



IMF Working Paper

Monetary and Fiscal Policy Interactions in the Post-war U.S.

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Research Department

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Abstract

A New Keynesian model allowing for an active monetary and passive fiscal policy (AMPF) regime and a passive monetary and active fiscal policy (PMAF) regime is fit to various U.S. samples from 1955 to 2007. Data in the pre-Volcker periods strongly prefer an AMPF regime, but the estimation is not very informative about whether the inflation coefficient in the interest rate rule exceeds one in pre-Volcker samples. Also, whether a government spending increase yields positive consumption in a PMAF regime depends on price stickiness. An income tax cut can yield a negative labor response if monetary policy aggressively stabilizes output.

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I. INTRODUCTION

Estimated New Keynesian models often omit government debt from model specifications and implicitly assume that lump-sum taxes adjust to clear the government budget (e.g., Christiano et al. (2005) and Smets and Wouters (2003, 2007)). Conditional on the existence of a unique equilibrium, this implies that monetary policy is active and fiscal policy is passive (AMPF) in the sense of Leeper (1991).¹ Economists generally agree that monetary policy in the post-1984 U.S. has been active (characterized by an inflation coefficient greater than one in the Taylor rule, e.g., Taylor (1999a), Clarida et al. (2000), and Cogley and Sargent (2005)), implying that the monetary and fiscal policy combination in the post-1984 U.S. fits an AMPF regime. Much uncertainty, however, exists before the appointment of Paul Volcker as Chairman of the Federal Reserve Board in 1979. Results from Markov-switching regressions suggest that some periods in the pre-Volcker era are likely to be consistent with a passive monetary and active fiscal policy (PMAF) regime (Favero and Monacelli (2005), Davig and Leeper (2006), and Davig and Leeper (2009)).

This paper estimates a New Keynesian model that accounts for monetary and fiscal policy interactions with Bayesian methods. Differing from most estimated New Keynesian models, our specification features government debt and fiscal financing, which is necessary to allow for the possibility of a PMAF regime. We estimate the model imposing an AMPF or a PMAF regime over three samples—1955Q1-1966Q4, 1967Q1-1979Q2, and 1984Q1-2007Q4. For all the samples investigated, estimations are conducted under three specifications. The first two have priors centered at an AMPF regime and a PMAF regime respectively, but allow for parameter combinations to be in the parameter space of both regions. The third specification imposes a PMAF regime by not allowing fiscal instruments to respond to debt growth.

Except for the third specification imposing the PMAF regime, the posterior distributions fall in the parameter space of the AMPF regime, regardless of the prior. Model comparisons indicate that for all three samples, the data prefer *least* the specification with a PMAF regime imposed. Moreover, competing estimates for the Federal Reserve's response to inflation are found in the pre-Volcker period within the parameter space of an AMPF regime: one where the inflation coefficient is larger than one—when the prior for this variable is larger than one as in the first specification, and one where it is smaller than one—when the prior is much below one as in the second specification. Although the conventional boundary of the monetary authority's response to inflation for active monetary policy is (near) one,² the boundary can be much below one in medium and large scale New Keynesian models. The result suggests that the estimates from New Keynesian models for the pre-Volcker sample are likely to be influenced by priors. Hence, the conclusion reached by estimated New Keynesian

¹An active authority is defined as an authority which is not constrained by current budgetary conditions and may choose a decision rule dependent on any variables it wants. In contrast, a passive authority is constrained by the consumers' and firms' optimizations and by the actions of the active authority. The passive authority must ensure that current budgetary conditions are satisfied, and thus, must ensure the intertemporal government budget constraint is satisfied. See Leeper (1991), Sims (1994), Cochrane (1999), and Woodford (2003) for more discussion.

²See Leeper (1991), Sims (1994), and Woodford (2003).

models about whether the monetary authority's response to inflation was sufficient in the pre-Volcker period may be driven to a large extent by the prior imposed.³

The distinctive difference in the macroeconomic dynamics in the pre- and post-Volcker periods, particularly in inflation, has spurred tremendous interests in search for explanations. The increasing macroeconomic stability in the post-Volcker period has been attributed to "Good Luck" or "Good Policy." The "Good Luck" theory argues that the Federal Reserve's response to inflation was sufficient in the pre-Volcker period and attribute the reduced economic instability in the post-Volcker period to the reduced variance of structural disturbances (Canova and Gambetti (2009), Sims and Zha (2006), and Primiceri (2005)). On the other hand, the "Good Policy" theory attributes the persistent high inflation in the pre-Volcker period to the Federal Reserve's insufficient abilities to control inflation. These conclusions are often based on the inflation coefficient in a Taylor-type rule being estimated as smaller than one (e.g., Judd and Rudebusch (1998), Taylor (1999b), Cogley and Sargent (2005), and Boivin (2006)).⁴ When analyzing the implication of a passive monetary policy rule in a New Keynesian model, several papers further conclude that monetary policy in the pre-Volcker period implies indeterminacy of the equilibrium, and that the high volatility in inflation and output during the period could be due to sunspot fluctuations (Clarida et al. (2000), Lubik and Schorfheide (2004), and Boivin and Giannoni (2006)). Instead, when allowing for regime switches in monetary policy, Davig and Leeper (2006), Davig and Doh (2009), and Bianchi (2010) conclude that monetary policy was passive (and determinate) at times in the pre-Volcker era.

This paper contributes to this literature by estimating AMPF and PMAF regimes in the pre- and post-Volcker periods and evaluating their relative fit. As noted in Sims (2008), many different monetary and fiscal policy combinations result in the same stochastic processes for variables in a model, posing an identification challenge. The approach in this paper is to estimate a DSGE model with fixed policy rules that deliver an AMPF or PMAF solution, depending upon the monetary and fiscal policy parameters. The specificity of the policy rules imposes identification restrictions that allow us to identify the AMPF and PMAF regimes.

We find that the PMAF regime is never favored by the data due to the high volatility the fixed PMAF regime implies for certain observables, particularly hours worked and inflation. The results suggest that the standard New Keynesian model used for policy analysis is not able to match features of the data if a fixed PMAF regime is assumed.⁵ In addition, substantial changes in the structural innovations in the pre- and post-Volcker periods are found. Contrary to the conclusions from VAR evidence, we do not find reduced monetary policy effects on

³Smets and Wouters (2007) obtain the mode for the inflation coefficient in the monetary policy rule 1.65 for the 1966Q1-1979Q2 sample under the prior mean of 1.5.

⁴Also see Romer and Romer (2002) and Meltzer (2005) for narrative evidence supporting the view that monetary policy was passive in the 1970s. Based upon the real-time estimates of the output gap, Orphanides (2003), however, argues that the Federal Reserve's response to inflation was sufficient in controlling inflation.

⁵Caivano (2007) reaches a similar conclusion that the fiscal theory of price determination (embedded in the PMAF regime) cannot explain the high inflation in the U.S. from 1968 to 1979 by fitting a stylized New Keynesian model.

output in the post-Volcker period (Gertler and Lown (1999), Barth and Ramey (2002), and Boivin and Giannoni (2002)).

Another finding of the paper is that a PMAF regime can generate a positive consumption response to an increase in government spending, but the degree of price stickiness is crucial to deliver the result. Kim (2003) and Davig and Leeper (2009) demonstrate that a PMAF regime can yield a positive consumption response following a government spending shock, due to a reduction in the real interest rate. Under the imposed PMAF regime (the third specification), a positive consumption response following a government spending increase is found for 1967Q1-1979Q2, but the consumption response is almost negligible for 1955Q1-1966Q4. Because the estimated degree of price stickiness for 1955Q1-1966Q4 is quite high, a government spending increase leads to a small and slow increase in the price level and does not lower the real interest rate.

Finally, the paper demonstrates that policy coordination is important for the expansionary effect of a tax cut. When the monetary authority reacts relatively weakly to inflation and strongly to output growth induced by a tax cut, labor can fall and thus dampen the stimulative effect of the tax cut. A monetary tightening triggers asset substitution between government bonds and physical capital and thus offsets the investment incentive from a lower income tax rate. As investment is dampened, firms' demand for labor also weakens. Despite the households' desires to increase labor supply given a lower income tax rate, equilibrium labor falls, and the expansionary effect from an income tax cut is diminished.

II. MODEL

We estimate a standard New Keynesian model that includes a stochastic growth path, as in Del Negro et al. (2007) and Fernandez-Villaverde et al. (2010a). Differing from most New Keynesian models with a focus on monetary policy, our model also emphasizes fiscal behavior, which allows for the interactions between monetary and fiscal policy.

A. Firms

The production sector consists of intermediate and final goods producing firms. A perfectly competitive final goods producer uses a continuum of intermediate goods $y_t(i)$, where $i \in [0, 1]$, to produce the final goods, Y_t , according to the constant-return-to-scale technology due to Dixit and Stiglitz (1977),

$$\left[\int_0^1 y_t(i)^{\frac{1}{1+\eta_t^p}} di \right]^{1+\eta_t^p} \geq Y_t, \quad (1)$$

where η_t^p denotes an exogenous time-varying markup to the intermediate goods' prices.

Denote the price of the intermediate goods i as $p_t(i)$ and the price of final goods Y_t as P_t . The final goods producing firm chooses Y_t and $y_t(i)$ to maximize profits subject to the technology (1). The demand for $y_t(i)$ is given by

$$y_t(i) = Y_t \left(\frac{p_t(i)}{P_t} \right)^{-\frac{1+\eta_t^p}{\eta_t^p}}, \quad (2)$$

where $\frac{1+\eta_t^p}{\eta_t^p}$ is the elasticity of substitution between intermediate goods.

Intermediate goods producers are monopolistic competitors in their product market. Firm i produces by a Cobb-Douglas technology

$$y_t(i) = A_t^{1-\alpha} k_t(i)^\alpha L_t(i)^{1-\alpha}, \quad (3)$$

where $\alpha \in [0, 1]$. Fixed costs of production are assumed to be zero, as in Fernandez-Villaverde et al. (2010a). A_t denotes a permanent shock to technology. Its growth rate, $a_t = \ln A_t - \ln A_{t-1}$, follows a stationary AR(1) process,

$$a_t = (1 - \rho_a)\gamma + \rho_a a_{t-1} + \epsilon_t^a, \quad \epsilon_t^a \sim \text{i.i.d. } N(0, \sigma_a^2), \quad (4)$$

where γ is the steady-state growth rate.

The price rigidity of the model is introduced by a Calvo (1983) mechanism. An intermediate firm has a probability of $(1 - \omega_p)$ each period to reoptimize its price to maximize the expected sum of discounted future real profits. Those cannot do so index their prices to past inflation according to the rule

$$p_t(i) = p_{t-1}(i) \pi_{t-1}^{\chi^p} \pi^{1-\chi^p}. \quad (5)$$

B. Labor Packers

A perfectly competitive labor packer purchases a continuum of differentiated labor inputs $L_t(j)$, where $j \in [0, 1]$, from the households and assembles them to produce a composite labor service L_t (sold to intermediate goods producing firms) by the technology,

$$L_t = \left[\int_0^1 L_t(j)^{\frac{1}{1+\eta_t^w}} dj \right]^{1+\eta_t^w}, \quad (6)$$

where η_t^w denotes a time-varying exogenous markup to wages.

The demand function for a labor packer is

$$L_t(j) = L_t \left(\frac{W_t(j)}{W_t} \right)^{-\frac{1+\eta_t^w}{\eta_t^w}}, \quad (7)$$

where $W_t(j)$ is the wage received from the labor packer by the household j , and W_t is the wage for the composite labor service paid by intermediate firms.

C. Households

Each household j maximizes its utility, given by

$$E_t \sum_{s=0}^{\infty} \beta^s u_{t+s}^b \left[\ln(c_{t+s} - \theta C_{t+s-1}) - \frac{\varphi L_{t+s}(j)^{1+\nu}}{1+\nu} \right], \quad (8)$$

where $\beta \in (0, 1)$ is the discount factor, $\theta \in (0, 1)$ is external habit formation, $\nu \geq 0$ is the inverse of the Frisch labor elasticity, and φ is the disutility weight on labor. Each household owns one unique labor input $L_t(j)$ and is the wage setter for that input, as in Erceg et al. (2000). Due to the existence of state-contingent claims, consumption c_t and asset holdings are the same for all households and thus are not indexed by j . u_t^b is a shock to general preferences that follows the AR(1) process,

$$\ln u_t^b = (1 - \rho_b) \ln u^b + \rho_b \ln u_{t-1}^b + \epsilon_t^b, \quad \epsilon_t^b \sim \text{i.i.d. } N(0, \sigma_b^2). \quad (9)$$

The household j 's flow budget constraint in units of consumption goods is

$$\begin{aligned} c_t + i_t + b_t + \varsigma_{t+1,t} x_t(j) = \\ (1 - \tau_t) W_t(j) L_t(j) + (1 - \tau_t) R_t^K v_t \bar{k}_{t-1} - \psi(v_t) \bar{k}_{t-1} + \frac{R_{t-1} b_{t-1} + x_{t-1}(j)}{\pi_t} + Z_t + D_t, \end{aligned} \quad (10)$$

where τ_t is the income tax rate.⁶ Asset holding consists of the accumulation of gross investment i_t for capital stock \bar{k}_t , one period risk-free government bonds b_t , and household j 's net acquisition of state contingent claims $x_t(j)$. Each household owns an equal share of all intermediate firms and receives the share D_t of intermediate firms' profits. In addition, each household receives a lump-sum transfer Z_t from the government.

Households control both the size of the capital stock and its utilization rate v_t . Effective capital, $k_t = v_t \bar{k}_{t-1}$ is rented to firms at the rate R_t^K . The cost of capital utilization is $\psi(v_t)$ per unit of physical capital. In the steady state, $v = 1$ and $\psi(1) = 0$. Define a parameter $\psi \in [0, 1)$ such that $\frac{\psi''(1)}{\psi'(1)} \equiv \frac{\psi}{1-\psi}$. Then, the law of motion for private capital is

$$\bar{k}_t = (1 - \delta) \bar{k}_{t-1} + u_t^i \left[1 - s \left(\frac{i_t}{i_{t-1}} \right) \right] i_t, \quad (11)$$

⁶Our modeling choice of a single income tax rate and tax-exempt government bonds is driven by two considerations. First, we intend to reduce the size of the system estimated. To model separately labor taxes, capital taxes, and interest income taxes on government bonds would require adding two additional tax variables in the observables. Second, while labor and capital income taxes have different effects, for the purpose of characterizing active and passive fiscal policy, they serve the same financing role to stabilize debt growth.

where $s \left(\frac{i_t}{i_{t-1}} \right) \times i_t$ is an investment adjustment cost, as in Smets and Wouters (2003) and Christiano et al. (2005). By assumption, $s(\gamma) = s'(\gamma) = 0$, and $s''(\gamma) \equiv s > 0$. u_t^i captures exogenous variations in the efficiency with which investment can be transformed into physical capital, as in Greenwood et al. (1997). It evolves according to

$$\ln u_t^i = (1 - \rho_i) \ln u^i + \rho_i \ln u_{t-1}^i + \epsilon_t^i, \quad \epsilon_t^i \sim \text{i.i.d. } N(0, \sigma_i^2). \quad (12)$$

Each period a fraction $(1 - \omega_w)$ of households are allowed to re-optimize their nominal wage rate by maximizing

$$E_t \sum_{s=0}^{\infty} \beta^s \omega_w^s \left[-u_{t+s}^b \frac{\varphi L_t(j)^{1+\nu}}{1+\nu} \right], \quad (13)$$

subject to their budget constraint (10) and the labor demand function (7). The fraction ω_w of households that cannot re-optimize index their wages to past inflation by the rule

$$W_t(j) = W_{t-1}(j) (\pi_{t-1} e^{a_{t-1}})^{\chi^w - 1} (\pi e^\gamma)^{1 - \chi^w}. \quad (14)$$

D. Monetary Policy

The monetary authority follows a Taylor-type rule, in which the nominal interest rate R_t responds to its lagged value, the current inflation rate, and current output. Denote a variable in percentage deviations from the steady state by a caret, as in \hat{R}_t . Specifically, the interest rate is set by

$$\hat{R}_t = \rho_r \hat{R}_{t-1} + (1 - \rho_r) \left(\phi_\pi \hat{\pi}_t + \phi_y \hat{Y}_t \right) + \epsilon_t^r, \quad \epsilon_t^r \sim N(0, \sigma_r^2). \quad (15)$$

E. Fiscal Policy

Each period the government collects tax revenues and issues one-period nominal bonds to finance its interest payments and expenditures, which include government consumption G_t and transfer payments to the households. Denote aggregate effective capital and bonds by K_t and B_t . The flow budget constraint in units of consumption goods is

$$B_t + \tau_t (R_t^k K_t + W_t L_t) = \frac{R_{t-1} B_{t-1}}{\pi_t} + G_t + Z_t. \quad (16)$$

Fiscal variables respond to the lagged debt-to-output ratio according to the following rules:

$$\hat{\tau}_t = \rho_\tau \hat{\tau}_{t-1} + (1 - \rho_\tau) \gamma_\tau \hat{s}_{t-1}^b + \epsilon_t^\tau, \quad \epsilon_t^\tau \sim \text{i.i.d. } N(0, \sigma_\tau^2), \quad (17)$$

$$\hat{G}_t = \rho_g \hat{G}_{t-1} - (1 - \rho_g) \gamma_g \hat{s}_{t-1}^b + \epsilon_t^g, \quad \epsilon_t^g \sim \text{i.i.d. } N(0, \sigma_g^2), \quad (18)$$

and

$$\hat{Z}_t = \rho_z \hat{Z}_{t-1} + \epsilon_t^z, \quad \epsilon_t^z \sim \text{i.i.d. } N(0, \sigma_z^2), \quad (19)$$

where $s_{t-1}^b \equiv \frac{B_{t-1}}{Y_{t-1}}$. Transfers are non-distortionary and are simply modeled as a residual in the government budget constraint, exogenously determined by an AR(1) process. Because our data set does not include transfers, Z_t can be thought of as capturing all movements in government debt that are not explained by the model or the government spending and tax shocks.⁷

Denote aggregate quantities by capital letters. The goods market clearing condition is

$$C_t + I_t + G_t + \psi(v_t)\bar{K}_{t-1} = Y_t . \quad (20)$$

F. Model Solution

The equilibrium consists of optimality conditions for the households' and firms' optimization problems, market clearing conditions, the government budget constraint, monetary and fiscal policy rules, and the stochastic processes for all shocks. Because the model features stochastic growth, some level variables are transformed by the technology level A_t to gain stationarity. The equilibrium system is log-linearized around the steady state of the transformed model and solved by Sims's (2001) algorithm. The Appendix describes the stationary equilibrium, the steady state, and the log-linearized system.

There are two distinct regions of the parameter subspace that deliver a unique rational expectations equilibrium—an active monetary, passive fiscal policy (AMPF) regime or a passive monetary, active fiscal (PMAF) policy regime. In the AMPF regime, the monetary authority responds to inflation deviations from its target level sufficiently to stabilize the inflation path, while the fiscal authority adjusts government spending or tax policy to stabilize government debt growth. In the PMAF regime, the fiscal authority does not take sufficient measures to stabilize debt; instead, the monetary authority pursues actions to stabilize debt growth through price adjustments. We consider both of these regimes in the analysis that follows.

III. ESTIMATION

The model is estimated with quarterly data for three samples in the post-war U.S.: 1955Q1-1966Q4, 1967Q1-1979Q2, and 1984Q1-2007Q4. The first sample has been shown to be consistent with a passive monetary policy and active fiscal policy regime (Davig and Leeper (2006) and Davig and Leeper (2009)). The remaining two samples correspond to the “Great Inflation” and “Great Moderation,” as recognized by the literature. The Great Inflation featured a period of rapid inflation growth and persistent, high inflation. It ended with the appointment of Paul Volcker as Chairman of the Federal Reserve Board in August 1979. The Great Moderation featured stable, low inflation and reduced volatility in macroeconomic

⁷One common specification in modeling income taxes is to include an automatic stabilizing component. Initial estimations find that the data we use are not informative about the parameter for contemporaneous output in (17). Thus, our analysis does not focus on the automatic stabilizing role of income taxes.

aggregates. It lasted until the beginning of the worst and longest recession in the post-WW2 history in December 2007.

Nine observables are used for the estimation, including real consumption, investment, wages, government spending, tax revenue, government debt, hours worked, inflation, and the federal funds rate.⁸ Data for the observables and the log-linearized variables are linked by the following equations:

$$\begin{bmatrix} dlCons_t \\ dlInv_t \\ dlWage_t \\ dlGovSpend_t \\ dlTaxRev_t \\ dlGovDebt_t \\ lHous_t \\ lInfl_t \\ lFedFunds_t \end{bmatrix} = \begin{bmatrix} 100\gamma \\ 100\gamma \\ 100\gamma \\ 100\gamma \\ 100\gamma \\ 100\gamma \\ 0 \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} \hat{c}_t - \hat{c}_{t-1} + \hat{a}_t \\ \hat{i}_t - \hat{i}_{t-1} + \hat{a}_t \\ \hat{w}_t - \hat{w}_{t-1} + \hat{a}_t \\ \hat{g}_t - \hat{g}_{t-1} + \hat{a}_t \\ \hat{t}_t - \hat{t}_{t-1} + \hat{a}_t \\ \hat{b}_t - \hat{b}_{t-1} + \hat{a}_t \\ \hat{L}_t \\ \hat{\pi}_t \\ \hat{R}_t \end{bmatrix}, \quad (21)$$

where l and dl stand for 100 times the log and the log difference of each variable. Small letters denote the transformed quantity of a level variable. \hat{t}_t is transformed tax revenue, and \hat{a}_t is the percentage deviation of the technology growth rate from the steady-state growth rate γ . The analysis focuses on the fiscal behaviors of the federal government; thus, fiscal data do not include those for state and local governments. The appendix provides a detailed description of the data.

A. Methodology

We assume that the parameters are drawn independently, and let $p(\theta)$ be the product of the marginal parameter distributions. Given the plausible interactions between monetary and fiscal policies, $p(\theta)$ has a non-zero density outside the determinacy region of the parameter space. The analysis is restricted to the parameter subspace that delivers a unique rational expectations equilibrium—i.e. an AMPF regime or a PMAF policy regime. Denote this subspace as Θ_D , and let $\mathcal{J}\{\theta \in \Theta_D\}$ be an indicator function that is one if θ is in the determinacy region and zero otherwise. Then, the joint prior distribution is defined as

$$\tilde{p}(\theta) = \frac{1}{c} p(\theta) \mathcal{J}\{\theta \in \Theta_D\}, \quad \text{where } c = \int_{\theta \in \Theta_D} p(\theta) d\theta.$$

⁸As pointed out by Schmitt-Grohe and Uribe (2010), without including the relative price of investment goods in observables, it is likely to obtain a counterfactually large estimate for the standard deviation for the investment efficiency shock. Also, because the paper focuses on feedbacks from debt to distorting fiscal variables, it is essential to include a measure of government debt in the observables. We found that using either government debt growth or the debt-to-GDP ratio as an observable made little difference for posterior estimates. Results are available in the Estimation Appendix, available upon request.

The equilibrium system is written in a state-space form, where observables are linked with other variables in the model. For a given set of structural parameters, the value for the log posterior function is computed. The minimization routine `csmine1` by Christopher Sims is used to search for a local minimum of the negative log posterior function.⁹

The posterior distribution is constructed using the random walk Metropolis-Hastings algorithm. In each estimation, we sample 2.02 million draws from the posterior distribution and discard the first 20,000 draws. The sample is thinned by every 25 draws, which leaves a final sample size of 80,000. A step size of 0.33 yields an acceptance ratio from 0.27 to 0.33 across estimations. Diagnostic tests are performed to ensure the convergence of the MCMC chain, including drawing trace plots, verifying whether the chain is well mixed, and performing Geweke's (2005, pp. 149-150) Separated Partial Means test.

B. Prior Distributions

Several parameters that are hard to identify from the data are calibrated. The discount factor, β , is set to 0.99. The capital income share of total output, α , is set to 0.3, implying a labor income share of 0.7. The quarterly depreciation rate for capital, δ , is set to 0.025, implying the annual depreciation rate is 10 percent. η^w and η^p are set to 0.14, so that the steady-state markups in the product and labor markets are 14 percent.

The steady-state fiscal variables are also calibrated to the mean values of our data from 1955Q1 to 2007Q4.¹⁰ The tax rate, the ratio of government spending to output, and the ratio of government debt to annual output are set to 0.185, 0.104, and 0.348, respectively. When computing these statistics from the data, output is defined as the sum of consumption, investment, and government consumption and investment, consistent with the output definition in the model.

For each sample, the model is estimated with three different priors, given under the prior column in Tables 1, 2, and 3. The only difference amongst the priors is the priors for the monetary and fiscal policy parameters: ϕ_π , γ_g , and γ_t . The specifications assign different weights to the AMPF and PMAF regimes. The first prior specification, P1, is centered at the AMPF regime. The inflation and output coefficients (ϕ_π and ϕ_y) follow the common priors adopted in the literature for U.S. data; the monetary authority raises the interest rate by more than the inflation rate to combat inflation deviations from its target (e.g., Smets and Wouters (2007), Del Negro et al. (2007)). The fiscal authority adjusts government spending and the tax rate to stabilize the debt growth relative to the size of output. We assume normal

⁹To search for the posterior mode, we first calculate the posterior likelihood at 5000 initial draws. The 50 draws with the highest posterior likelihood are used to initialize the search. The mode search that delivers the lowest negative log posterior value is used as the local mode to initialize the random walk Metropolis-Hastings algorithm.

¹⁰Whether the steady-state fiscal values are calibrated to sub-sample means or the means of the entire sample makes little difference for the estimation. Calibrating steady-state fiscal variables to the average of a longer horizon implies that the fiscal authority may not raise taxes or cut spending when the debt-to-output ratio is temporarily higher than the sub-sample mean but lower than the mean of the entire sample.

distributions for the responses of fiscal instruments to debt (γ_g and γ_t) with a mean of 0.15 and a standard deviation 0.05, similar to those used in Traum and Yang (2010).

The second prior specification, P2, is centered at the PMAF regime. In this specification, the monetary authority raises the interest rate less than one-for-one with inflation deviations, and the fiscal authority does not adjust instruments sufficiently to control debt growth. ϕ_π has a beta distribution with a mean of 0.5 and a standard deviation of 0.2, and γ_g and γ_t both have normal distributions with zero means and standard deviations of 0.03. The third prior specification, P3, is restricted to the PMAF regime, and assumes the fiscal authority cannot use the fiscal instruments to control debt growth. ϕ_π has a beta distribution with a mean of 0.5 and a standard deviation of 0.2, as in P2.

A priori, we do not have a view about how policy regimes influence the structural parameters. Thus, our priors for all other estimated parameters follow closely those of Smets and Wouters (2007) and Justiniano et al. (2010). The prior for the percentage growth rate of technology (100γ) is normally distributed with a mean of 0.5 and a standard deviation of 0.03. The tight prior is meant to guide the estimate to match the average quarterly growth rate of real output (the sum of consumption, investment, and government consumption and investment) per capita, which is 0.47 from 1955Q1 to 2007Q4.

Given the complexity of the model, the parameter space for policy regimes cannot be characterized analytically. Instead, a numerical approach is used to search for the boundaries of the parameter space that yield an AMPF or a PMAF regime. For a parameter combination that delivers a determinate equilibrium, we further check whether the determinacy can be preserved if the fiscal policy specification is replaced with one where transfers adjust sufficiently to stabilize debt growth—a definite passive fiscal policy. In this case, $\gamma_g = \gamma_t = 0$, the coefficient of transfers' response to debt is set to 0.5, and other parameters are held at their original values. If a determinate equilibrium is found under this passive fiscal policy, then the original parameter combination implies an active monetary policy.¹¹ The same approach is used to examine the policy regimes implied by parameter combinations drawn from the three prior specifications. The probabilities for the PMAF regime under P1, P2, and P3 specifications are 1.15, 99.97, and 100 percent, respectively.

Figure 1 plots combinations of various parameters and the monetary authority's response to inflation, ϕ_π , that deliver the AMPF regime. For each plot, all other parameters are held at their mean values in the P1 specification. Although the boundary condition for ϕ_π occurs around one for most parameter combinations, the plots show that the values of ω_p , ω_w , ϕ_y , and ρ_r influence the boundary value of ϕ_π . This finding is consistent with the results of Flaschel et al. (2008). Values of ϕ_π much smaller than one are consistent with active monetary policy when wages and/or prices are very sticky. For instance, $\phi_\pi \geq 0.7$ is consistent with an AMPF regime when $\omega_w = 0.9$ (and all other parameters are kept at their

¹¹To ensure our approach is robust, the exercise is also conducted from the opposite direction. We also check if a determinate equilibrium can be found when an active fiscal policy is imposed (by not allowing any fiscal variables respond to debt), which implies the original parameter combination has a PMAF regime. The results show that checking from either direction yield the same conclusion in determining the policy regime of a parameter combination.

prior means). High price stickiness implies that current and future prices adjust very slowly. In this case, the monetary authority need not respond more than one-for-one to inflation, provided it responds to output, as expectations of future inflation deviations are already small. Similarly, very sticky nominal wages translate into smaller inflation deviations and inflation expectations, because the marginal cost of the intermediate goods producing firms and, in turn, the general price level are driven by factor prices.

C. Posterior Estimates

Tables 1, 2, and 3 compare the means and 90-percent credible intervals of the posterior distributions estimated from the three prior specifications across all the sample periods. Overall the data are informative about most of the parameters, as the 90-percent credible intervals for most of the parameters are different from those implied by the prior distributions. The sole exception is the technology growth rate γ , whose posterior estimate closely mimics its prior. Our estimates for structural parameters are similar to previous estimates from similar DSGE models (e.g., Smets and Wouters (2007) and Del Negro et al. (2007)).

Several observations can be made when comparing the estimates across the sample periods. Conditional on a sample period, the prior specifications only have a small influence on the estimates of most non-policy parameters. The exceptions are the degrees of price and wage stickiness (ω_p and ω_w), which have higher estimates from the P2 and P3 specifications than the typical estimates in the literature. In Section IV, we investigate further why nominal rigidities have high estimates under P2 and P3. Both government spending and taxes are consistently used to finance debt, as the 90-percent credible intervals for γ_g and γ_t are positive in all samples of the P1 and P2 specification, except the estimate for γ_g for 1955Q1-1966Q4 under P2. In addition, adjustments in government spending are increasingly made across samples to finance debt. The volatility of several shocks, including the monetary policy shock, decreases over time. However, the largest magnitude reduction in the standard deviation of the monetary policy shocks—from 0.17 in the 1967Q1-1979Q2 sample to 0.14 in the 1984Q1-2007Q4 sample under P1—is smaller than those found in the literature.¹² The volatility of the tax and transfer shocks is the highest in 1967Q1-1979Q2, allowing the model to match the increase in the standard deviation of government debt growth over this period (see Table 4).

Our estimated response of the interest rate to inflation, ϕ_π , for the two pre-Volcker samples under the standard prior specification (P1) is substantially higher than several previous estimates (Clarida et al. (2000), Cogley and Sargent (2005), Boivin (2006) and Bilbiie et al. (2008)), but are comparable to those from Bayesian estimations of DSGE models (see Smets and Wouters (2007) and Arestis et al. (2010)). Low values of ϕ_π are often thought to be necessary to match the persistence and volatility of inflation in the Great Inflation era.

¹²Boivin and Giannoni (2006) find that the standard deviation of the interest rate is 0.48 for the 1959Q1-1979Q2 sample and 0.23 for the 1979Q3-2002Q2 sample. Smets and Wouters (2007) report that the estimated mode for the standard deviation of the monetary policy shock falls from 0.2 in the 1966Q1-1979Q2 sample to 0.12 in the 1984Q1-2007Q4 sample.

Consistent with this view, most of our estimates for ϕ_π are lower in the two pre-Volcker samples than the Great Moderation era, but the model still tends to overestimate the volatility of inflation (see Table 4). Because of the need to match the large variances of government debt growth and tax revenue growth in the data and the fact that distortionary financing of government debt increases the volatility in the model, our model setup, which is a rather standard New Keynesian model, cannot quite reconcile its estimated variances of inflation and the nominal interest rate with the data counterpart.¹³ This suggests that further research is needed in exploring alternative model specifications to better capture the observed variances among various monetary and fiscal variables.

Finally, our estimated response of the interest rate to output is also somewhat high. The interest rate's response to output (ϕ_y) in the post-Volcker sample under P1 is close to the standard Taylor-rule value of 0.5 (based on the annualized interest rate) from a single-equation estimation but higher than those obtained from structural estimations. Our mean estimate of ϕ_y is 0.12 in the 1984Q1-2007Q4 sample under P1, much higher than 0.08 obtained by Smets and Wouters (2007) for a similar sample period. Also, using the method of minimum distance estimation, Boivin and Giannoni (2006) obtain almost zero responses of the interest rate to output deviations for both the pre- and post-Volcker samples.

IV. REGIME ANALYSIS

Given that the different prior specifications force the model into the AMPF or PMAF regimes, we perform posterior odds comparisons to determine which regime is favored by the data. Bayes factors are used to evaluate the relative model fit for the three samples. Table 5 presents the results. Bayes factors are based on log-marginal data densities calculated using Geweke's (1999) modified harmonic mean estimator with a truncation parameter of 0.5. Across all three samples, the data prefer the P1 specification, although the evidence favoring P1 over P2 for 1955Q1-1966Q4 and 1967Q1-1979Q2 is weak.¹⁴ Consistent with expectations, the P1 specification performs much better than the alternative specifications for the 1984Q1-2007Q4 sample. All samples strongly dislike the P3 specification.

The P2 and P3 specifications have a harder time than the P1 specification matching various unconditional moments of the observables. When the monetary authority responds less than one-for-one with inflation deviations, the model specification implies a high volatility in prices, the nominal interest rate, and hours worked. This can be seen from the unconditional mean and 90-percent credible interval from the prior distributions of the observables' standard deviations (see Table 6). Given that the fiscal authority does not respond sufficiently to maintain budget solvency under P2 and P3 and that the model only features one-quarter, short-term government bonds, prices must adjust sufficiently within the quarter to stabilize the real value of government indebtedness.

¹³In contrast, Justiniano et al. (2010) slightly underpredict this volatility over the period 1954Q3-2004Q4 using a similar model specification without fiscal policy and fiscal observables.

¹⁴The results from the priors centered at the PMAF regime (P2 and P3) may be penalized by the high posterior estimates for the degrees of price and wage stickiness, which are outliers from their priors.

In estimation, to reconcile the volatile inflation implied by the P2 and P3 priors and the much smoother inflation series in the data, the posterior forces the estimated price and wage stickiness to be high, much higher than the common estimated values observed under P1 or in the literature. High degrees of nominal stickiness imply slow price adjustments that dampen the volatility of inflation, allowing the model to better match the data. Figure 2 plots prior and posterior bivariate densities of the unconditional standard deviation of inflation and the Calvo pricing parameter ω_p under the P2 and P3 specifications estimated from the 1955Q1-1966Q4 sample. Unlike the priors, the posterior densities give high weight exclusively to large degrees of price stickiness. Similar changes from prior to posterior densities are also observed when plotting bivariate densities of the unconditional standard deviation (covariance) of inflation or (and) the nominal interest rate against one of the two Calvo parameters— ω_p or ω_w —across all samples estimated.

It may seem puzzling that the P2 specification is preferred to P3, given that the priors are very similar. However, the estimates from these two specifications assign quite different weights to the policy regimes. The posterior draws under P3 are entirely concentrated in the PMAF regime (by design), while the posterior draws under P2 are almost exclusively located in the AMPF regime, despite that the P2 prior gives substantial weight to the PMAF region (with 99.97 percent probability in the PMAF regime). Specifically, 99.95, 99.85, and 100 percent of the posterior draws under P2 are located in the AMPF region for 1955Q1-1966Q4, 1967Q1-1979Q2, and 1984Q1-2007Q4 respectively.

The difference in regime estimates by the P2 and P3 specifications has important consequences for the estimated volatility of the model. Table 4 gives the unconditional mean and 90-percent credible interval from the posterior distribution of the observables' standard deviations for the various specifications. It also lists the standard deviations calculated from the data. In all samples, the P3 estimates substantially increase the volatility of hours worked and the covariance of hours worked with other variables (not presented)—much higher than the data counterpart. In contrast, the P2 estimates match the statistics from the data much better, which explains why P2 is preferred in model comparisons.

What accounts for the volatility to hours worked? Given that prices and/or wages are estimated to be very sticky, wages are slow to adjust. Slower wage adjustments induce more changes in firms' labor demand following structural and policy shocks, which drives up the variance of hours worked. Although this effect occurs in both the P2 and P3 specifications, the effect is much stronger in the P3 specification due to different monetary policy estimates. The estimated response of the interest rate to output, ϕ_y , under P2 is approximately double the one under P3. The P2 specification allows the monetary authority to respond more aggressively to output fluctuations, dampening the effects of expansions or contractions in the economy. As a result, firms do not adjust their labor demand as much following shocks under P2 compared to under P3, where the monetary authority responds weakly to output fluctuations. Figure 3 illustrates this by plotting prior and posterior bivariate densities of the unconditional standard deviation of labor and the interest rate response to output ϕ_y for the P2 and P3 specifications estimated from 1955Q1-1966Q4.

The difference in monetary policy estimates across P2 and P3 (specifically ϕ_y) is explained by the different policy regimes implied by the prior and the posterior under P2. As we have seen, the P2 specification implies a very high estimated degree of nominal stickiness *and* a large interest rate response to output deviations. Both of these features help simultaneously dampen inflation and hours worked volatility. Thus, the interest rate's response to inflation need not be larger than one in order to sufficiently stabilize inflation. Monetary policy for the vast majority of draws from the posterior distribution under P2 is *active* despite that the mean estimate of ϕ_π is centered at values much below one for all three samples (see Table 2). On the other hand, under P3, while the posterior estimations also push the estimates for nominal rigidities to be high to reduce the price and interest rate volatilities, the fixed PMAF regime forces the interest rate response to inflation to be low (with the mean estimate from 0.23 to 0.4 across sample, see Table 3) in order to maintain passive monetary policy. Thus, the estimation under P3 does not have sufficient degree of freedom among parameters to reduce volatility of inflation and hours worked to be more in line with the data. It is not surprising that the model fit to data under P3 is the worst among the three specifications.

The analysis here suggests that although the model comparisons indicate that the data across all three samples prefer the P1 specification (where the posterior falls in the AMPF regime and the monetary authority's response to inflation is much higher than one), it is unclear whether our conclusion about policy regimes, particularly for the pre-Volcker samples, would hold in a more general model of monetary and fiscal policy interactions. Echoing the implication in Section 3 regarding the over-estimated variances of inflation and the nominal interest rate, our results suggest that the standard New Keynesian model used for policy analysis is not able to match features of the data if a PMAF regime is assumed. One possible future generalization that may reduce the inflation volatility of the PMAF regime is a model that includes longer maturity horizons for government debt.

V. APPLICATIONS

In this section, we use the estimated model to study monetary and fiscal policy effects. Three applications are investigated: the evolution of monetary policy effects in the post-war U.S., the effect of a government spending increase under a PMAF regime, and the expansionary effect of an income tax cut.

A. The Evolution of Monetary Policy Effects

The estimates from the three samples allow us to examine the evolution of monetary policy effects. Estimates based on identified VARs find that monetary policy has a diminished effect on output and inflation in recent decades compared to earlier samples (e.g., Gertler and Lown (1999), Barth and Ramey (2002), Boivin and Giannoni (2002), and Boivin and Giannoni (2006)). Our estimates, however, do not imply a diminished effect on output in the post-Volcker sample.

Figures 4 and 5 compare the impulse responses across the three samples to an exogenous monetary tightening. Solid lines are the responses under the mean parameter values, and dotted-dashed lines are the 90-percent credible intervals from the posterior distribution. Because the pre-Volcker samples only weakly prefer the P1 specification to P2, the results for the P1 and P2 specifications are plotted for the two earlier samples. Figure 4 displays the responses across the three samples under the P1 specification. Figure 5 plots the responses under the P2 specification for the 1955Q1-1966Q4 and 1967Q1-1979Q2 samples and under the P1 specification for the 1984Q1-2007Q4 sample.

Based on the two plots, no evidence is found that monetary policy has had diminished effects on output. Conditional on the P1 specification for all samples (Figure 4), monetary policy's effect on output for the 1984Q1-2007Q4 sample (the right column) is not much different from that for the 1967Q1-1979Q2 sample (the middle column). The mean response peaks at about 2.5 percent in both cases. If, instead, the actual output responses are more in line with the P2 specification (Figure 5), then it appears that monetary policy has become more effective in influencing output in the post-Volcker sample. The estimated mean peak response of output for the two pre-Volcker samples is about 1 percent. This magnitude is more comparable to those obtained by identified VARs for the pre-Volcker sample (e.g., see Boivin and Giannoni's (2006) estimate over 1959Q1-1979Q3).

For inflation, our estimation is inconclusive about whether monetary policy has had a diminished effect in the post-Volcker period. When all samples are conditioned on the P1 specification (Figure 4), the mean inflation response declines substantially, from more than 0.2 percent in 1967Q1-1979Q2 to less than 0.05 percent in the 1984Q1-2007Q4 sample. However, the upper bounds of the responses across all three samples are quite similar. When the earlier two samples are estimated under the P2 specification, the results yield a different conclusion. Monetary tightening has little effect in lowering inflation, as the central bank responds less than one-for-one to inflation deviations. In the case of the 1967-1979 sample, a monetary tightening can even drive up inflation in the medium run.

Many parameters can affect the responses of output and inflation over time. The discussion here focuses on the the persistence in monetary policy shocks (ρ_r), the response of the interest rate to inflation (ϕ_π), and the degree of price rigidity (ω_p). A more persistent monetary policy innovation implies a stronger effect on output. When monetary tightening is expected to last for a long time, the asset substitution effect between government bonds and physical capital intensifies, leading output to contract more. Under the P1 specification, the mean estimates of ρ_r are 0.83, 0.88, and 0.86 for the three samples sequentially. Under P2, the mean estimates of ρ_r for 1955Q1-1966Q4 and 1967Q1-1979Q2 are 0.79 and 0.70. In both figures, the ordering of the expansionary effects are consistent with the ordering for ρ_r across the three samples.

The parameters ϕ_π and ω_p also are important for the effects of monetary policy on inflation. Under the P1 specification, a high inflation response dampens the fall in inflation to a monetary tightening, as shown in the 1984Q1-2007Q4 sample with the estimated mean of $\phi_\pi = 2$. Further, this sample also features a relatively high ω_p under P1, which contributes to the reduced effectiveness of monetary policy in influencing inflation in the post-Volcker

sample. When ω_p approaches one and prices become completely fixed, as estimated under the P2 specification for the 1955Q1-1966Q4 sample, the monetary policy's ability to influence inflation is almost nil, as shown by the (2,1) panel in Figure 5.

Notice that a small "price puzzle" is observed following a monetary tightening in the 1967Q1-1979Q2 sample under P2, as shown in the (2,2) panel in Figure 5. This sample features a high degree of wage stickiness. In this circumstance, a monetary tightening reduces equilibrium labor and drives up the wage rate. Given the slow wage adjustment process and the relatively small response of the interest rate to inflation, the increasing marginal costs leads to inflation and inflation expectations to rise.

B. Government Spending Increase under a PMAF Regime

Estimated neoclassical or New Keynesian models generally imply a negative consumption response to an increase in government spending, unless the model includes a sufficiently large fraction of rule-of-thumb consumers (e.g., Cogan et al. (2009) and Traum and Yang (2010)). Using calibrated New Keynesian models, Kim (2003) (in a fixed regime environment) and Davig and Leeper (2009) (in a regime-switching environment) demonstrate that an increase in government spending yields a positive consumption response under the PMAF regime. When the regime is PMAF, a government spending increase does not necessarily imply increases in the real interest rate. Since monetary policy is not expected to raise the nominal rate sufficiently to combat inflation, higher expected inflation can turn the real interest rate negative and spur consumption.

Figures 6 and 7 plot the impulse responses to a one standard deviation increase in the government spending shock for the 1955Q1-1966Q4 and 1967Q1-1979Q2 samples under the P1 (the left column) and P3 (the right column) specifications. Solid lines are responses of the mean estimates for the parameters, and dotted-dashed lines are the 90-percent confidence bands. We examine the imposed PMAF regime (the P3 specification) to see if the positive consumption response to a government spending increase is likely in the estimated model. The responses are compared to those obtained from the P1 specification, which is preferred by the data.

Several observations can be made. First, a positive consumption response to a government spending increase is observed under the P3 specification for the 1967Q1-1979Q2 sample, but not for the 1955Q1-1966Q4 sample. This suggests that a PMAF regime is not a sufficient condition to generate a positive consumption response to a government spending increase. Second, the estimation under P1 produces the same qualitative responses as most New Keynesian or neoclassical growth models; the competition for goods from the government drives up the real interest rate, and the negative wealth effect from the increase in government spending lowers consumption. Third, the output multipliers for government spending are small, especially under the P1 specification. Under the mean parameter values, the present-value output multiplier at the end of two years following the shock for the 1955Q1-1966Q4 (1967Q1-1979Q2) is about 0.5 (0.6) under P1 and 1.1 (1.2) under P3. Further, the cumulative output multiplier computed over 1000 quarters is -0.7 (-0.7) under

P1 and around 1.1 (1.2) under P3 for the 1955Q1-1966Q4 (1967Q1-1979Q2) sample. Although output multipliers with an imposed PMAF regime under P3 can be larger than 1, this is much smaller than those obtained by Davig and Leeper (2009), around 2.3 with a fixed PMAF regime.

Why doesn't consumption always respond positively under the PMAF regime? Notice that our estimated mean degree of price rigidity $\omega_p = 0.98$ is quite high for the 1955Q1-1966Q4 sample under the P3 specification (v.s. 0.78 for the 1967Q1-1979Q2 sample). When prices are highly sticky, the magnitude of the price increase in response to a positive spending shock is rather small. The high degree of price stickiness also implies that future price levels will only adjust slowly, generating smaller inflation expectations. Thus, instead of a falling real interest rate as observed in the earlier analyses under the PMAF regime, the real interest rate can still rise, resulting in a decline in consumption. The real interest rate in Figure 6 under P3 remains positive, while the real interest is negative in Figure 7 under P3.

The small (or negative) cumulative output multipliers obtained here are mainly driven by the high persistence of the government spending shock. Under the P1 specification, $\rho_g = 0.98$ for the two pre-Volcker samples. A highly persistent shock induces a large negative wealth effect because agents expect that government spending will remain high for a sustained period. As shown in the (1,1) panel of Figures 6 and 7, consumption is persistently negative even 10 years after the initial increase of government spending.¹⁵ In the longer run, a higher government debt-to-output ratio triggers distorting fiscal adjustments through higher income taxes and lower government spending; thus, output turns negative and hence the negative cumulative multipliers, as shown in the (1,2) panel of both figures. Under P3, while the short-run output response is similar to those under P1, the cumulative multipliers is larger than 1 for both sample periods (compared to a negative multiplier under P1). Because fiscal policy does not adjust to control debt growth under P3 (the PMAF regime) and consumption can turn positive, cumulative output multipliers are much larger compared to those under P1 (the AMPF regime).

Finally, our estimations yield high degrees of habit formation. All mean estimates of θ exceed 0.7. A high degree of habit formation punishes consumption from deviating severely from its previous level. Under the AMPF regime (P1), a high degree of habit formation dampens the negative consumption response to a government spending increase and thus makes the output multiplier rise more. On the other hand, under the PMAF regime (P3), a high degree of habit formation prevents consumption from rising too much and thus dampens the output multiplier.

¹⁵The high persistence of the government spending shock obtained here is not uncommon in the literature: Zubairy (2009) obtains $\rho_g = 0.92$ in a model with deep habit for the sample of 1958 to 2008, Leeper et al. (2010) obtain the mean estimate of ρ_g around 0.97 under various fiscal policy rules for the sample of 1960 to 2008, and Justiniano et al. (2010) obtain a median estimate of ρ_g of 0.99.

C. The Expansionary Effect of an Income Tax Cut

When investigating the effects of a tax shock under various specifications, we find one unusual result: the labor response can be negative in the pre-Volcker period under the P2 specification.

Figures 8 and 9 plot the impulse responses to a one standard deviation tax cut for the two earlier samples. The left column has responses under the P1 specification, and the right column has responses under the P2 specification. The solid lines are the responses conditional on the mean estimates for the parameters, and the dotted-dashed lines are the 90-percent credible intervals. Under the P1 specification, a deficit-financed reduction in the income tax rate is expansionary, increasing labor and output as expected. An income tax rate reduction encourages savings and increases labor. More savings leads to higher capital accumulation, raising the marginal product of labor and the demand for labor. This lowers the marginal cost of intermediate goods producing firms and hence the price level. Labor falls slightly in later periods partly due to the positive wealth effect and partly due to fiscal adjustments, which involve a decrease in government spending. In both samples, the monetary authority responds more to the falling price level than the increased level of output, causing the nominal interest rate to decline.

Under the P2 specification, instead of lowering the nominal interest rate, the monetary authority raises the interest rate to counteract the rise in output. A higher nominal interest rate effectively suppresses investment and thus labor demand. Although agents are induced to supply more labor from the lower income tax rate, in equilibrium labor turns negative, opposite to the expected positive response from an income tax cut.

The different responses of the monetary authority under the two specifications are driven by the reaction magnitudes to output and inflation fluctuations. As explained earlier, an income tax cut lowers the price level and expands output. Thus, it triggers two opposite nominal interest rate responses: a negative response to the falling price level and a positive response to the increased output. Under the P2 specification, the estimated monetary policy's reaction to output is relatively strong for the pre-Volcker samples. The mean estimates of ϕ_y is 0.18 and 0.14 for the 1955Q1-1966Q4 and 1967Q1-1979Q2 samples respectively. At the same time, the estimated reaction to inflation is small, around 0.5-0.6. Thus, the net response is likely to be positive, opposite the response estimated under the P1 specification. The response differences between specifications highlight the significance of monetary policy accommodation for the expansionary effects of an income tax cut.

Despite the negative labor response, an income tax cut remains expansionary under the P2 specification. While consumption and investment responses are muted initially, the capital utilization rate is higher due to the lower income tax rate, which produces more output. Overall the output responses for an income tax cut presented in Figures 8 and 9 are quite small; the present-value output multipliers at the end of year two after a tax shock are all below 0.1 under either P1 or P2 specification for both pre-Volcker samples. Aside from the monetary authority's counter-expansionary response to rising output, the model specification, which only allows for distorting financing, also dampens the expansionary effect of a tax cut.

Since in reality the government also adjusts transfers to control debt growth, our estimates for the effects of income tax cuts are likely to overstate the negative effect of fiscal financing and under-estimate the expansionary effects on output, labor, consumption, and investment, because our policy rules do not allow the use of non-distorting transfers in stabilizing government debt.

VI. CONCLUSIONS

We study the interactions of monetary and fiscal policy by fitting a New Keynesian model to various samples in the post-WW2 U.S. We do not find evidence supporting a fixed PMAF regime in any period, largely because the estimated volatility of hours worked and inflation in the PMAF regime is much higher than that observed in the data.

Aside from estimating the policy regimes in the post-war U.S., we also study several issues related to the effects of monetary and fiscal policy. Unlike the VAR literature, we do not find that monetary policy has had reduced effectiveness on output in the post-Volcker samples. Also, we show that a government spending increase can generate a positive consumption response under a PMAF regime, but the result depends on the estimated degree of price stickiness. Finally, an income tax cut can generate a negative labor response if the monetary authority raises the nominal interest rate to counteract the expansionary effect induced by an income tax cut.

One caveat in our analysis is worth noting. Our estimation fixes policy parameters and does not allow for regime switches. Davig and Doh (2009) and Bianchi (2010) have estimated New Keynesian models without fiscal policy and found that monetary policy has switched several times from active to passive, and vice versa. Fernandez-Villaverde et al. (2010b) estimates a similar model that allows for parameter drift in the Taylor rule and finds evidence of several changes in monetary policy as well. Such models may have more favorable support from the data for the PMAF regime, as expectations of future monetary and fiscal policy changes could alleviate some of the complications our fixed PMAF regime encounters to match the volatility of the data. We leave this extension to future research.

VII. APPENDIX: THE EQUILIBRIUM SYSTEM

This appendix consists of the stationary equilibrium, the steady state, and the log-linearized system.

A. The Stationary Equilibrium

Since the economy features a permanent shock to technology, several variables are not stationary along the balanced-growth path. In order to induce stationarity, we perform a change of variables and define: $y_t = \frac{Y_t}{A_t}$, $c_t = \frac{C_t}{A_t}$, $k_t = \frac{K_t}{A_t}$, $\bar{k}_t = \frac{\bar{K}_t}{A_t}$, $i_t = \frac{I_t}{A_t}$, $g_t = \frac{G_t}{A_t}$, $z_t = \frac{Z_t}{A_t}$, $w_t = \frac{W_t}{A_t}$, and $\lambda_t = \Lambda_t A_t$, where λ_t is the Lagrange multiplier from the household's budget constraint. The equilibrium system written in stationary form consists of the following equations.

Production function:

$$y_t = k_t^\alpha L_t^{1-\alpha} \quad (22)$$

Capital-labor ratio:

$$\frac{k_t}{L_t} = \frac{w_t}{R_t^k} \frac{\alpha}{1-\alpha} \quad (23)$$

Marginal cost:

$$mc_t = (1-\alpha)^{\alpha-1} \alpha^{-\alpha} (R_t^k)^\alpha w_t^{1-\alpha} \quad (24)$$

Intermediate firm FOC for price level:

$$0 = E_t \left\{ \sum_{s=0}^{\infty} (\beta \omega_p)^s \lambda_{t+s} \bar{y}_{t+s} \left[\bar{p}_t \prod_{k=1}^s \left[\left(\frac{\pi_{t+k-1}}{\pi} \right)^{\chi^p} \left(\frac{\pi}{\pi_{t+k}} \right) \right] - (1 + \eta_{t+s}^p) mc_{t+s} \right] \right\} \quad (25)$$

where $\bar{p}_t = p_t/P_t$ and

$$\bar{y}_{t+s} = \left(\bar{p}_t \prod_{k=1}^s \left[\left(\frac{\pi_{t+k-1}}{\pi} \right)^{\chi^p} \left(\frac{\pi}{\pi_{t+k}} \right) \right] \right)^{-\frac{1+\eta_{t+s}^p}{\eta_{t+s}^p}} y_{t+s} \quad (26)$$

Aggregate price index:

$$1 = \left\{ (1 - \omega_p) \bar{p}_t^{\frac{1}{\eta_t^p}} + \omega_p \left[\left(\frac{\pi_{t-1}}{\pi} \right)^{\chi^p} \left(\frac{\pi}{\pi_t} \right) \right]^{\frac{1}{\eta_t^p}} \right\}^{\eta_t^p} \quad (27)$$

Household FOC for consumption:

$$\lambda_t = \frac{e^{a_t} u_t^b}{e^{a_t} c_t - \theta c_{t-1}} \quad (28)$$

Euler Equation:

$$\lambda_t = \beta R_t E_t \frac{\lambda_{t+1} e^{-a_{t+1}}}{\pi_{t+1}} \quad (29)$$

Household FOC for capacity utilization:

$$(1 - \tau_t) R_t^k = \psi'(v_t) \quad (30)$$

Household FOC for capital:

$$q_t = \beta E_t \frac{\lambda_{t+1} e^{-a_{t+1}}}{\lambda_t} \left[(1 - \tau_{t+1}) R_{t+1}^k v_{t+1} - \psi(v_{t+1}) + (1 - \delta) q_{t+1} \right] \quad (31)$$

where $q_t = \lambda_t / \xi_t$. Household FOC for investment:

$$1 = q_t \left[1 - s \left(\frac{i_t e^{a_t}}{i_{t-1}} \right) - s' \left(\frac{i_t e^{a_t}}{i_{t-1}} \right) \frac{i_t e^{a_t}}{i_{t-1}} \right] + E_t \left[q_{t+1} \frac{\lambda_{t+1} e^{-a_{t+1}}}{\lambda_t} s' \left(\frac{i_{t+1} e^{a_{t+1}}}{i_t} \right) \left(\frac{i_{t+1} e^{a_{t+1}}}{i_t} \right)^2 \right] \quad (32)$$

Effective capital:

$$k_t = v_t e^{-a_t} \bar{k}_{t-1} \quad (33)$$

Law of motion for capital:

$$\bar{k}_t = (1 - \delta) e^{-a_t} \bar{k}_{t-1} + u_t^i \left[1 - s \left(\frac{i_t e^{a_t}}{i_{t-1}} \right) \right] i_t \quad (34)$$

Household FOC for wage:

$$0 = E_t \left\{ \sum_{s=0}^{\infty} (\beta \omega_w)^s \lambda_{t+s} \bar{L}_{t+s} \left[\bar{w}_t \prod_{k=1}^s \left[\left(\frac{\pi_{t+k-1} e^{a_{t+k-1}}}{\pi e^\gamma} \right) \left(\frac{\pi e^\gamma}{\pi_{t+k} e^{a_{t+k}}} \right) \right] - (1 + \eta_{t+s}^w) \frac{u_{t+s}^b \varphi \bar{L}_{t+s}^\nu}{\lambda_{t+s} (1 - \tau_{t+s})} \right] \right\} \quad (35)$$

where \bar{w} is the wage given from the labor packer to the household and

$$\bar{L}_{t+s} = \left\{ \bar{w}_{t+s} \prod_{k=1}^s \left[\left(\frac{\pi_{t+k-1} e^{a_{t+k-1}}}{\pi e^\gamma} \right) \left(\frac{\pi e^\gamma}{\pi_{t+k} e^{a_{t+k}}} \right) \right] \right\}^{-\frac{1 + \eta_{t+s}^w}{\eta_{t+s}^w}} L_{t+s} \quad (36)$$

Aggregate wage index:

$$w_t^{\frac{1}{\eta_t^w}} = (1 - \omega_w) \bar{w}_t^{\frac{1}{\eta_t^w}} + \omega_w \left[\left(\frac{\pi_{t-1} e^{a_{t-1}}}{\pi e^\gamma} \right)^{\chi^w} \left(\frac{\pi e^\gamma}{\pi_t e^{a_t}} \right) w_{t-1} \right]^{\frac{1}{\eta_t^w}} \quad (37)$$

Aggregate resource constraint:

$$y_t = c_t + i_t + g_t + \psi(v_t) e^{-a_t} \bar{k}_{t-1} \quad (38)$$

Government budget constraint:

$$b_t + \tau_t R_t^k k_t + \tau_t w_t L_t = \frac{R_{t-1}}{\pi_t e^{a_t}} b_{t-1} + g_t + z_t \quad (39)$$

B. The Steady State

By assumption, in steady state $v = 1$, $\psi(1) = 0$, $s(\gamma) = s'(\gamma) = 0$. In addition, we assume that $\pi = 1$, implying $R = \gamma/\beta$.

$$R^k = \frac{\gamma/\beta - (1 - \delta)}{1 - \tau}$$

$$\psi'(1) = R^k(1 - \tau)$$

$$mc = \frac{1}{1 + \eta^p}$$

$$w = \left[\frac{1}{1 + \eta^p} \alpha^\alpha (1 - \alpha)^{1-\alpha} (R^k)^{-\alpha} \right]^{\frac{1}{1-\alpha}}$$

$$\frac{k}{L} = \frac{w}{R^k} \frac{\alpha}{1 - \alpha}$$

$$\frac{k}{y} = \left(\frac{w}{R^k} \frac{\alpha}{1 - \alpha} \right)^{1-\alpha}$$

$$\frac{L}{y} = \left(\frac{w}{R^k} \frac{\alpha}{1 - \alpha} \right)^{-\alpha}$$

$$\frac{i}{L} = [1 - (1 - \delta)e^{-\gamma}] e^\gamma \frac{k}{L}$$

$$\frac{c}{L} = \frac{y}{L} \left(1 - \frac{g}{y} \right) - \frac{i}{L}$$

$$\frac{z}{y} = (1 - Re^{-\gamma}) \frac{b}{y} - \frac{g}{y} + \tau \left[R^k \frac{k}{y} + w \frac{L}{y} \right]$$

$$L = \left[\frac{w(1 - \tau)}{(1 + \eta^w)\varphi} \left(\frac{c}{L} \right)^{-1} \frac{e^\gamma}{e^\gamma - \theta} \right]^{\frac{1}{1+\nu}}$$

We calibrate φ so that steady state labor L equals unity. Given L , the levels of all other steady state variables can be backed out.

C. The Log-Linearized System

We define the log deviations of a variable X from its steady state as $\hat{X}_t = \ln X_t - \ln X$, except for $\hat{a}_t \equiv a_t - \gamma$, $\hat{\eta}_t^p = \ln(1 + \eta_t^p) - \ln(1 + \eta^p)$, and $\hat{\eta}_t^w = \ln(1 + \eta_t^w) - \ln(1 + \eta^w)$. The equilibrium system in the log-linearized form consists of the following equations.

Production function:

$$\hat{y}_t = \alpha \hat{k}_t + (1 - \alpha) \hat{L}_t \quad (40)$$

Capital-labor ratio:

$$\hat{R}_t^k - \hat{w}_t = \hat{L}_t - \hat{k}_t \quad (41)$$

Marginal cost:

$$\hat{m}c_t = \alpha \hat{R}_t^k + (1 - \alpha) \hat{w}_t \quad (42)$$

Phillips equation:

$$\hat{\pi}_t = \frac{\beta}{1 + \chi^p \beta} E_t \hat{\pi}_{t+1} + \frac{\chi^p}{1 + \chi^p \beta} \hat{\pi}_{t-1} + \kappa_p \hat{m}c_t + \kappa_p \hat{\eta}_t^p$$

where $\kappa_p = [(1 - \beta\omega_p)(1 - \omega_p)]/[\omega_p(1 + \beta\chi^p)]$.

Household FOC for consumption:

$$\hat{\lambda}_t = \hat{u}_t^b + \hat{a}_t - \frac{e^\gamma}{e^\gamma - \theta} (\hat{c}_t + \hat{a}_t) + \frac{\theta}{e^\gamma - \theta} \hat{c}_{t-1} \quad (43)$$

Euler Equation:

$$\hat{\lambda}_t = \hat{R}_t + E_t \hat{\lambda}_{t+1} - E_t \hat{\pi}_{t+1} - E_t \hat{a}_{t+1} \quad (44)$$

Household FOC for capacity utilization:

$$\hat{R}_t^k - \frac{\tau}{1 - \tau} \hat{\tau}_t = \frac{\psi}{1 - \psi} \hat{v}_t \quad (45)$$

Household FOC for capital:

$$\hat{q}_t = E_t \hat{\lambda}_{t+1} - \hat{\lambda}_t - E_t \hat{a}_{t+1} + \beta e^\gamma (1 - \tau) R^k E_t \hat{R}_{t+1}^k - \beta e^\gamma \tau R^k E_t \hat{\tau}_{t+1} + \beta e^\gamma (1 - \delta) E_t \hat{q}_{t+1} \quad (46)$$

Household FOC for investment:

$$(1 + \beta) \hat{i}_t + \hat{a}_t - \frac{1}{s e^{2\gamma}} [\hat{q}_t + \hat{u}_t^i] - \beta E_t \hat{i}_{t+1} - \beta E_t \hat{a}_{t+1} = \hat{i}_{t-1} \quad (47)$$

Effective capital:

$$\hat{k}_t = \hat{v}_t + \hat{k}_{t-1} - \hat{a}_t \quad (48)$$

Law of motion for capital:

$$\hat{k}_t = (1 - \delta) e^{-\gamma} (\hat{k}_{t-1} - \hat{a}_t) + [1 - (1 - \delta) e^{-\gamma}] (\hat{u}_t^i + \hat{i}_t) \quad (49)$$

Wage equation:

$$\begin{aligned} \hat{w}_t = & \frac{1}{1 + \beta} \hat{w}_{t-1} + \frac{\beta}{1 + \beta} E_t \hat{w}_{t+1} - \kappa_w [\hat{w}_t - \nu \hat{L}_t - \hat{u}_t^b + \lambda_t - \frac{\tau}{1 - \tau} \hat{\tau}_t] + \frac{\chi^w}{1 + \beta} \hat{\pi}_{t-1} \\ & - \frac{1 + \beta \chi^w}{1 + \beta} \hat{\pi}_t + \frac{\beta}{1 + \beta} E_t \hat{\pi}_{t+1} + \frac{\chi^w}{1 + \beta} \hat{a}_{t-1} - \frac{1 + \beta \chi^w - \rho_a \beta}{1 + \beta} \hat{a}_t + \kappa_w \hat{\eta}_t^w \end{aligned} \quad (50)$$

where $\kappa_w \equiv [(1 - \beta\omega_w)(1 - \omega_w)]/[\omega_w(1 + \beta) \left(1 + \frac{(1 + \eta^w)\kappa}{\eta^w}\right)]$.

Aggregate resource constraint:

$$y \hat{y}_t = c \hat{c}_t + i \hat{i}_t + g \hat{g}_t + \psi'(1) k \hat{v}_t \quad (51)$$

Government budget constraint:

$$\frac{b}{y}\hat{b}_t + \tau R^k \frac{k}{y}[\hat{\tau}_t + \hat{R}_t^k + \hat{k}_t] + \tau w \frac{L}{y}[\hat{\tau}_t + \hat{w}_t + \hat{L}_t] = \frac{R}{e^\gamma} \frac{b}{y}[\hat{R}_{t-1} + \hat{b}_{t-1} - \hat{\pi}_t - \hat{a}_t] + \frac{g}{y}\hat{g}_t + \frac{z}{y}\hat{z}_t \quad (52)$$

We normalize several shocks, as in Smets and Wouters (2007). Specifically, we estimate $\hat{u}_t^w = \kappa_w \hat{\eta}_t^w$, $\hat{u}_t^p = \kappa_p \hat{\eta}_t^p$, $\hat{u}_t^{b*} = (1 - \rho_b) \hat{u}_t^b$, $\hat{u}_t^{i*} = (1 / [(1 + \beta) s e^{2\gamma}]) \hat{u}_t^i$, and $\hat{u}_t^{z*} = (z/b) \hat{u}_t^z$. With these normalizations, the shocks enter their respective equations with a coefficient of one. In addition, due to the large variances of fiscal observables, we estimate $\sigma_g/10$, $\sigma_\tau/10$, and $\sigma_z/10$. Estimates reported in Tables 1-3 are for these transformed variables.

VIII. APPENDIX: DATA DESCRIPTION

Unless otherwise noted, the following data are from the National Income and Product Accounts Tables released by the Bureau of Economic Analysis. All data in levels are nominal values. Nominal data are converted to real values by the price deflator for GDP (Table 1.1.4, line 1).

Consumption. Consumption, C , is defined as the sum of personal consumption expenditures on nondurable goods (Table 1.1.5, line 5) and services (Table 1.1.5, line 6).

Investment. Investment, I , is defined as the sum of personal consumption expenditures on durable goods (Table 1.1.5, line 4) and gross private domestic investment (Table 1.1.5, line 7).

Tax revenue. Tax revenue, T , is defined as the sum of federal personal current tax (Table 3.2, line 3), federal taxes on corporate income (Table 3.2, line 7), and federal contributions for social insurance (Table 3.2, line 11).

Government Spending. Government spending, G , is defined as federal government consumption expenditure and investment (Table 1.1.5, line 22).

Government Debt. Government debt, B , is the market value of privately held gross federal debt, published by the Federal Reserve Bank of Dallas. The quarterly data are the monthly data at the beginning of each quarter.

Hours Worked. Hours worked are constructed from the following variables:

H the index for nonfarm business, all persons, average weekly hours duration, 1992 = 100, seasonally adjusted (from the Department of Labor).

Emp civilian employment for sixteen years and over, measured in thousands, seasonally adjusted (from the Department of Labor, Bureau of Labor Statistics, CE16OV). The series is transformed into an index where 1992Q3 = 100.

Hours worked are then defined as

$$N = \frac{H * Emp}{100} .$$

Wage Rate. The wage rate is defined as the index for hourly compensation for nonfarm business, all persons, 1992 = 100, seasonally adjusted (from the U.S. Department of Labor).

Inflation. The gross inflation rate is defined using the price deflator for GDP (Table 1.1.4, line 1).

Interest Rate. The nominal interest rate is defined as the average of daily figures of the federal funds rate (from the Board of Governors of the Federal Reserve System).

Definitions of Observable Variables

The observable variable X is defined by making the following transformation to variable x :

$$X = \ln \left(\frac{x}{Popindex} \right) * 100 ,$$

where

Popindex index of *Pop*, constructed such that 1992Q3 = 1;

Pop Civilian noninstitutional population in thousands, ages 16 years and over, seasonally adjusted (from the Bureau of Labor Statistics), LNS10000000.

x = consumption, investment, hours worked, government spending, tax revenues. The real wage rate is defined in the same way, except that it is not divided by the total population.

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Table 1. Estimates for the prior 1 specification (P1), centered at the active monetary and passive fiscal policy regime.

	Priors		1955Q1-1966Q4		1967Q1-1979Q2		1984Q1-2007Q4	
	mean	[5, 95]	mean	[5, 95]	mean	[5, 95]	mean	[5, 95]
Structural Parameters								
100γ	0.5	[0.45, 0.55]	0.49	[0.45, 0.54]	0.49	[0.44, 0.54]	0.49	[0.45, 0.54]
ν	2	[0.95, 3.37]	2.50	[1.37, 3.92]	2.31	[1.16, 3.76]	3.19	[1.87, 4.80]
θ	0.5	[0.17, 0.83]	0.89	[0.81, 0.94]	0.88	[0.81, 0.94]	0.80	[0.74, 0.87]
ψ	0.5	[0.17, 0.83]	0.34	[0.096, 0.66]	0.27	[0.068, 0.52]	0.34	[0.17, 0.54]
s	4	[2.51, 5.77]	3.01	[1.91, 4.36]	3.36	[2.23, 4.72]	4.86	[3.46, 6.50]
ω_p	0.66	[0.49, 0.82]	0.83	[0.75, 0.91]	0.68	[0.60, 0.76]	0.90	[0.85, 0.94]
ω_w	0.66	[0.49, 0.82]	0.69	[0.58, 0.79]	0.76	[0.62, 0.90]	0.79	[0.68, 0.90]
χ^p	0.5	[0.25, 0.75]	0.24	[0.097, 0.44]	0.41	[0.22, 0.61]	0.26	[0.10, 0.49]
χ^w	0.5	[0.25, 0.75]	0.17	[0.096, 0.25]	0.13	[0.058, 0.22]	0.35	[0.22, 0.48]
Monetary and Fiscal Policies								
ϕ_π	1.5	[1.09, 1.91]	1.67	[1.39, 1.98]	1.62	[1.27, 1.96]	2.0	[1.67, 2.32]
ϕ_y	0.125	[0.043, 0.21]	0.10	[0.039, 0.17]	0.12	[0.052, 0.19]	0.12	[0.075, 0.18]
ρ_r	0.7	[0.32, 0.96]	0.83	[0.76, 0.88]	0.88	[0.83, 0.92]	0.86	[0.83, 0.89]
γ_g	0.15	[0.068, 0.23]	0.12	[0.043, 0.21]	0.17	[0.10, 0.25]	0.20	[0.13, 0.27]
γ_t	0.15	[0.068, 0.23]	0.11	[0.036, 0.20]	0.10	[0.036, 0.18]	0.094	[0.043, 0.17]
ρ_g	0.7	[0.32, 0.96]	0.98	[0.94, 0.997]	0.98	[0.97, 0.99]	0.97	[0.95, 0.98]
ρ_t	0.7	[0.32, 0.96]	0.95	[0.88, 0.99]	0.85	[0.69, 0.99]	0.92	[0.84, 0.98]
Shock Processes								
ρ_a	0.7	[0.32, 0.96]	0.51	[0.30, 0.69]	0.31	[0.13, 0.51]	0.30	[0.16, 0.44]
ρ_b	0.7	[0.32, 0.96]	0.35	[0.13, 0.62]	0.51	[0.27, 0.75]	0.86	[0.78, 0.93]
ρ_i	0.7	[0.32, 0.96]	0.61	[0.38, 0.82]	0.45	[0.22, 0.70]	0.87	[0.79, 0.94]
ρ_p	0.7	[0.32, 0.96]	0.76	[0.51, 0.96]	0.30	[0.12, 0.51]	0.69	[0.42, 0.87]
ρ_w	0.7	[0.32, 0.96]	0.53	[0.31, 0.74]	0.49	[0.27, 0.69]	0.42	[0.25, 0.61]
ρ_z	0.7	[0.32, 0.96]	0.35	[0.16, 0.56]	0.47	[0.28, 0.66]	0.34	[0.20, 0.48]
σ_a	0.1	[0.02, 0.28]	1.10	[0.93, 1.31]	0.96	[0.81, 1.14]	0.69	[0.61, 0.78]
σ_b	0.1	[0.02, 0.28]	3.43	[1.31, 6.37]	2.45	[0.82, 4.80]	0.38	[0.20, 0.67]
σ_r	0.1	[0.02, 0.28]	0.21	[0.18, 0.25]	0.17	[0.15, 0.21]	0.14	[0.12, 0.16]
σ_i	0.1	[0.02, 0.28]	1.12	[0.81, 1.49]	1.21	[0.88, 1.57]	0.35	[0.29, 0.43]
σ_p	0.1	[0.02, 0.28]	0.074	[0.042, 0.11]	0.23	[0.18, 0.29]	0.065	[0.042, 0.096]
σ_w	0.1	[0.02, 0.28]	0.12	[0.079, 0.17]	0.19	[0.12, 0.26]	0.21	[0.16, 0.27]
σ_g	0.1	[0.02, 0.28]	0.23	[0.19, 0.27]	0.19	[0.16, 0.23]	0.15	[0.13, 0.17]
σ_t	0.1	[0.02, 0.28]	0.25	[0.21, 0.29]	0.35	[0.30, 0.42]	0.24	[0.21, 0.27]
σ_z	0.1	[0.02, 0.28]	0.72	[0.61, 0.86]	1.15	[0.97, 1.36]	0.91	[0.80, 1.02]

Table 2. Estimates for the prior 2 specification (P2), centered at the passive monetary and active fiscal policy regime.

		Priors		1955Q1-1966Q4		1967Q1-1979Q2		1984Q1-2007Q4	
		mean	[5, 95]	mean	[5, 95]	mean	[5, 95]	mean	[5, 95]
Structural Parameters									
100γ	0.5		[0.45, 0.55]	0.49	[0.44, 0.54]	0.50	[0.45, 0.55]	0.49	[0.44, 0.54]
ν	2		[0.95, 3.37]	2.1	[1.1, 3.4]	2.33	[1.21, 3.77]	2.261	[1.42, 4.10]
θ	0.5		[0.17, 0.83]	0.91	[0.76, 0.97]	0.83	[0.69, 0.90]	0.83	[0.75, 0.92]
ψ	0.5		[0.17, 0.83]	0.28	[0.07, 0.57]	0.37	[0.10, 0.67]	0.27	[0.096, 0.48]
s	4		[2.51, 5.77]	3.3	[2.1, 4.7]	3.27	[2.1, 4.68]	4.95	[3.48, 6.67]
ω_p	0.66		[0.49, 0.82]	0.98	[0.96, 0.99]	0.74	[0.67, 0.81]	0.96	[0.94, 0.98]
ω_w	0.66		[0.49, 0.82]	0.78	[0.68, 0.87]	0.93	[0.90, 0.95]	0.93	[0.88, 0.96]
χ^p	0.5		[0.25, 0.75]	0.22	[0.084, 0.41]	0.36	[0.19, 0.56]	0.22	[0.083, 0.44]
χ^w	0.5		[0.25, 0.75]	0.17	[0.1, 0.25]	0.13	[0.056, 0.22]	0.30	[0.18, 0.42]
Monetary and Fiscal Policies									
ϕ_π	0.5		[0.17, 0.83]	0.54	[0.19, 0.86]	0.60	[0.36, 0.84]	0.84	[0.65, 0.96]
ϕ_y	0.125		[0.043, 0.21]	0.18	[0.12, 0.24]	0.14	[0.085, 0.20]	0.16	[0.11, 0.21]
ρ_r	0.7		[0.32, 0.96]	0.79	[0.68, 0.87]	0.70	[0.54, 0.82]	0.85	[0.80, 0.89]
γ_g	0		[-0.049, 0.049]	0.043	[-0.0035, 0.09]	0.056	[0.012, 0.10]	0.089	[0.051, 0.13]
γ_t	0		[-0.049, 0.049]	0.052	[0.024, 0.082]	0.062	[0.033, 0.093]	0.042	[0.017, 0.068]
ρ_g	0.7		[0.32, 0.96]	0.93	[0.84, 0.99]	0.98	[0.96, 0.99]	0.97	[0.96, 0.99]
ρ_t	0.7		[0.32, 0.96]	0.94	[0.84, 0.99]	0.76	[0.60, 0.91]	0.90	[0.83, 0.97]
Shock Processes									
ρ_a	0.7		[0.32, 0.96]	0.64	[0.36, 0.80]	0.27	[0.11, 0.45]	0.33	[0.17, 0.50]
ρ_b	0.7		[0.32, 0.96]	0.41	[0.16, 0.79]	0.66	[0.33, 0.95]	0.82	[0.66, 0.93]
ρ_i	0.7		[0.32, 0.96]	0.7	[0.48, 0.87]	0.42	[0.21, 0.64]	0.80	[0.70, 0.88]
ρ_p	0.7		[0.32, 0.96]	0.56	[0.28, 0.80]	0.30	[0.12, 0.52]	0.53	[0.25, 0.74]
ρ_w	0.7		[0.32, 0.96]	0.50	[0.25, 0.77]	0.42	[0.21, 0.62]	0.36	[0.21, 0.52]
ρ_z	0.7		[0.32, 0.96]	0.33	[0.15, 0.53]	0.40	[0.22, 0.57]	0.33	[0.19, 0.47]
σ_a	0.1		[0.02, 0.28]	1.2	[0.97, 1.4]	0.95	[0.80, 1.13]	0.70	[0.62, 0.80]
σ_b	0.1		[0.02, 0.28]	5.0	[0.71, 10.5]	1.29	[0.17, 2.59]	0.63	[0.21, 1.73]
σ_r	0.1		[0.02, 0.28]	0.19	[0.16, 0.23]	0.15	[0.12, 0.18]	0.14	[0.12, 0.16]
σ_i	0.1		[0.02, 0.28]	1.0	[0.77, 1.37]	1.36	[1.05, 1.73]	0.41	[0.33, 0.49]
σ_p	0.1		[0.02, 0.28]	0.079	[0.041, 0.12]	0.22	[0.17, 0.28]	0.08	[0.054, 0.11]
σ_w	0.1		[0.02, 0.28]	0.12	[0.066, 0.17]	0.19	[0.12, 0.27]	0.21	[0.16, 0.26]
σ_g	0.1		[0.02, 0.28]	0.22	[0.19, 0.27]	0.24	[0.17, 0.24]	0.16	[0.14, 0.18]
σ_t	0.1		[0.02, 0.28]	0.25	[0.21, 0.29]	0.35	[0.30, 0.41]	0.24	[0.21, 0.27]
σ_z	0.1		[0.02, 0.28]	0.72	[0.61, 0.86]	1.12	[0.95, 1.32]	0.90	[0.80, 1.01]

Table 3. Estimates for the prior 3 specification (P3), centered at the passive monetary and active fiscal policy regime.

	Priors		1955Q1-1966Q4		1967Q1-1979Q2		1984Q1-2007Q4	
	mean	[5, 95]	mean	[5, 95]	mean	[5, 95]	mean	[5, 95]
Structural Parameters								
100γ	0.5	[0.45, 0.55]	0.49	[0.45, 0.54]	0.50	[0.45, 0.55]	0.49	[0.44, 0.54]
ν	2	[0.95, 3.37]	2.16	[1.05, 3.60]	2.22	[1.12, 3.62]	2.76	[1.51, 4.30]
θ	0.5	[0.17, 0.83]	0.74	[0.58, 0.86]	0.95	[0.91, 0.97]	0.85	[0.80, 0.90]
ψ	0.5	[0.17, 0.83]	0.38	[0.13, 0.66]	0.18	[0.043, 0.39]	0.15	[0.048, 0.28]
s	4	[2.51, 5.77]	3.98	[2.59, 5.63]	3.98	[2.70, 5.50]	6.03	[4.39, 7.93]
ω_p	0.66	[0.49, 0.82]	0.98	[0.97, 0.98]	0.78	[0.67, 0.88]	0.99	[0.98, 0.99]
ω_w	0.66	[0.49, 0.82]	0.78	[0.68, 0.87]	0.93	[0.89, 0.96]	0.86	[0.78, 0.93]
χ^p	0.5	[0.25, 0.75]	0.27	[0.10, 0.48]	0.48	[0.28, 0.69]	0.24	[0.087, 0.48]
χ^w	0.5	[0.25, 0.75]	0.19	[0.10, 0.28]	0.12	[0.049, 0.21]	0.35	[0.22, 0.48]
Monetary and Fiscal Policies								
ϕ_π	0.5	[0.17, 0.83]	0.23	[0.066, 0.46]	0.40	[0.25, 0.54]	0.36	[0.13, 0.61]
ϕ_y	0.125	[0.043, 0.21]	0.087	[0.046, 0.13]	0.074	[0.02, 0.15]	0.026	[0.012, 0.043]
ρ_r	0.7	[0.32, 0.96]	0.70	[0.52, 0.84]	0.61	[0.46, 0.75]	0.86	[0.83, 0.89]
γ_g	0	-	0	-	0	-	0	-
γ_t	0	-	0	-	0	-	0	-
ρ_g	0.7	[0.32, 0.96]	0.85	[0.69, 0.96]	0.96	[0.94, 0.98]	0.99	[0.98, 0.99]
ρ_t	0.7	[0.32, 0.96]	0.83	[0.70, 0.93]	0.74	[0.57, 0.90]	0.93	[0.88, 0.97]
Shock Processes								
ρ_a	0.7	[0.32, 0.96]	0.40	[0.21, 0.60]	0.30	[0.11, 0.53]	0.29	[0.13, 0.48]
ρ_b	0.7	[0.32, 0.96]	0.94	[0.82, 0.99]	0.42	[0.18, 0.73]	0.92	[0.80, 0.99]
ρ_i	0.7	[0.32, 0.96]	0.88	[0.77, 0.95]	0.45	[0.21, 0.71]	0.83	[0.71, 0.92]
ρ_p	0.7	[0.32, 0.96]	0.49	[0.20, 0.75]	0.31	[0.12, 0.56]	0.46	[0.19, 0.68]
ρ_w	0.7	[0.32, 0.96]	0.52	[0.20, 0.90]	0.72	[0.44, 0.91]	0.49	[0.29, 0.70]
ρ_z	0.7	[0.32, 0.96]	0.27	[0.12, 0.42]	0.32	[0.17, 0.46]	0.27	[0.15, 0.39]
σ_a	0.1	[0.02, 0.28]	1.08	[0.91, 1.28]	0.97	[0.81, 1.16]	0.69	[0.61, 0.79]
σ_b	0.1	[0.02, 0.28]	0.31	[0.081, 0.80]	5.67	[1.88, 10.45]	0.32	[0.088, 0.75]
σ_r	0.1	[0.02, 0.28]	0.18	[0.15, 0.22]	0.15	[0.12, 0.18]	0.15	[0.13, 0.17]
σ_i	0.1	[0.02, 0.28]	0.95	[0.71, 1.24]	1.30	[0.91, 1.73]	0.31	[0.22, 0.42]
σ_p	0.1	[0.02, 0.28]	0.094	[0.052, 0.14]	0.21	[0.16, 0.28]	0.088	[0.058, 0.12]
σ_w	0.1	[0.02, 0.28]	0.13	[0.05, 0.20]	0.10	[0.04, 0.20]	0.19	[0.12, 0.25]
σ_g	0.1	[0.02, 0.28]	0.22	[0.19, 0.26]	0.21	[0.18, 0.26]	0.17	[0.15, 0.19]
σ_t	0.1	[0.02, 0.28]	0.24	[0.20, 0.28]	0.35	[0.30, 0.41]	0.25	[0.22, 0.28]
σ_z	0.1	[0.02, 0.28]	0.73	[0.61, 0.86]	1.11	[0.95, 1.30]	0.90	[0.80, 1.02]

Table 4. **Standard deviations from data and unconditional standard deviations from the posterior distribution.**

1955Q1 - 1966Q4	Data	P1	P2	P3
<i>G</i> Growth	2.43	2.65 [2.31, 3.09]	2.78 [2.39, 3.27]	2.56 [2.24, 2.99]
<i>C</i> Growth	0.53	0.85 [0.69, 1.09]	0.99 [0.76, 1.33]	1.20 [1.01, 1.45]
<i>I</i> Growth	4.40	5.12 [4.23, 6.41]	5.46 [4.33, 7.00]	7.19 [5.77, 8.89]
<i>B</i> Growth	7.00	8.20 [6.82, 10.49]	7.87 [6.60, 9.76]	7.65 [6.50, 9.17]
<i>w</i> Growth	0.40	0.90 [0.70, 1.24]	0.95 [0.65, 1.42]	0.84 [0.68, 1.16]
<i>T</i> Growth	2.94	3.01 [2.67, 3.45]	2.98 [2.63, 3.44]	3.08 [2.73, 3.54]
<i>L</i>	1.89	4.13 [3.06, 6.49]	3.43 [2.50, 5.38]	11.22 [7.10, 32.15]
π	0.27	0.77 [0.52, 1.70]	0.66 [0.39, 1.73]	1.86 [0.80, 7.81]
<i>R</i>	0.37	0.83 [0.59, 1.72]	0.78 [0.52, 1.78]	1.87 [0.85, 7.65]
1967Q1 - 1979Q2	Data	P1	P2	P3
<i>G</i> Growth	1.94	2.25 [1.97, 2.63]	2.26 [1.98, 2.64]	2.37 [2.06, 2.79]
<i>C</i> Growth	0.52	0.73 [0.59, 0.92]	0.74 [0.57, 0.96]	0.69 [0.57, 0.91]
<i>I</i> Growth	3.81	4.31 [3.62, 5.34]	3.93 [3.30, 4.86]	4.57 [3.75, 5.82]
<i>B</i> Growth	12.04	13.46 [11.08, 17.39]	12.28 [10.37, 15.15]	11.56 [9.93, 13.73]
<i>w</i> Growth	0.51	0.80 [0.68, 1.00]	0.76 [0.66, 0.90]	0.83 [0.70, 1.07]
<i>T</i> Growth	4.09	3.99 [3.49, 4.65]	3.99 [3.48, 4.69]	4.11 [3.59, 4.8]
<i>L</i>	2.68	4.14 [2.91, 7.25]	5.64 [3.41, 13.93]	41.36 [22.79, 106.91]
π	0.55	0.99 [0.72, 2.03]	1.12 [0.73, 2.64]	5.09 [1.69, 14.73]
<i>R</i>	0.32	0.86 [0.58, 1.96]	0.98 [0.56, 2.57]	4.94 [1.45, 14.66]
1984Q1 - 2007Q4	Data	P1	P2	P3
<i>G</i> Growth	1.85	1.76 [1.60, 1.95]	1.79 [1.62, 1.99]	1.84 [1.66, 2.05]
<i>C</i> Growth	0.40	0.69 [0.62, 0.77]	0.66 [0.57, 0.76]	0.78 [0.65, 0.92]
<i>I</i> Growth	1.95	3.23 [2.76, 3.78]	2.82 [2.43, 3.30]	3.38 [2.76, 4.21]
<i>B</i> Growth	10.08	9.85 [8.68, 11.40]	9.67 [0.67, 0.85]	9.53 [8.46, 10.87]
<i>w</i> Growth	0.65	0.79 [0.70, 0.91]	0.75 [0.67, 0.85]	0.89 [0.77, 1.10]
<i>T</i> Growth	2.55	2.75 [2.51, 3.05]	2.72 [2.47, 3.03]	2.89 [2.63, 3.21]
<i>L</i>	1.99	3.57 [2.82, 4.68]	2.86 [2.31, 4.16]	13.98 [8.27, 38.27]
π	0.24	0.48 [0.38, 0.63]	0.42 [0.31, 0.81]	1.09 [0.55, 3.26]
<i>R</i>	0.58	0.54 [0.44, 0.68]	0.46 [0.37, 0.84]	1.08 [0.54, 3.24]

Note: Square brackets indicate the 90-percent credible intervals.

Table 5. **Model fit comparisons.**

Model Specification	Bayes Factor Rel. to P1
1955Q1-1966Q4	P1
	P2 exp[9.8]
	P3 exp[25.3]
1967Q1-1979Q2	P1
	P2 exp[7.9]
	P3 exp[27.9]
1984Q1-2007Q4	P1
	P2 exp[22]
	P3 exp[64]

Table 6. **Standard deviations from the unconditional standard deviations from the prior distribution.**

	P1	P2	P3
<i>G</i> Growth	0.81 [0.32, 3.45]	0.71 [0.27, 3.19]	0.70 [0.26, 3.19]
<i>C</i> Growth	0.58 [0.18, 3.25]	1.25 [0.31, 8.91]	1.26 [0.31, 9.06]
<i>I</i> Growth	1.36 [0.44, 7.42]	1.91 [0.57, 12.93]	1.92 [0.58, 13.31]
<i>B</i> Growth	1.61 [0.60, 7.51]	1.32 [0.42, 9.11]	1.33 [0.43, 9.33]
<i>w</i> Growth	0.37 [0.14, 1.65]	0.43 [0.16, 2.04]	0.44 [0.16, 2.10]
<i>T</i> Growth	1.37 [0.56, 6.02]	2.07 [0.72, 12.07]	2.08 [0.72, 12.44]
<i>L</i>	3.02 [0.78, 26.66]	4.75 [1.29, 35.62]	4.81 [1.30, 37.38]
π	0.93 [0.24, 8.21]	2.17 [0.60, 15.85]	2.20 [0.61, 16.34]
<i>R</i>	0.83 [0.18, 7.81]	1.36 [0.32, 11.60]	1.37 [0.32, 12.10]

Note: Square brackets indicate the 90-percent credible intervals.

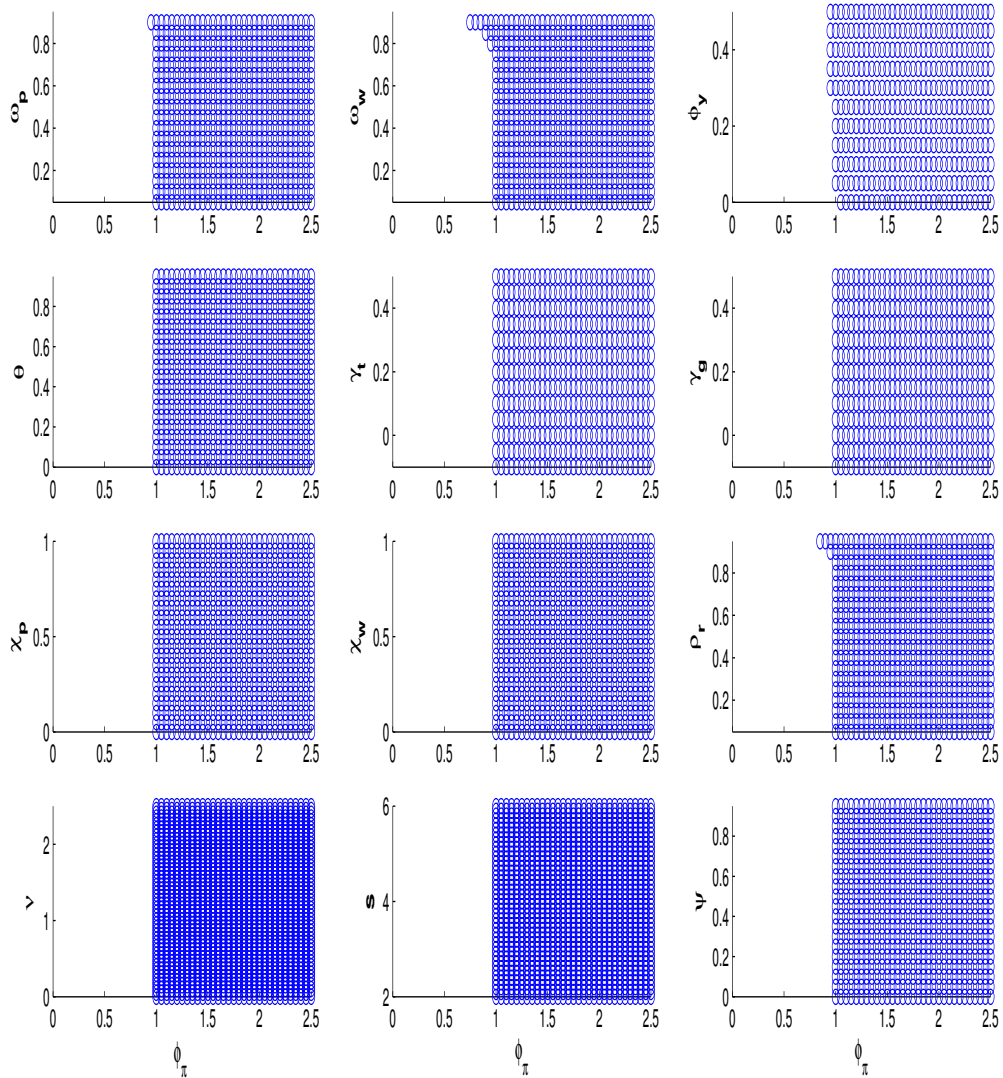


Figure 1. **Combinations of various parameters that deliver the AMPF regime.**

Note: In all cases the x-axis denotes the value of the monetary authority's response to inflation ϕ_π . All the parameters not plotted are held at their mean values from the P1 prior specification.

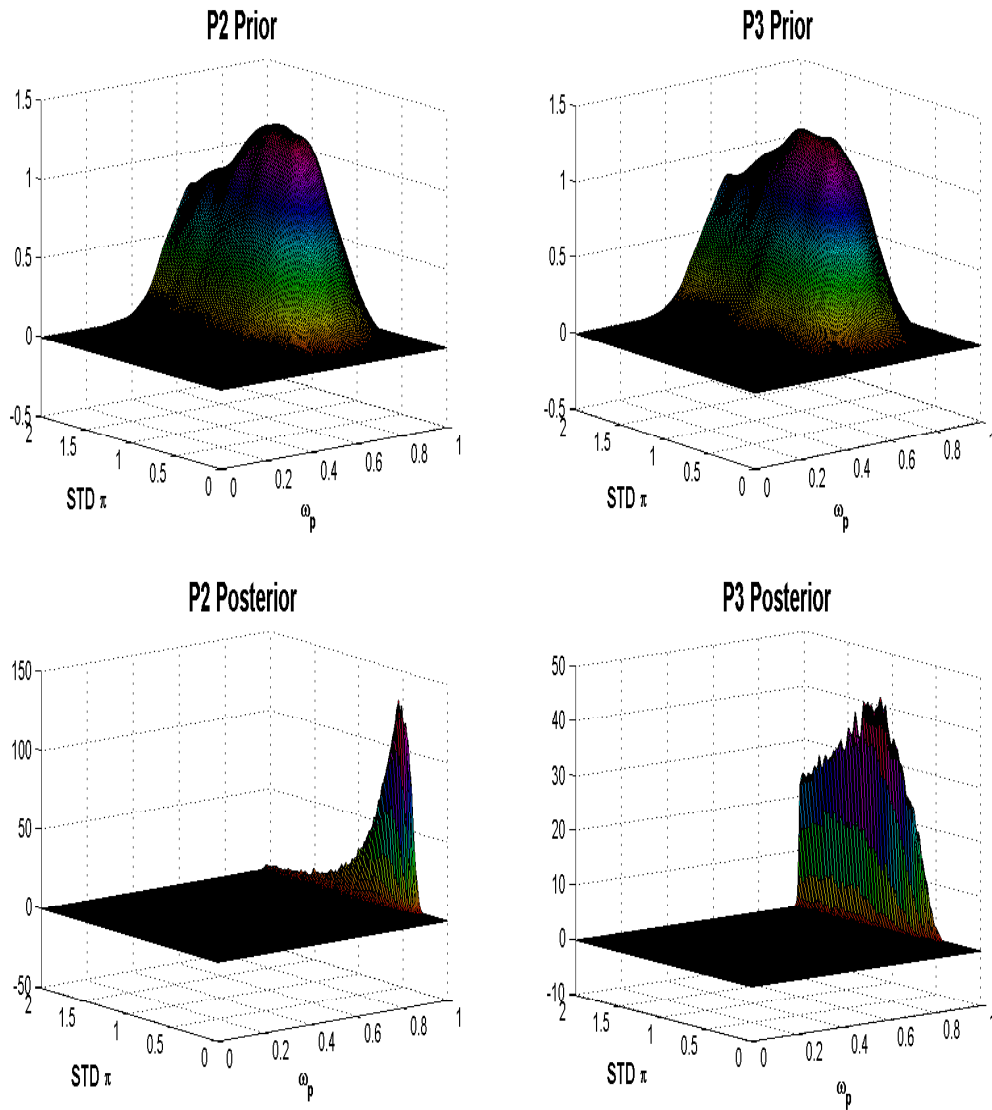


Figure 2. **Prior and posterior bivariate density plots.**

Note: In all cases the x-axis denotes the Calvo price parameter (ω_p), and the y-axis denotes the standard deviation of inflation (STD_π). Posteriors are taken from the P2 and P3 specifications for the 1955Q1-1966Q4 sample.

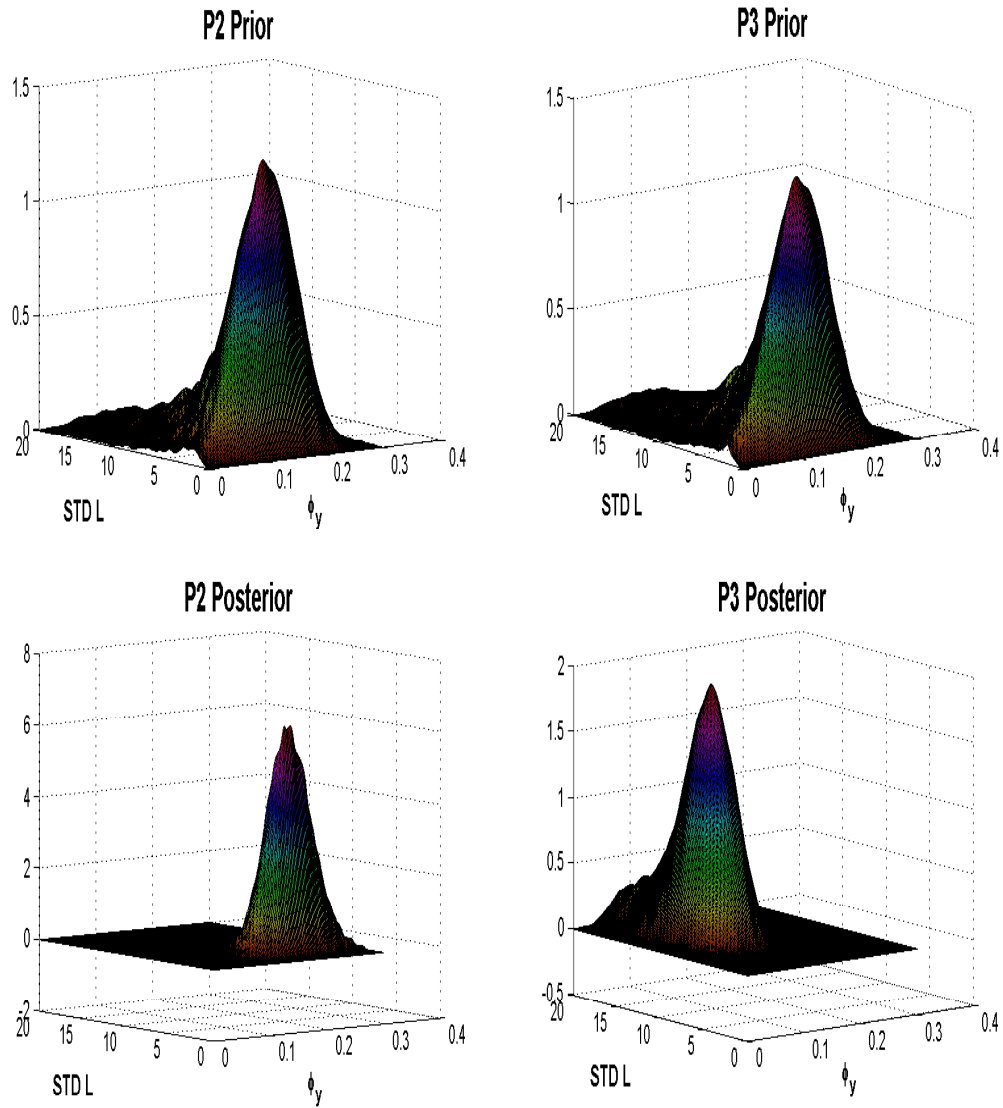


Figure 3. **Prior and posterior bivariate density plots.**

Note: In all cases the x-axis denotes the value of the monetary authority's response to output (ϕ_y), and the y-axis denotes the standard deviation of labor ($STD L$). Posteriors are taken from the P2 and P3 specifications for the 1955Q1-1966Q4 sample.

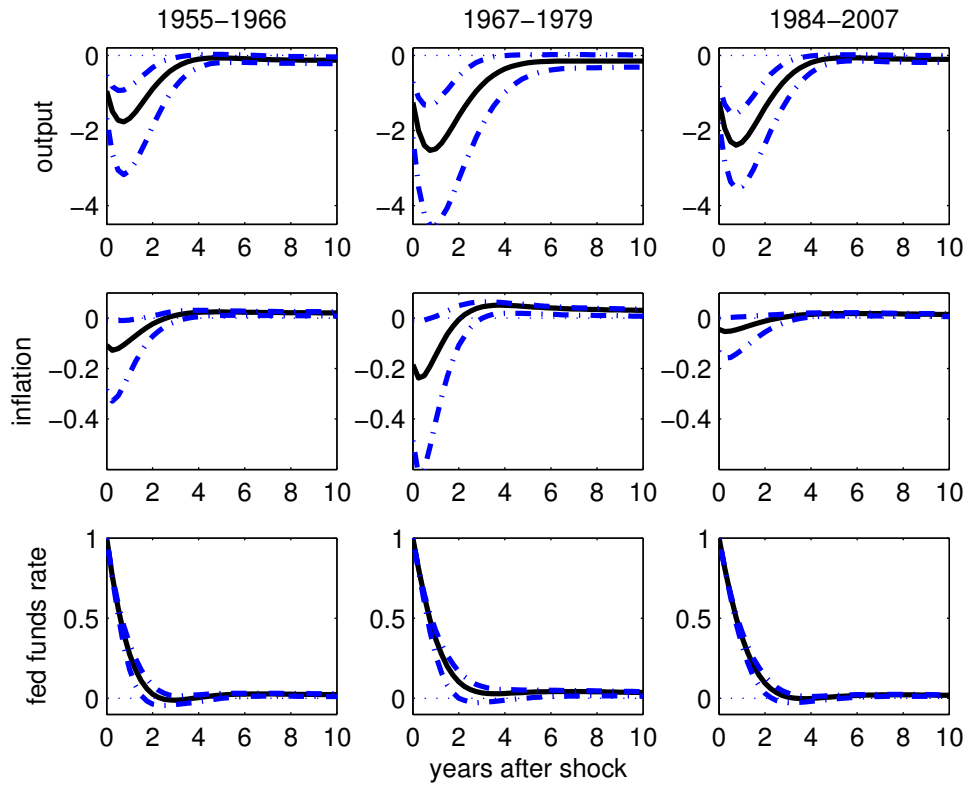


Figure 4. **The effects of monetary policy across samples: all samples under P1.**

Note: Y-axis is in percentage deviation to the steady state. Solid lines: responses under the mean estimates of the parameters; dotted-dashed lines: 90% confidence bands.

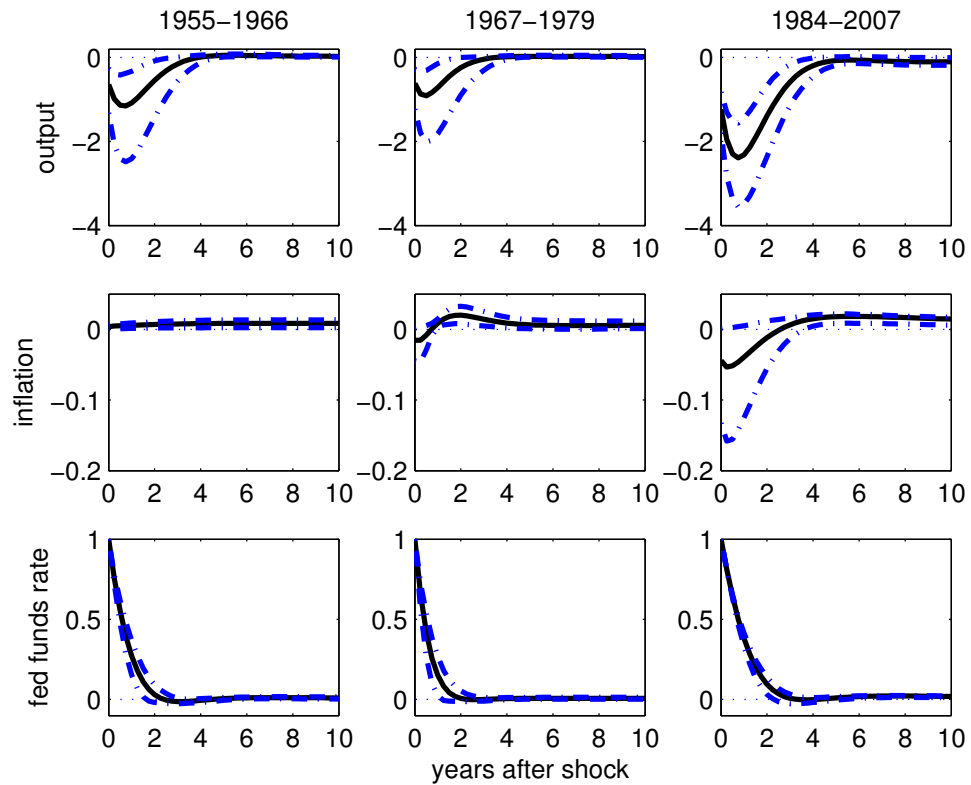


Figure 5. **The effects of monetary policy across samples: 1955Q1-1966Q4 and 1967Q1-1979Q2 are under P2, and 1984Q1-2007Q4 is under P1.**

Note: Y-axis is in percentage deviation to the steady state. Solid lines: responses under the mean estimates of the parameters; dotted-dashed lines: 90% confidence bands.

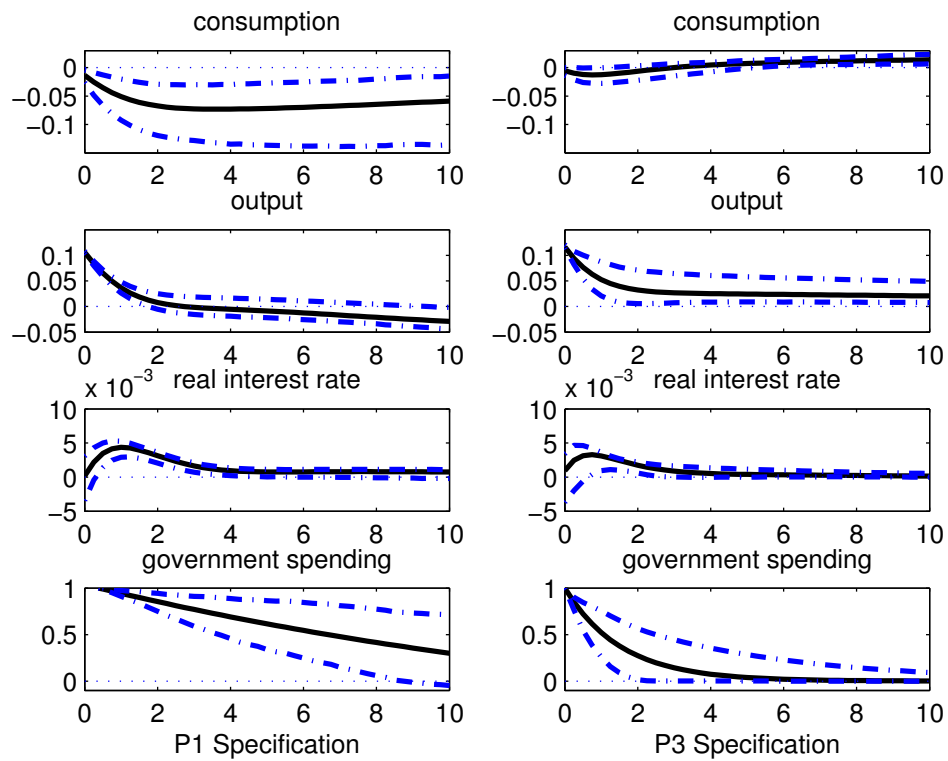


Figure 6. **The effects of a government spending increase for 1955Q1-1966Q4.**

Note: Y-axis is in percentage deviation to the steady state. Solid lines: responses under the mean estimates of the parameters; dotted-dashed lines: 90% confidence bands.

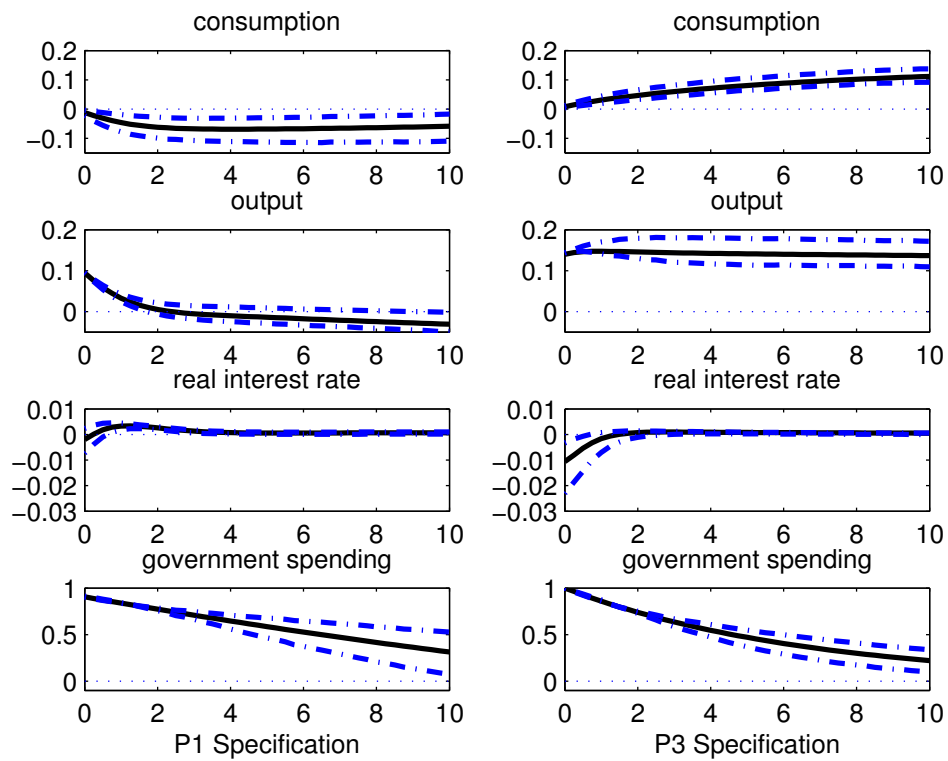


Figure 7. **The effects of a government spending increase for 1967Q1-1979Q2.**

Note: Y-axis is in percentage deviation to the steady state. Solid lines: responses under the mean estimates of the parameters; dotted-dashed lines: 90% confidence bands.

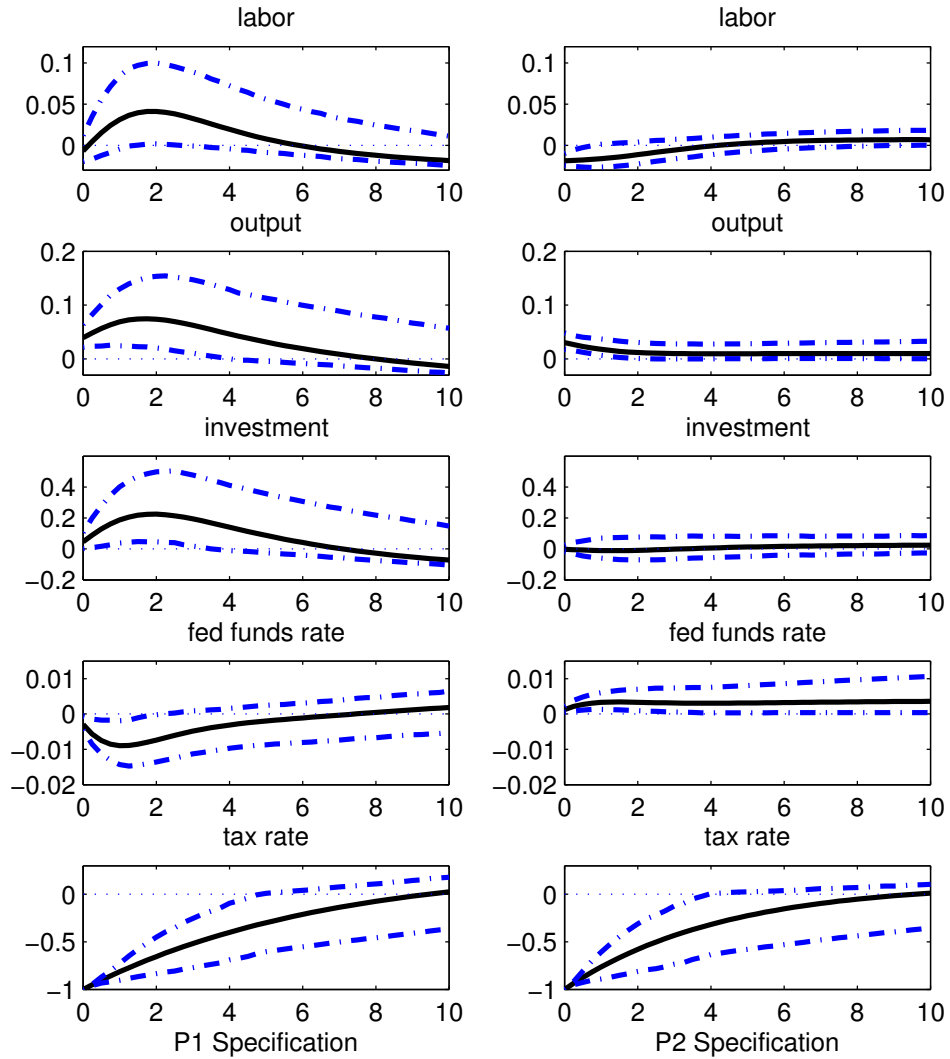


Figure 8. **The effects of a tax cut for 1955Q1-1966Q4.**

Note: Y-axis is in percentage deviation to the steady state. Solid lines: responses under the mean estimates of the parameters; dotted-dashed lines: 90% confidence bands.

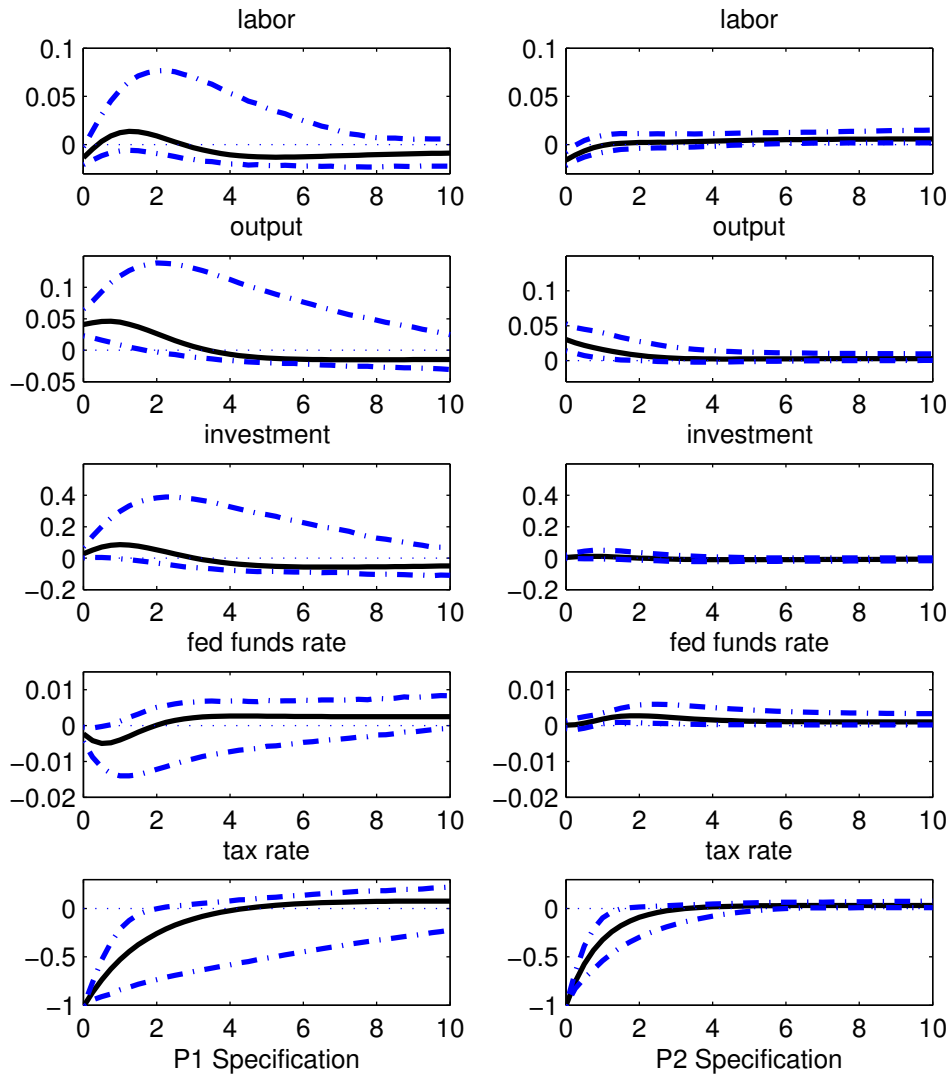


Figure 9. **The effects of a tax cut for 1967Q1-1979Q2.**

Note: Y-axis is in percentage deviation to the steady state. Solid lines: responses under the mean estimates of the parameters; dotted-dashed lines: 90% confidence bands.