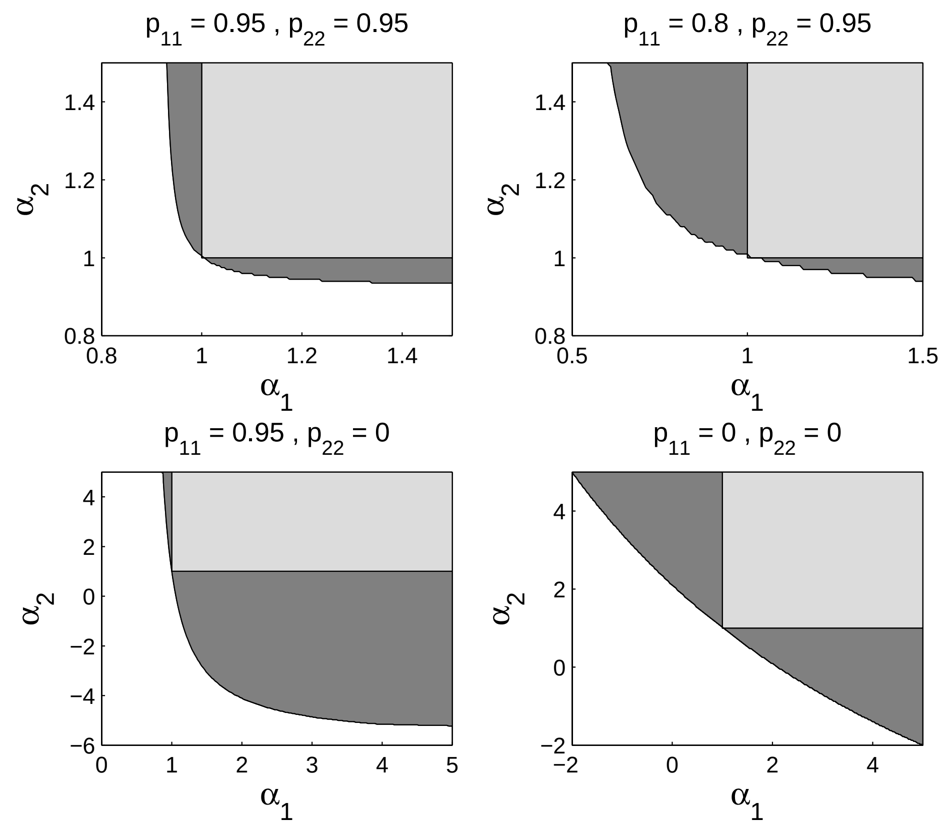

Figure 3. **Determinacy Regions: Model of Output and Inflation Determination.** Parameter combinations in the light-shaded regions imply a unique equilibrium in fixed-regime model; combinations in dark-shaded plus light-shaded regions imply a unique equilibrium in regime-switching model.

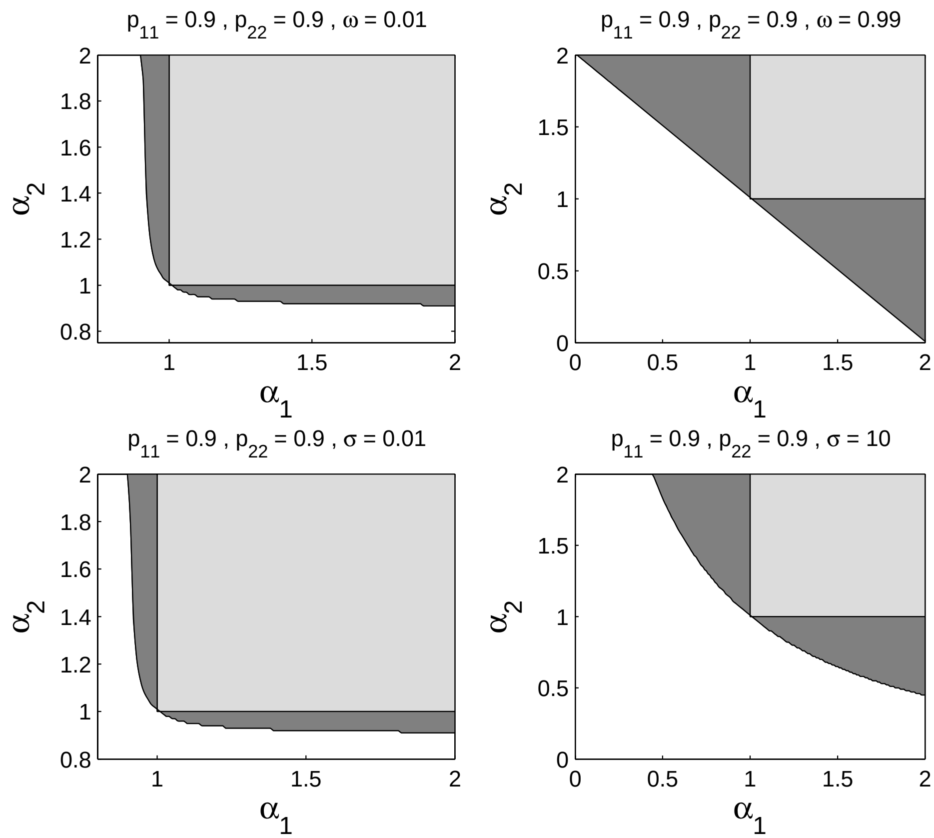

FIGURE 4. **Determinacy Regions and Private Parameters: Model of Output and Inflation Determination.** Parameter combinations in the light-shaded regions imply a unique equilibrium in fixed-regime model; combinations in dark-shaded plus light-shaded regions imply a unique equilibrium in regime-switching model for various settings of ω and σ.

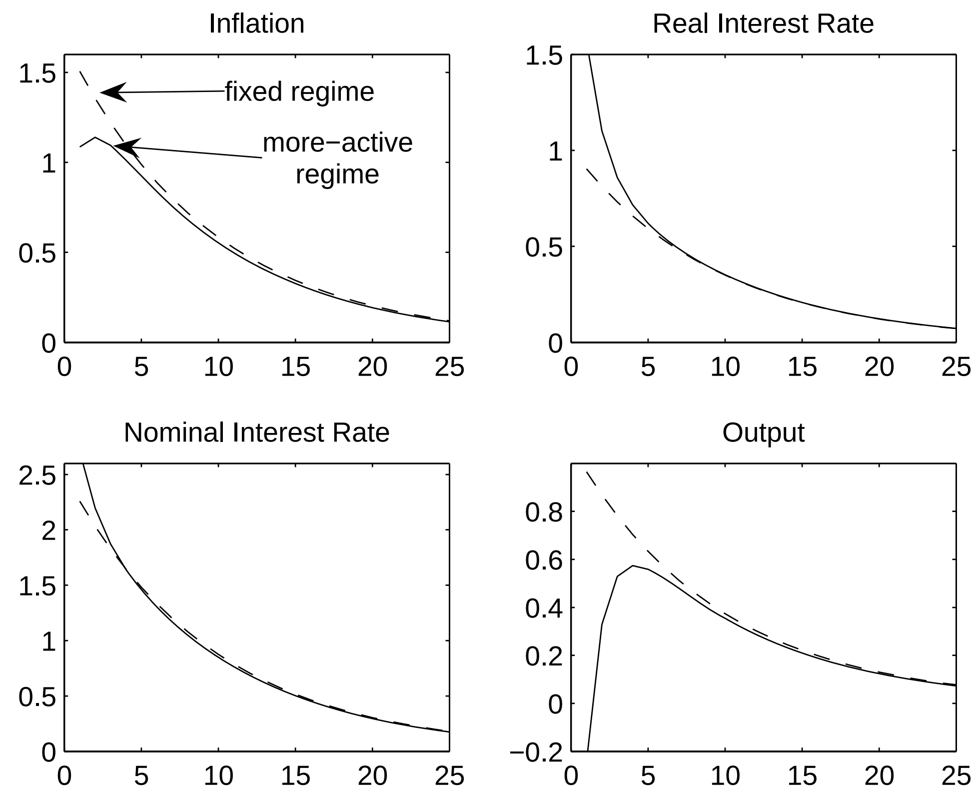

Figure 5. **Inflation Scares and Responses to an Aggregate Demand Shock.** Solid line is conditional on more-active policy ($\alpha_2 = 2.5$ and $p_{22} = .5$); alternative regime has $\alpha_1 = 1.5$ and $p_{11} = .975$. Dashed line is fixed regime with $\alpha = \alpha_1$. In switching regime, figures plot the mean responses from 50,000 draws of regime, beginning in the second period.

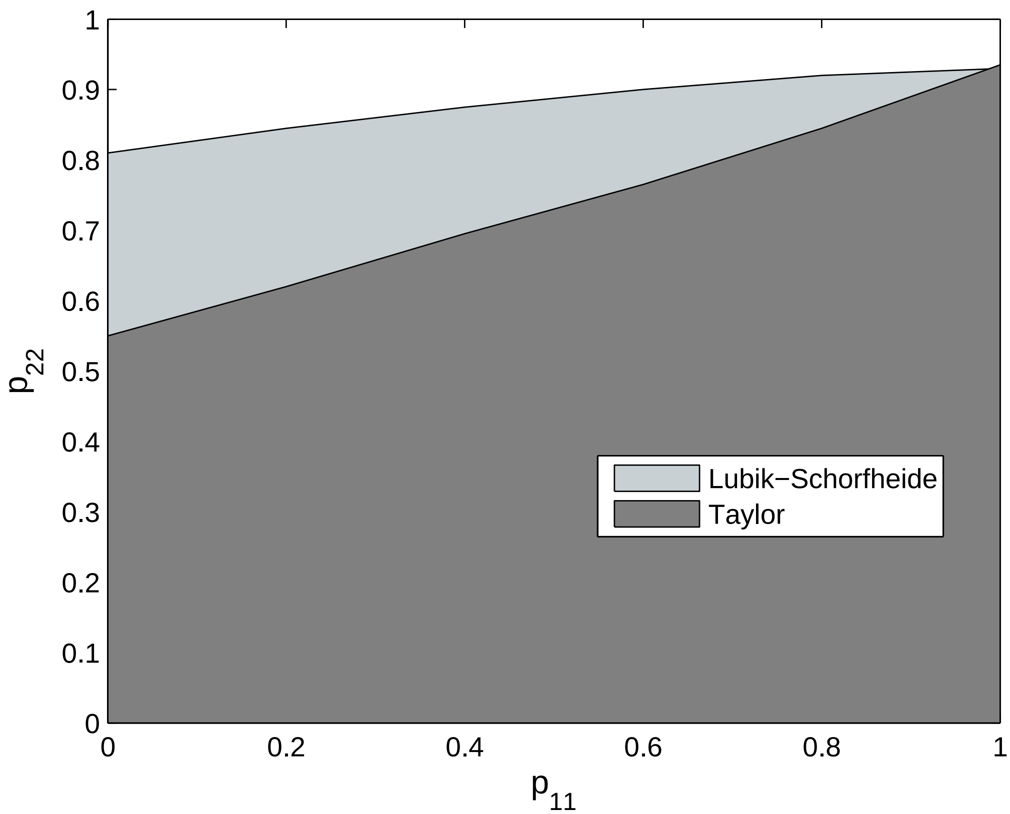

FIGURE 6. **Determinacy Regions for Taylor and Lubik-Schorfheide Estimates.** Shaded regions give (p_{11}, p_{22}) combinations that yield unique equilibrium. Dark region is for Taylor's (1999a) estimates: $\alpha_1 = 1.5, \gamma_1 = .75, \alpha_2 = .8, \gamma_2 = .25$; light plus dark region is for Lubik and Schorfheide's (2004) estimates: $\alpha_1 = 2.19, \gamma_1 = .17, \alpha_2 = .77, \gamma_2 = .3$.

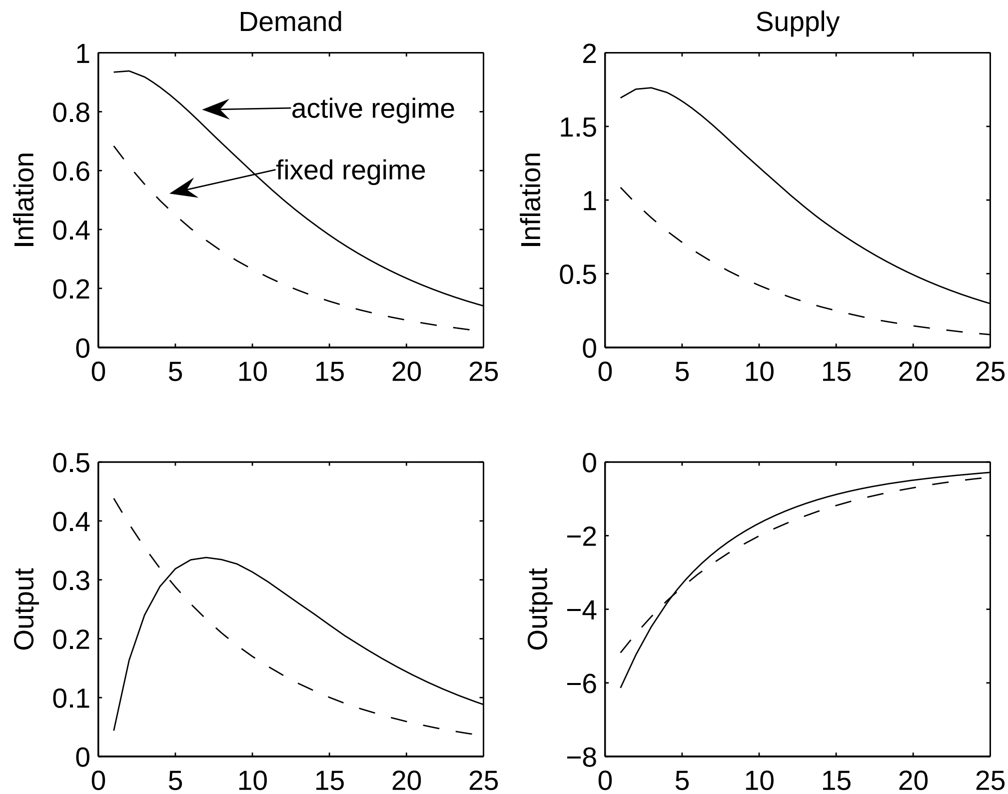

FIGURE 7. **Demand and Supply Shocks Under Lubik-Schorfheide Estimates of Policy Parameters.** Solid line is conditional on active regime initially ($\alpha_1 = 2.19, \gamma_1 = .17$) when other regime is passive ($\alpha_2 = .77, \gamma_2 = .3$). Transition probabilities are $p_{11} = .95, p_{22} = .93$. Dashed line is fixed regime with $\alpha = \alpha_1, \gamma = \gamma_1$. Figures plot the mean responses from 50,000 draws of regime, beginning in the second period.