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Policy Regimes, Policy Shifts, and U.S. Business Cycles*

Saroj Bhattarai† Jae Won Lee‡ Woong Yong Park§

Abstract

Using an estimated DSGE model with monetary and fiscal policy interactions and allowing for equilibrium indeterminacy, we find that a passive monetary and passive fiscal policy regime prevailed in the pre-Volcker period. This gave rise to self-fulfilling beliefs and unconventional transmission mechanisms of policy shifts: unanticipated increases in interest rates increased inflation and output while unanticipated increases in lump-sum taxes decreased inflation and output. We show that had the monetary policy regime of the post-Volcker era been in place pre-Volcker, inflation volatility would have been lower by 25% and the rise of inflation in the 1970s would not have occurred. JEL Classifications: C52, C54, E31, E32, E52, E63

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†Department of Economics, University of Texas at Austin. 2225 Speedway, Stop C3100, Austin, TX 78712, U.S.A.

‡Corresponding author. Department of Economics, Seoul National University. 1 Gwanak-ro, Gwanak-gu, Seoul 151-746, South Korea. Phone: +82-2-880-6372.

§Department of Economics, University of Illinois at Urbana-Champaign and CAMA. 214 David Kinley Hall, 1407 W. Gregory, Urbana, IL 61801, U.S.A.

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1 Introduction

Macroeconomic models that are estimated and used for monetary policy analysis typically abstract from non-trivial monetary and fiscal policy interactions. A theoretical literature starting with the work of Sargent and Wallace (1981) and Aiyagari and Gertler (1985) has however, long emphasized that monetary and fiscal policies jointly determine equilibrium model dynamics. Moreover, the recent crisis, which has brought to the fore issues of monetary and fiscal policy interactions due to unconventional monetary policy actions that can have significant effects on the government budget and great uncertainty about the future course of fiscal policy, provides an additional impetus to model monetary and fiscal policies jointly in models geared towards policy analysis.

Motivated by these considerations, we extend a standard dynamic stochastic general equilibrium (DSGE) model to include a non-trivial fiscal policy. Similar to the standard rule for monetary policy that governs how nominal interest rates respond to inflation and output, our model features a feedback rule for fiscal policy that determines how taxes respond to debt and output, and how government spending responds to output. In such a set-up, as shown by Leeper (1991), Sims (1994), and Woodford (1995), the equilibrium model dynamics depend crucially on monetary and fiscal policy stances, that is, the strength with which policies respond to the state of the economy. Equilibrium in our model is determinate under two cases: either when both the interest rate response to inflation and the tax response to debt are strong (an active monetary and passive fiscal policy regime) or when both the responses are weak (a passive monetary and active fiscal policy regime). Indeterminacy of equilibrium arises when a weak interest rate response to inflation is coupled with a strong response of taxes to debt (a passive monetary and passive fiscal policy regime).[1]

The model is solved using the method proposed by Lubik and Schorfheide (2003; 2004) and is fit to data on both conventional and fiscal variables through Bayesian methods. Following a large literature, we split the data into two time periods based on the timing of Paul Volcker's chairmanship at the Federal Reserve and assess the best-fitting policy regime in each period. We then use the best-fitting model as a laboratory to answer four broad set of questions. First, what

[1]We use the language of Leeper (1991) in characterizing policies as active or passive. The exact bounds for active and passive policies are model-specific and we make these definitions precise later after introducing the model.

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monetary and fiscal policy regimes characterized post-War U.S. data? Second, what were the monetary and fiscal policy transmission mechanisms over time? Third, which shocks were the primary sources of short and long-run variation in inflation? Fourth, what would have been the path of inflation under a counterfactual monetary policy regime different from the estimated one? While these questions are classic, allowing for the possibility of indeterminacy in estimating a DSGE model that features monetary and fiscal policy interactions is a distinct contribution of our paper, and one that matters for our results

Our main findings are as follows.[2] First, we find that, pre-Volcker, the best-fitting model is a passive monetary and passive fiscal policy regime, while post-Volcker, it is an active monetary and passive fiscal policy regime. As a result, there was equilibrium indeterminacy in the pre-Volcker era. Thus, our findings are consistent with earlier studies that focus only on monetary policy such as Clarida, Gali, and Gertler (2000), Mavroeidis (2010), Coibion and Gorodnichenko (2011), Boivin and Giannoni (2006), and Lubik and Schorfheide (2004).

Second, equilibrium indeterminacy pre-Volcker substantially altered the propagation mechanism of shocks, which leads to different transmissions of monetary and fiscal policies in the two time periods. For example, while post-Volcker, an unanticipated increase in interest rates led to a decrease in output and inflation, it led to an increase in output and inflation pre-Volcker. Moreover, while post-Volcker, an unanticipated increase in the lump-sum tax revenues-to-output ratio had no effects on output or inflation, it decreased output and inflation pre-Volcker.

Pre-Volcker, in contrast to Post-Volcker when the policy transmission mechanisms conformed standard monetary theories, the effects on output and inflation of policy shocks were thus similar to those predicted by the fiscal theory of the price level (FTPL).[3] The similarity however is not because the mechanism underlying FTPL is operative as the theory applies only under a passive

[2]Some preliminary and partial results of this research program, based on a simpler model, appear in Bhattarai, Lee, and Park (2012).

[3]Canzoneri, Cumby, and Diba (2011) is a recent survey of the FTPL literature. Under FTPL, an increase in interest payments due to a contractionary monetary policy increases spending by agents because of a positive wealth effect. This then leads to an increase in inflation and output. Moreover, shifts in fiscal policy influence inflation and output under FTPL due to wealth effects. Bhattarai, Lee, and Park (2014a) contains a detailed treatment of these effects in a simpler model.

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monetary and active fiscal policy regime. It is instead due to both changes in the nature of the solution and agents' self-fulfilling beliefs under indeterminacy.[4] Despite such a similarity, the two regimes are different in several other dimensions, and our best-fitting regime is well identified.

These findings about the effects of monetary and fiscal policy shocks in the pre-Volcker period are new to the literature. For example, Lubik and Schorfheide (2004) find that in the indeterminate policy regime of the pre-Volcker period, inflation does not rise on impact following an interest rate increase. Our results are in fact quite close to those obtained from the identified VAR literature. Since the work of Sims (1992), it has been observed that in many VAR specifications, inflation tends to increase on impact following a contractionary monetary policy shock. This has been dubbed the "price puzzle" in the literature since it goes against the predictions of the standard models of price level determination. Hanson (2004) in a comprehensive study shows that this price puzzle seems to be a feature only of the pre-Volcker period and not for the entire post-War U.S. data. Our results are thus consistent with his findings and moreover, have a model-based interpretation. In addition, Sims (2011) provides some VAR-based evidence on predictory power of fiscal variables in explaining U.S. inflation. We provide complementary evidence from our estimated model on this front, albeit only for the pre-Volcker period.

Third, monetary and fiscal policy shocks play only a minor role in the dynamics of inflation and output, in both the time periods and at both the short- and long-run. The result that random variations in monetary policy do not explain much of the fluctuations in the data, is consistent with the results in the identified VAR literature, for example, Sims and Zha (2006a) and also with the

[4]One major reason for this similarity is that unanticipated increase in interest rates can lead to an increase in inflation under either FTPL or indeterminacy in the standard sticky price model. As is well understood, inflation increases due to wealth effects under FTPL. On the other hand, indeterminacy under passive monetary and passive fiscal policy changes the nature of the solution in a way such that the component of the solution that is a unique function only of the structural parameters implies that inflation rises in response to interest rate increases. This is shown analytically in Bhattarai, Lee, and Park (2014a) in a simple sticky-price model. Obviously, the indeterminate component – the part that is governed by agents' self-fulfilling beliefs – can countervail that effect strongly, in which case inflation may decline. Both the cases will be fully explored in this paper.

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DSGE literature, for example, Smets and Wouters (2007). That the same conclusion also holds for random variations in fiscal policy, given by unanticipated movements in tax revenues-to-output ratios, is new, to our knowledge, to the DSGE literature that features both monetary and fiscal policies.[5] While we find that random disturbances to policy do not matter significantly, this does not imply that the systematic component to policy is also unimportant. In fact, to the contrary, the propagation mechanisms of shocks are substantially different pre- and post-Volcker, precisely because the systematic components of policy were different. A similar point can be made for indeterminacy. Sunspot shocks introduced pre-Volcker due to indeterminacy play a minor role in the dynamics of inflation and output. This however does not imply that indeterminacy is unimportant as it produces a different propagation mechanism of fundamental shocks, as mentioned above.

Fourth, pre-Volcker, in sharp contrast to post-Volcker, variations in the inflation target do not explain low-frequency movements in inflation.[6] Several recent studies, including Ireland (2007) and Cogley, Primiceri, and Sargent (2010), show that the long-run variation in inflation is explained mostly by changes in the (smoothed) inflation target both pre- and post-Volcker. While we find a similar result in the post-Volcker period, our results are different in the pre-Volcker era: changes in the inflation target explain only about 10% of the long-run variation in inflation. The reason for this difference is that, under our best-fitting regime, pre-Volcker, inflation target movements do not track actual inflation: an increase in the interest rate, triggered by the central bank's decreasing the inflation target, tends to increase inflation, as pointed out above.[7]

[5]Our results are complementary to those of Leeper, Plante, and Traum (2010), who use a real model with a rich specification of fiscal policy. While detailed variance decomposition results are not available in the paper, one can reasonably infer from their impulse response analysis that fiscal policy shocks might not have had quantitatively significant effects on macroeconomic variables. Their use of a real model though precludes a comparison with our results in terms of inflation.

[6]Bhattarai, Lee, and Park (2014a) provide several analytical results that characterize the role of a time-varying inflation target in a simple sticky price model under different policy regimes.

[7]Davig and Doh (2014) do not find a significant role for time-varying inflation target in explaining low-frequency inflation movements in post-War U.S. data while allowing for regime-switching in both policy coefficients and volatility. Our result from sub-sample estimation is different from theirs since we do find a role for a time-varying inflation target in the post-Volcker era.

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Fifth, the primary sources of short- and long-run variation in inflation are different in the two time periods because of changes in policy stances. As mentioned above, post-Volcker, low frequency movement in inflation is explained by changes in the inflation target. The high frequency movement is mostly explained by mark-up shocks, which is also a standard result. In contrast, no single shock played a predominant role pre-Volcker at either horizon, but rather all "non-policy shocks" of both demand and supply types were major drivers of inflation dynamics. In particular, since monetary policy was passive pre-Volcker, demand shocks, that would typically be stabilized under active monetary policy, end up influencing inflation dynamics significantly.

Sixth, in a counterfactual exercise, we show that had the more aggressive monetary policy regime of the post-Volcker era been in place pre-Volcker, inflation volatility would have been significantly lower: the predicted standard deviation of inflation is 2.03% compared to the actual value of 2.72%. Moreover, the persistent rise of inflation in the 1970s would not have occurred. Our results are thus consistent with the "good policy" hypothesis that a change in monetary policy after Paul Volcker assuming chairmanship at the Federal Reserve led to stabilization of inflation.[8]

Our paper is related to several other papers that estimate a monetary DSGE model with non-trivial fiscal policy. Important recent contributions include Drautzberg and Uhlig (2011), Traum and Yang (2015), and Zubairy (2014). In addition, Fernandez-Villaverde et al. (2012) estimate fiscal rules with volatility shocks and feed them into a standard medium-scale DSGE model and Leeper, Richer, and Walker (2012) analyze effects of fiscal foresight. A relative contribution of our paper is to estimate a DSGE model with non-trivial interactions of monetary and fiscal policies while allowing for multiple equilibria. Lubik and Schorfheide (2004) assess the role of equilibrium indeterminacy due to passive monetary policy but abstract from fiscal policy while Kim (2003) and Traum and Yang (2011) tackle monetary and fiscal policy interactions but abstract from the possibility of equilibrium indeterminacy. In a closely related independent paper, Bianchi and Ilut (2015) estimate a model with a switch from an active fiscal to passive fiscal regime and use it to explain the rise of inflation in the 1970s, while also abstracting from equilibrium indeterminacy.

[8]This finding is not consistently accepted in the literature, however. For example, see Sims and Zha (2006b) who instead emphasize the change in volatility of shocks using a regime-switching VAR approach.

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Their method allows for an interesting analysis of how the possibility of regime switching can alter the properties of the solution by affecting agent's beliefs. We make it clear later in the paper why allowing for both a non-trivial fiscal policy and indeterminacy is crucial for our results, and that constitutes our relative contribution.

2 Model

Our model is based on the prototypical New Keynesian set-up, for example as in Woodford (2003), augmented with some propagation mechanisms and a complete description of fiscal policy.

2.1 Households

There is a continuum of households in the unit interval. Each household specializes in the supply of a particular type of labor. A household that supplies labor of type-j maximizes the utility function:

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \delta_t \left[\log \left(C_t^j - \eta C_{t-1} \right) - \frac{\left(H_t^j \right)^{1+\varphi}}{1+\varphi} \right] \right\},$$

where C_t^j is consumption of household j, C_t is aggregate consumption, and H_t^j denotes the hours of type-j labor services. The parameters β, φ, and η are, respectively, the discount factor, the inverse of the (Frisch) elasticity of labor supply, and the degree of external habit formation. Finally, δ_t represents an intertemporal preference shock which follows $\delta_t = \delta_{t-1}^{\rho_\delta} \exp(\varepsilon_{\delta,t})$, where $\varepsilon_{\delta,t} \sim$ i.i.d. $N(0, \sigma_\delta^2)$.

Household j's flow budget constraint is:

$$P_t C_t^j + B_t^j + E_t \left[Q_{t,t+1} V_{t+1}^j \right] = W_t(j) H_t^j + V_t^j + R_{t-1} B_{t-1}^j + \Pi_t + S_t - T_t,$$

where P_t is the price level, B_t^j is the amount of one-period risk-less nominal government bond held by household j, R_t is the interest rate on the bond, $W_t(j)$ is the competitive nominal wage rate for type-j labor, Π_t denotes profits of intermediate firms, and $(S_t - T_t)$ denotes government transfers net of taxes.[9] In addition to the government bond, households trade at time t one-period

[9]The budget constraint reflects our assumptions that each household owns an equal share of all

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state-contingent nominal securities V^j_{t+1} at price $Q_{t,t+1}$, and hence fully insure against idiosyncratic risk.

2.2 Firms

The final good Y_t, which is consumed by the government and households, is produced by perfectly competitive firms assembling intermediate goods, $Y_t(i)$, with a Dixit and Stiglitz (1977) production technology $Y_t = \left(\int_0^1 Y_t(i)^{\frac{\theta_t-1}{\theta_t}} di\right)^{\frac{\theta_t}{\theta_t-1}}$, where θ_t denotes time-varying elasticity of substitution between intermediate goods that follows $\theta_t = \bar{\theta}^{1-\rho_\theta}\theta_{t-1}^{\rho_\theta}\exp(\varepsilon_{\theta,t})$ with the steady-state value $\bar{\theta}$. The corresponding price index for the final consumption good is $P_t = \left(\int_0^1 P_t(i)^{1-\theta_t} di\right)^{\frac{1}{1-\theta_t}}$, where $P_t(i)$ is the price of the intermediate good i. The optimal demand for $Y_t(i)$ is given by $Y_t(i) = (P_t(i)/P_t)^{-\theta_t} Y_t$.

Monopolistically competitive firms produce intermediate goods using the production function, $Y_t(i) = A_t H_t(i)$, where $H_t(i)$ denotes the hours of type-i labor employed by firm i and A_t represents exogenous economy-wide technological progress. The gross growth rate of technology $a_t \equiv A_t/A_{t-1}$ follows $a_t = \bar{a}^{1-\rho_a}a_{t-1}^{\rho_a}\exp(\varepsilon_{a,t})$, where $\bar{a}$ is the steady-state value of a_t and $\varepsilon_{a,t} \sim$ i.i.d. $N(0, \sigma_a^2)$.

As in Calvo (1983), a firm resets its price optimally with probability $1-\alpha$ every period. Firms that do not optimize adjust their price according to the simple partial dynamic indexation rule, $P_t(i) = P_{t-1}(i)\pi_{t-1}^{\gamma}\bar{\pi}^{1-\gamma}$, where γ measures the extent of indexation and $\bar{\pi}$ is the steady-state value of the gross inflation rate $\pi_t \equiv P_t/P_{t-1}$.[10] All optimizing firms choose a common price P_t^* to maximize the present discounted value of future profits:

$$E_t \sum_{k=0}^{\infty} \alpha^k Q_{t,t+k}\left[P_t^* X_{t,k} - \frac{W_{t+k}(i)}{A_{t+k}}\right] Y_{t+k}(i),$$

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intermediate firms and receives the same amount of net lump-sum transfers from the government.

[10]Coibion and Gorodnichenko (2011) show that with non-zero steady-state inflation and non-indexation of prices to past inflation, the indeterminacy region of a model like ours expands substantially relative to the "Taylor principle." In our model, with the partial dynamic indexation rule specification, this issue does not arise and the long-run response of interest rates to inflation is still the relevant condition for determinacy.

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where

$$X_{t,k} \equiv \begin{cases} (\pi_t \pi_{t+1} \cdots \pi_{t+k-1})^{\gamma} \bar{\pi}^{(1-\gamma)k}, & k \geq 1 \\ 1, & k = 0 \end{cases} .$$

2.3 Government

2.3.1 Budget constraint

Each period, the government collects lump-sum tax revenues T_t and issues one-period nominal bonds B_t to finance its consumption G_t, lump-sum transfer payments S_t, and interest payments.[11] Accordingly, the flow budget constraint is given by:

$$b_t = R_{t-1} b_{t-1} \frac{1}{\pi_t} \frac{Y_{t-1}}{Y_t} + g_t - \tau_t + s_t,$$

where $b_t = B_t / P_t Y_t$, $g_t = G_t / Y_t$, $\tau_t = T_t / Y_t$, and $s_t = S_t / Y_t$.

2.3.2 Monetary policy

The central bank sets the nominal interest rate according to a Taylor-type rule:

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}} \right)^{\rho_R} \left[\left(\frac{\pi_t}{\pi_t^*} \right)^{\phi_\pi} \left(\frac{Y_t}{Y_t^*} \right)^{\phi_Y} \right]^{1-\rho_R} \exp\left(\varepsilon_{R,t}\right), \tag{1}$$

which features interest rate smoothing and systematic responses to deviation of output from its natural level Y_t^* and deviation of inflation from a time-varying target π_t^*. The natural level of output is the output that would prevail under flexible prices and in the absence of shocks to θ_t. The steady-state value of R_t is $\bar{R}$ and the non-systematic monetary policy shock $\varepsilon_{R,t}$ is assumed to follow i.i.d. $N(0, \sigma_R^2)$. The inflation target evolves exogenously as $\pi_t^* = \bar{\pi}^{1-\rho_\pi} \left(\pi_{t-1}^*\right)^{\rho_\pi} \exp(\varepsilon_{\pi,t})$, where $\varepsilon_{\pi,t} \sim$ i.i.d. $N(0, \sigma_\pi^2)$.

[11] In future work, we could relax the restriction of one-period government bonds by allowing for long term debt as in Cochrane (2001). This will reduce inflation volatility under a passive monetary and active fiscal policy regime.

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2.3.3 Fiscal policy

We assume parsimonious fiscal policy rules that somewhat resemble the interest rate rule (1).[12] The fiscal authority sets its two fiscal policy instruments – tax revenues and government spending – according to the fiscal rules:

$$\frac{\tau_t}{\bar{\tau}} = \left(\frac{\tau_{t-1}}{\bar{\tau}}\right)^{\rho_\tau} \left[\left(\frac{b_{t-1}}{b^*_{t-1}}\right)^{\tilde{\psi}_b} \left(\frac{Y_t}{Y^*_t}\right)^{\tilde{\psi}_Y}\right]^{1-\rho_\tau} \exp\left(\tilde{\varepsilon}_{\tau,t}\right), \tag{2}$$

$$\frac{g_t}{\bar{g}} = \left(\frac{g_{t-1}}{\bar{g}}\right)^{\rho_g} \left(\frac{Y_{t-1}}{Y^*_{t-1}}\right)^{-\tilde{\chi}_Y(1-\rho_g)} \exp\left(\tilde{\varepsilon}_{g,t}\right). \tag{3}$$

Fiscal rule (2) features tax smoothing and systematic responses of tax revenues-to-output ratio to deviation of lagged debt-to-output ratio from a time varying target b^*_{t-1} and deviation of output from its natural level. The steady-state value of τ_t is $\bar{\tau}$ and the non-systematic tax policy shock $\tilde{\varepsilon}_{\tau,t}$ is assumed to follow i.i.d. $N\left(0, \tilde{\sigma}^2_\tau\right)$. Similarly to the inflation target, the debt-to-output ratio target evolves exogenously as $b^*_t = (1-\rho_b)\,\bar{b} + \rho_b b^*_{t-1} + \varepsilon_{b,t}$, where $\bar{b}$ is the steady-state value of b_t and $\varepsilon_{b,t} \sim$ i.i.d. $N\left(0, \sigma^2_b\right)$. Fiscal rule (3) – motivated by empirical findings of Cúrdia and Reis (2010) – features government consumption smoothing and (potentially) counter-cylical responses of government spending-to-output ratio to the lagged output gap. The steady-state value of g_t

[12]The monetary policy specification is standard, although some extended versions of (1) are often employed in the DSGE literature. The specification of the tax rule is similar to that in Davig and Leeper (2007b), Davig and Leeper (2011), and Sims (2011). While some recent studies consider more elaborate fiscal rules with realistic empirical features – for example, Leeper, Plante and Traum (2010) model different types of distortionary taxes separately rather than an aggregate measure of tax revenues – we focus on a simple specification to keep the model relatively standard. It will be interesting to investigate if new results emerge when the model is extended in various dimensions regarding the specifications of monetary and fiscal policy. In a robustness exercise, we consider some alternative specifications that are relatively straightforward to incorporate in our current framework. We leave more involved extensions that would substantially alter our framework as a future research project.

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is $\bar{g}$ and the exogenous shock to government spending $\tilde{\varepsilon}_{g,t}$ follows i.i.d. $N\left(0, \tilde{\sigma}_g^2\right)$.[13] Finally, government transfers follow an exogenous process given by $s_t = (1-\rho_s)\,\bar{s} + \rho_s s_{t-1} + \varepsilon_{s,t}$, where $\bar{s}$ is the steady-state value of s_t and $\varepsilon_{s,t} \sim$ i.i.d. $N\left(0, \sigma_s^2\right)$.[14]

2.4 Equilibrium, policy regimes, and determinacy

Equilibrium is characterized by the prices and quantities that satisfy the households' and firms' optimality conditions, the government budget constraint, monetary and fiscal policy rules, and the clearing conditions for the product, labor, and asset markets:

$$\int_0^1 C_t^j dj + G_t = Y_t,\ \ H_t(j) = H_t^j,\ \ \int_0^1 V_t^j dj{=}0, \text{ and} \int_0^1 B_t^j dj{=}B_t.$$

The details of the equilibrium conditions are provided in the online appendix (Section 1.1).

We use approximation methods to solve for equilibrium: we detrend variables on the balanced growth path by normalizing with A_t and obtain a first-order approximation to the equilibrium conditions around the non-stochastic steady state.[15] The linearized equations are standard and are provided in the online appendix (Section 1.2). Here we describe the linearized policy rules and the government budget constraint to facilitate our discussion of determinacy and policy regimes:

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1-\rho_R)\left[\phi_\pi\left(\hat{\pi}_t - \hat{\pi}_t^*\right) + \phi_Y\left(\widehat{\tilde{Y}}_t - \widehat{\tilde{Y}}_t^*\right)\right] + \varepsilon_{R,t},$$

$$\hat{\tau}_t = \rho_\tau \hat{\tau}_{t-1} + (1-\rho_\tau)\left[\psi_b\left(\hat{b}_{t-1} - \hat{b}_{t-1}^*\right) + \psi_Y\left(\widehat{\tilde{Y}}_t - \widehat{\tilde{Y}}_t^*\right)\right] + \varepsilon_{\tau,t},$$

$$\hat{g}_t = \rho_g \hat{g}_{t-1} - (1-\rho_g)\,\chi_Y\left(\widehat{\tilde{Y}}_{t-1} - \widehat{\tilde{Y}}_{t-1}^*\right) + \varepsilon_{g,t},$$

[13] In Bhattarai, Lee, and Park (2012) we used a simple specification where government spending followed an exogenous process.

[14] We introduce this exogenous process for transfers to help the model fit the data on fiscal variables.

[15] We denote variable X_t/A_t by $\tilde{X}_t$. We define the log deviation of a variable X_t from its steady state $\bar{X}$ as $\hat{X}_t = \ln X_t - \ln \bar{X}$, except for the four fiscal variables: $\hat{b}_t = b_t - \bar{b}$, $\hat{g}_t = g_t - \bar{g}$, $\hat{\tau}_t = \tau_t - \bar{\tau}$, and $\hat{s}_t = s_t - \bar{s}$.

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$$\hat{b}_t = \frac{1}{\beta}\hat{b}_{t-1} + \frac{\bar{b}}{\beta}\left(\hat{R}_{t-1} - \hat{\pi}_t - \hat{\tilde{Y}}_t + \hat{\tilde{Y}}_{t-1} - \hat{a}_t\right) + \hat{g}_t - \hat{\tau}_t + \hat{s}_t.$$

The equilibrium of the economy will be determinate either if monetary policy is active while fiscal policy is passive (the AMPF regime) or if monetary policy is passive while fiscal policy is active (the PMAF regime). Multiple equilibria exist if both monetary and fiscal policies are passive (the PMPF regime). In our model, we can analytically characterize the boundaries for the various policy regimes.[16] In particular, monetary policy is active if $\phi_\pi > 1 - \phi_Y\left(\frac{1-\tilde{\beta}}{\tilde{\kappa}}\right)$, where $\tilde{\beta} = \frac{\gamma+\beta}{1+\gamma\beta}$ and $\tilde{\kappa} = \frac{(1-\alpha\beta)(1-\alpha)}{\alpha(1+\varphi\theta)(1+\gamma\beta)}\left(1+\varphi+\frac{\chi_Y}{1-\bar{g}}\right)$, and fiscal policy is active if $\psi_b < \frac{1}{\beta} - 1$.[17]

3 Empirical analysis

3.1 Method

We solve the system of linearized equations for its state space representation and then apply the solution method for linear rational expectations models of Sims (2002) under determinacy. Under indeterminacy, we use a generalization of this method proposed in Lubik and Schorfheide (2003,

[16] This analytical solution for the boundaries is possible because we consider lump-sum taxes and transfers only. In Bhattarai, Lee, and Park (2014b), we derive analytically a necessary and sufficient condition for the boundary of monetary policy in a model with exogenous government spending. The condition requires a weak restriction on the parameter space, which is not numerically relevant. We can apply the necessary and sufficient condition to pin down the boundary also for our model here with endogenous government spending response, except for some extremely large and unlikely values for χ_Y. For such large values of χ_Y, there is the possibility of an unstable solution, which we rule out by restricting the parameter space. Also, a set of the parameter values that imply a negative slope of the Phillips curve due to endogenous government spending is discarded. Due to the block recursive nature of the model, the boundary for fiscal policy can be obtained separately from that of monetary policy. See Bhattarai, Lee, and Park (2014a) for details.

[17] Note here that as shown in the online appendix (Section 1.2), the relationships between the feedback parameters of the non-linear and linearized fiscal policy rules are given by: $\psi_b \equiv \frac{\bar{\tau}}{\bar{b}}\tilde{\psi}_b$, $\psi_Y \equiv \bar{\tau}\tilde{\psi}_Y$, and $\chi_Y \equiv \bar{g}\tilde{\chi}_Y$.

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2004) which expresses the solution of the model as:

$$\mathbf{z}_t = \Gamma_1^* (\boldsymbol{\theta}) \mathbf{z}_{t-1} + \left\{ \Gamma_{0,\varepsilon}^* (\boldsymbol{\theta}) + \Gamma_{0,\zeta}^* (\boldsymbol{\theta}) M \right\} \boldsymbol{\varepsilon}_t + \Gamma_{0,\zeta}^* (\boldsymbol{\theta}) \boldsymbol{\zeta}_t, \tag{4}$$

where $\mathbf{z}_t$ is a vector of model variables, $\boldsymbol{\varepsilon}_t$ is a vector of fundamental shocks, and $\boldsymbol{\zeta}_t$ is a vector of sunspot shocks. The coefficient matrices $\Gamma_1^* (\boldsymbol{\theta})$, $\Gamma_{0,\varepsilon}^* (\boldsymbol{\theta})$, and $\Gamma_{0,\zeta}^* (\boldsymbol{\theta})$ are functions of the structural model parameters $\boldsymbol{\theta}$. The matrix $\Gamma_{0,\zeta}^* (\boldsymbol{\theta}) = 0$ under determinacy, but is not zero in general under indeterminacy. Thus indeterminacy introduces additional parameters, given by the matrix M in (4), and a sunspot shock.[18]

With a distributional assumption on $\boldsymbol{\zeta}_t$ (and $\boldsymbol{\varepsilon}_t$), one can construct the likelihood of the solution of the model using the Kalman filter. We use standard Bayesian methods to fit the model to the data.[19] We conduct several convergence checks of our posterior simulations, the details of which are provided in the online appendix (Section 4.3). For model comparison purposes, we estimate marginal likelihoods using the modified harmonic mean estimator by Geweke (1999).

3.2 Data

We use six quarterly U.S. data as observables: per-capita output growth, annualized inflation, annualized federal funds rate, tax revenues-to-output ratio, market value of government debt-to-output ratio, and government spending-to-output ratio.[20] To make our results comparable to the related literature, we estimate the model over two samples: a pre-Volcker sample from 1960:Q1

[18]The online appendix (Section 3) provides a more detailed discussion of the solution method. Beyer and Farmer (2007) argue that some caution needs to be applied in using the methodology in Lubik and Schorfheide (2003; 2004) since one needs to make some assumption about the dynamic structure of the underlying model in distinguishing a determinate equilibrium from an indeterminate one. Lubik and Schorfheide (2007) reply that such identifying assumptions are inherent in any structural econometric work. For another recent application of the Lubik and Schorfheide (2003; 2004) method, see Bilbiie and Straub (2013).

[19]We explain details of the Bayesian methods in the online appendix (Section 4.1). For a general introduction to Bayesian methods, see An and Schorfheide (2007).

[20]Note that we do not use data on government transfers, which is treated as an unobservable.

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to 1979:Q2 and a post-Volcker sample from 1982:Q4 to 2008:Q2.[21] In particular, we drop the Volcker disinflation period. A detailed description of the data and the corresponding measurement equations are given in the online appendix (Section 2).

3.3 Prior distributions

We calibrate $\varphi = 1$ and $\bar{\theta} = 8$ since they are not separately identified from α. We also calibrate ρ_{π^*} and ρ_{b^*} to 0.995 in order to restrict the role for time-varying policy targets to that of explaining low frequency behavior of the data only. For the mean value of observables and the technology growth rate, we use sample specific priors. We use the same priors across the two sample periods for all other parameters. Most of the priors that we use are standard in the literature and are provided in the online appendix (Section 4.2). We discuss in detail two sets of priors that are unique to our analysis.

The first are those for the two key policy parameters in the monetary and fiscal rules: ϕ_π and ψ_b. We reparameterize the model by introducing new parameters ϕ_π^* and ψ_b^* that measure the distance from the boundary of active and passive policies. Let us denote the boundary for monetary policy and fiscal policy by $\Phi^M(\boldsymbol{\theta}) \equiv 1 - \phi_Y \left(\frac{1-\tilde{\beta}}{\tilde{\kappa}}\right)$ and $\Phi^F(\boldsymbol{\theta}) \equiv \frac{1}{\beta} - 1$, respectively.[22] Then let:

$$\phi_\pi = \Phi^M(\boldsymbol{\theta}) + \phi_\pi^*;\ \psi_b = \Phi^F(\boldsymbol{\theta}) + \psi_b^*,$$
$$\phi_\pi = \Phi^M(\boldsymbol{\theta}) - \phi_\pi^*;\ \psi_b = \Phi^F(\boldsymbol{\theta}) - \psi_b^*,$$
$$\phi_\pi = \Phi^M(\boldsymbol{\theta}) - \phi_\pi^*;\ \psi_b = \Phi^F(\boldsymbol{\theta}) + \psi_b^*,$$

for the AMPF, PMAF, and PMPF regimes, respectively. We assume that ϕ_π^* and ψ_b^* have a gamma

[21] An alternative approach to split-sample estimation is a recurrent regime-switching framework. Among other contributions, Sims and Zha (2006b) estimate a VAR while Bianchi (2013) and Baele et al. (2015) estimate a DSGE model with regime switching in monetary policy.

[22] This reparamterization would not be possible if we did not have analytical characterization of the boundary for various policy regimes. In particular, we would not have been able to use this strategy if there were distortionary taxes, since that precludes an analytical solution for the boundary.

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prior distribution whose domain is positive. This reparameterization thus ensures that we completely impose a particular policy regime during estimation. Imposing a particular policy regime through this reparameterization makes the posterior density behave well near the boundary of the policies, which leads to stable numerical operations in estimation and good convergence of posterior simulation. The implied 90% prior probability interval for ϕ_π is $(1.190, 1.812)$ under AM and $(0.218, 0.806)$ under PM while for ψ_b it is $(0.003, 0.106)$ under PF and $(-0.101, 0.002)$ under AF (see Table 1).[23]

The second are those related to the case of indeterminacy. As mentioned above, indeterminacy introduces additional parameters, denoted by the matrix M in (4). We try a few alternate specifications for the priors of those parameters and our results are robust. Our baseline specification is one where we set set the prior mean of M to zero. Since $\Gamma^*_{0,\varepsilon}(\boldsymbol{\theta})$ and $\Gamma^*_{0,\zeta}(\boldsymbol{\theta})$ in (4) are orthogonal, this specification implies that the initial impact of fundamental shocks is orthogonal to that of sunspot shocks at the prior mean.

3.4 Model comparison

To compare model fit, we use marginal likelihoods across different policy regime specifications. As Table 2 makes clear, the best-fitting model is the PMPF regime pre-Volcker, which implies indeterminacy, and the AMPF regime post-Volcker. In this regard, our finding is in line with Lubik and Schorfheide (2004). As we will show below however, the propagation mechanism under our PMPF regime is different from that under passive monetary policy in their paper. This underscores the importance of an explicit specification of both monetary and fiscal policies and the inclusion of fiscal variables in model estimation as we discuss in detail later.[24]

[23] These intervals cover the range of values found in the literature, for example, Davig and Leeper (2011). Note that we restrict the parameter space of ϕ^*_π so that ϕ_π is always positive.

[24] Moreover, note that although we estimate the model conditional on one policy regime at a time, it is possible to construct an unconditional posterior distribution of the parameters across all three policy regimes. This requires specifying a prior distribution over the policy regimes and then sampling from the posterior distribution of the parameters conditional on each policy regime, according to the posterior distribution over the policy regimes. However, since the best-fitting policy regime in both time periods dominates other policy regimes in terms of marginal

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3.5 Posterior estimates

For brevity, all the details of the posterior distributions are provided in the online appendix (Section 4.2). Here, we discuss some of the major findings. As to be expected, the estimates of some key policy parameters are different across the two periods: the implied estimate of the posterior mean for ϕ_π is 0.258 pre-Volcker and 1.348 post-Volcker while for ψ_b it is 0.052 pre-Volcker and 0.096 post-Volcker. The 90% posterior probability interval for ϕ_π is $(0.032, 0.451)$ pre-Volcker and $(0.971, 1.721)$ post-Volcker while for ψ_b it is $(0.012, 0.089)$ pre-Volcker and $(0.031, 0.157)$ post-Volcker. In addition to the feedback parameters, we also find that the volatility of the two shocks in the monetary policy rule, $\varepsilon_{\pi,t}$ and $\varepsilon_{R,t}$, changed significantly across the sample periods. The standard deviation of the shock to the inflation target dropped from 0.060 to 0.036 while the volatility of the monetary policy shock fell from 0.174 to 0.108. This finding is in line with that of Cogley, Primiceri, and Sargent (2010), even though our policy regime in the pre-Volcker period is different from theirs and unlike them, we include fiscal variables in our estimation. In contrast to shocks in the monetary policy reaction function, there was no substantial change in the volatility of the two shocks in the fiscal policy rule, $\varepsilon_{b,t}$ and $\varepsilon_{\tau,t}$, after the Volcker disinflation.

In terms of exogenous processes not related to the policy reaction functions, the standard deviation of most shocks decreased in the post-Volcker compared to the pre-Volcker period.[25] For example, the standard deviation of the cost-push shock $\hat{u}_t$ declined by a quantitatively important amount, which probably reflects less significant oil price shocks in the post-Volcker period. The notable exception to this is the demand shock $\hat{d}_t$ which became more volatile in the post-Volcker

likelihoods, with any reasonable prior distributions over the policy regimes, the unconditional posterior distribution of the parameters will be almost the same as the posterior distribution of the parameters conditional on the best-fitting policy regime. Finally, we estimate cumulative predictive likelihoods, following Geweke and Amisano (2010), to understand relative fit of different policy regimes in the pre-Volcker period. The details of this additional exercise are presented in the online appendix (Section 4.5).

[25] Similar to Smets and Wouters (2007), we normalized some shocks. Specifically, we estimated $\hat{d}_t \equiv (1-\rho_\delta)\,\hat{\delta}_t$ and $\hat{u}_t \equiv -\frac{(1-\alpha\beta)(1-\alpha)}{\alpha(1+\varphi\theta)(1+\gamma\beta)}\frac{1}{\theta-1}\hat{\theta}_t$. See the online appendix (Section 1.2) for the model equations used in our estimation.

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period. In terms of the persistence parameter, while it decreased for most shocks, it increased quite a bit for the technology shock $\hat{a}_t$ and increased marginally for the government spending shock $\hat{g}_t$. With respect to the other structural model parameters, our estimates are largely consistent with results from similar subsample analyses in Smets and Wouters (2007), Cogley, Primiceri, and Sargent (2010) and Benati (2008).[26]

3.6 Propagation of shocks

3.6.1 Transmission mechanism of policy

In Figures 1-4 we present impulse responses to monetary and fiscal policy shocks in the two sample periods. Our main finding is that for the best fitting models, PMPF pre-Volcker and AMPF post-Volcker, the monetary and fiscal policy transmission mechanisms are substantially different.

For the best fitting model pre-Volcker, as shown in panel (b) of Figure 1, a monetary contraction (i.e. an unanticipated increase in the nominal interest rate) leads to an increase in output and inflation.[27] Thus our results provide a model based interpretation to the "price puzzle" of the identified VAR literature: the tendency of inflation to increase on impact following a contractionary monetary policy shock. Hanson (2004) in a comprehensive study showed that this "price puzzle" seems to be a feature only of the pre-Volcker period and not for the entire post-War U.S. data, which is consistent with our results.[28] In addition, panel (a) of Figure 1 reveals that the PMAF model also

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[26]We have also undertaken prior sensitivity analysis using the method of Müller (2012). The results, provided in the online appendix (Section 4.4), show that the data is not very informative and thus the prior distribution plays an important role in the posterior distribution for some of the parameters. In particular, the prior for ψ_b^* and χ_Y does not get updated much after observing the data under PMPF in the pre-Volcker period and under AMPF in the post-Volcker period. We leave it for future research to fully analyze identification issues of some fiscal policy parameters in this class of models.

[27]For comparison, we show the impulse responses to the inflation target shock in the online appendix (Section 5).

[28]Hanson (2004) also shows that for the pre-Volcker period, output also increases initially in response to an unanticipated increase in nominal interest rates. Our results are also consistent in

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generates similar unconventional responses of inflation and output to monetary policy shocks. The underlying mechanism, however, is different. Under PMAF, FTPL is operative, and thus an interest rate increase generates a positive wealth effect, which increases output and inflation. In our best-fitting estimated model FTPL is not operative however and the results are due to indeterminacy.[29]

The effects of fiscal policy shocks are also different from conventional wisdom in the pre-Volcker period. For example, an exogenous increase in the lump-sum tax-to-output ratio produces a recession, decreasing output and inflation as shown in panel (b) of Figure 3, an event one would not observe under conventional AMPF. The interest rate decreases as well, as it only weakly responds to lower inflation due to passive monetary policy. This type of response would also happen under FTPL: an increase in taxes leads to a negative wealth effect, which decreases spending and thereby inflation and output. This is shown in panel (a) of Figure 3.

We thus find that our estimated best-fitting model pre-Volcker, the PMPF regime, mimics the PMAF regime in some dimensions, even though it is not technically one where FTPL is operative. Note that although the PMPF regime mimics the PMAF regime in the aforementioned dimensions, it is different in other dimensions and thus is well identified. For example, note that the response of tax-to-output, debt-to-output, and government spending-to-output ratios to a monetary shock are different in the two regimes in the pre-Volcker period. Moreover, as we discuss later in detail, while the impulse responses to policy shocks look similar, the strength of wealth-effect based transmission mechanism of policy shocks implied by the PMAF regime is at odds with the data.

While the pre-Volcker U.S. economy was characterized by PMPF, it was under the AMPF regime post-Volcker. Accordingly, and unlike the pre-Volcker era, the impulse responses are in line with the predictions of standard monetary models: panel (a) of Figure 2 shows that an unanticipated increase in the nominal interest rate leads to a decrease, not an increase, in inflation. In addition,

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this regard with his paper. This result however might be sensitive to different VAR specifications. For example, Castelnuovo and Surico (2010) using a three-variable VAR with CBO based measure of output gap find a negative response of output gap due to an increase in nominal interest rate in the pre-Volcker era.

[29]The reason for this similarity is that in this simple sticky price model, it is only under PMPF or PMAF that inflation can increase in response to an unanticipated increase in interest rates (under AMPF, inflation would decrease, leading to an increase in the real interest rate and determinacy).

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as panel (a) of Figure 4 makes clear, exogenous adjustments in tax revenues do not affect output, inflation, and the interest rate, a conventional Ricardian equivalence result.

Interestingly, panel (b) of Figures 2 and 4 show that post-Volcker, the PMPF model also produces quite similar dynamics to AMPF. For example, as shown in Figure 2, the impulse responses to a monetary contraction are quite similar between the two regimes, although the error bands are much wider under PMPF. Similarly, Figure 4 illustrates that the two regimes have similar predictions also for the propagation of fiscal shocks, since an unanticipated increase in tax-to-output ratio has no meaningful impacts on output, inflation and the interest rate while reducing debt-to-output ratio under both the regimes. While the dynamics are similar, since the PMPF regime involves many more estimated parameters, it is not favored over the AMPF regime in our Bayesian model comparison.

We emphasize that our results for the pre-Volcker period are data-driven and not hard-wired into our model specification and estimation. Depending on how self-fulfilling beliefs are formed, as shown above, the model under PMPF can generate a wide range of dynamics, including those that are similar to the outcomes under AMPF or PMAF or neither. With the additional parameters in M and the sunspot shocks, we characterize the full set of indeterminate beliefs and construct their distribution conditional on the data. While doing so, we find, for example, that the pre-Volcker data favors the agents' beliefs that inflation would increase in response to a monetary contraction. Under PMPF post-Volcker however, we find that the agents did not believe that inflation would increase in response to interest rate increases. Similarly, the pre-Volcker data favors the agents' beliefs that inflation would decrease in response to fiscal contractions. Under PMPF post-Volcker however, our estimates imply that the agents believed that inflation would increase in response to lump-sum tax increases on average. However, since the error band is quite wide and covers zero, the effect is not significant.

To make these mechanisms even more transparent, in panels (a) and (b) of Figure 5, we decompose the impulse responses to monetary policy shocks under PMPF in the two time periods into two components as given by (4): the part due to $\Gamma^*_{0,\varepsilon}(\boldsymbol{\theta})$ that is uniquely determined by the structural parameters of the model and changes in nature compared to AMPF due to indeterminacy and the part due to $\Gamma^*_{0,\zeta}(\boldsymbol{\theta})\,M$ that is not uniquely determined by the structural parameters because of M and captures self-fulfilling beliefs. The solution gets affected even for the part of the solution that

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is uniquely pined down by the structural parameters of the model.[30] In particular, the determined component implies that inflation increases in response to an increase in interest rates. Therefore, unless the undetermined component – the part that is governed by agents' self-fulfilling beliefs – countervail that effect sufficiently, the PMPF model generates a positive response of inflation to an increase in interest rates. As is clear from Figure 5, pre-Volcker, self-fulfilling beliefs captured by the undetermined component imply an increase in inflation following a monetary contraction, which reinforces the effect from the determined component. In the post-Volcker period however, the self-fulfilling beliefs imply a significant decrease in inflation. This countervailing effect from the undetermined component thus plays a decisive role post-Volcker in the overall negative response of inflation to a positive interest rate shock.

Similarly, in panels (c) and (d) of Figure 5, we decompose the impulse responses to fiscal policy shocks under PMPF in the two time periods into the determined and undetermined components. As is clear, while pre-Volcker, self-fulfilling beliefs captured by the undetermined component imply a decrease in inflation following a fiscal contraction, post-Volcker, they imply an increase in inflation. The undetermined component thus plays a decisive role in both the periods in pinning down the response of inflation to a lump-sum tax shock.

3.6.2 Variance decomposition

We showed above that transmission mechanisms of monetary and fiscal policies are substantially different in the two time periods. We next assess how important the random components in policies were in explaining variations in inflation and output growth. Variance decomposition results, as given in Tables 3 and 4, show that in both the time periods and in both the short run (4 quarters) and the long run (40 quarters), unanticipated shifts in monetary and fiscal policies play only a minor role in explaining the dynamics of inflation and output.

For example, for inflation, pre-Volcker, monetary and fiscal policy shocks explain less than 11% of the variation at both horizons. In particular, pre-Volcker, lump-sum tax shocks explain 2.7% of inflation variation in the short-run and 0.9% in the long-run. These effects, while smaller, are roughly similar to those of monetary policy shocks, which explain 10.7% of inflation variation

[30]Bhattarai, Lee, and Park (2014a) contains a formal proof of these results in a simple model.

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in the short-run and 5.7% in the long-run. Post-Volcker, while the fiscal policy shock explains no variation at either horizon because the prevailing regime is AMPF, the monetary policy shock also is estimated to explain basically no variation at either horizon.

For output growth, pre-Volcker, monetary policy shocks explain around 1.6% while fiscal policy shocks explain around 4.6% of the variation in both the short and long-run. Post-Volcker, the monetary shock explains around 2.5% of the variation at both horizons while fiscal policy shocks explain basically no variation in output growth. Our result that random variations in monetary policy do not explain much of the fluctuations in inflation and output is consistent with the results in the identified VAR literature, for example, Sims and Zha (2006a). That the same conclusion also holds for random variations in fiscal policy, given by unanticipated movements in taxes, is new, as far as we are aware, to the literature on estimated DSGE models that jointly feature both monetary and fiscal policies.

We next assess the role of time-varying inflation target in explaining inflation dynamics, in particular the rise in inflation in the pre-Volcker period. In the recent estimated DSGE literature, a finding has emerged that the long-run variation in inflation is explained mostly by shocks to the inflation target in the monetary reaction function. For example, Ireland (2007) and Cogley, Primiceri, and Sargent (2010) show that both pre- and post-Volcker, smoothed values of the inflation target recovered from estimation track actual inflation remarkably well. In contrast, we find that pre-Volcker, as opposed to post-Volcker, variations in the inflation target do not explain low-frequency movements in inflation.

Table 3 clearly shows that while we find a similar result to Cogley, Primiceri, and Sargent (2010) in the post-Volcker period, where the inflation target shock accounts for 82.6% of the long-run variation in inflation, our results are quite different in the pre-Volcker era, where the inflation target shock explains only 10.1% of the long-run variation in inflation. We make this result also clear in Figure 6, which plots smoothed inflation target recovered from the estimation of the model in the two time periods under various policy regime combinations. While inflation target changes track inflation well under an AMPF regime, this correspondence weakens substantially under either PMPF or PMAF.

The major reason for this difference is that we explicitly allow for the possibility of indeterminacy while estimating our model that features both monetary and fiscal policy. When the regime

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is active monetary and passive fiscal policy, as is the implicit assumption in Ireland (2007) and Cogley, Primiceri, and Sargent (2010) for both the time periods, then changes in inflation target do explain inflation in the long-run since monetary policy fully controls inflation dynamics. Our best-fitting estimated model in the pre-Volcker features indeterminacy due to passive monetary policy, however. In this case, consider an increase in the inflation target. This, through the central bank reaction function, does tend to decrease the interest rate. A decrease in interest rate in this model though, as we pointed out above, tends to decrease inflation. Thus, inflation target movements do not track actual inflation in the long-run. Figure 6 thus makes clear how the role of time-varying inflation target in explaining the low-frequency movement in inflation depends crucially on the monetary and fiscal policy regime in place.

We now address in detail which shocks were major drivers of the dynamics of inflation. Our main finding is that the primary sources of short- and long-run variations in inflation are quite different in the two time periods as the propagation mechanism of shocks varies because of the change in monetary policy stances. As mentioned above, and shown in Table 3, post-Volcker, low-frequency movement in inflation is explained mostly by changes in the inflation target (82.6%). The high frequency movement is mostly explained by mark-up shocks (71.2%), which is also a standard result in the literature. In the pre-Volcker period, in contrast, no single shock played a predominant role, but rather all three types of "non-policy shocks" – the demand shock, the technology shock and the mark-up shock – were major drivers of inflation dynamics. They collectively account for 75% of the short-run variation and 79.8% of the long-run variation in inflation. The important role of mark-up shocks at both horizons in the pre-Volcker period is not surprising given the oil price shocks of the 1970s. Moreover, in the pre-Volcker period, since the monetary policy regime was passive, such non-policy shocks, whose effects on inflation would typically be stabilized under active monetary policy over the long run, end up influencing inflation dynamics significantly. To illustrate this role of non-policy shocks, in the online appendix (Section 6.1), we report the counterfactual path of inflation under PMPF in the pre-Volcker period if we simulate our model using the posterior distribution of all other shocks while shutting down non-policy shocks. The rise of inflation in the 1970s is muted in that case.

Finally, how important are sunspot shocks in explaining variation in inflation and output growth in the pre-Volcker period? As Tables 3 and 4 make clear, sunspot shocks introduced due to inde-

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terminacy play a quite minor role in explaining the dynamics of inflation and output. Lubik and Schorfheide (2004) also found a minor role of sunspot shocks. Indeterminacy matters in our estimated model, not because of a non-trivial role for sunspot fluctuations, but mostly because self-fulfilling beliefs regarding fundamental shocks significantly alter the propagation mechanisms in the model.[31]

3.6.3 Role of policy in the rise of inflation

Having found that neither exogenous variations in the inflation target nor sunspot shocks played a major role in the rise of inflation and its high volatility in the pre-Volcker period, we now evaluate the role of changes in the monetary policy regime, which can presumably be important given the non-trivial influences on inflation of the non-policy shocks pre-Volcker as discussed above. To this end, we conduct a counterfactual exercise assessing the model implied path of various observables had the post-Volcker monetary policy regime been in place since 1962:Q1 in the pre-Volcker period. Specifically, using the posterior distribution of model parameters and shocks of the pre-Volcker period, we simulate our model from 1962:Q1 onwards by setting ϕ_π and ϕ_Y to their respective posterior mean in the post-Volcker period.[32]

[31] In the interest of space, we present the detailed variance decomposition of government debt in the online appendix (Section 6.2). During both pre- and post-Volcker, the transfer shock explains the majority of the variation in the debt-to-output ratio in the short-run (62% and 75% respectively), but plays a minor role in the long-run. The lump-sum tax shock explains some variation in the short-run for both periods, with its role reduced in the long-run while the monetary policy shock is not relevant in either horizons. In the long-run, for pre-Volcker, while the government spending shock explains the most (37%), there is non-trivial contribution also of preference, technology and mark-up shocks and no contribution of the inflation target shock. Post-Volcker, the role of the government spending shock gets amplified substantially, as it explains 61.5% of the variation, with no role for technology and markup shocks, but much more of a role of the inflation target shock, which now explains 11.1% of the variation. Thus, some differences do exist in terms of the underlying sources of debt dynamics in the two periods.

[32] Note here that we keep the fiscal parameters the same as the estimated values in the pre-Volcker period. We shut down the exogenous shock in the monetary policy rule $\varepsilon_{R,t}$ to consider in isolation

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First, we find that the model implied standard deviation of inflation is 2.03%, which is substantially lower than the actual value of 2.72%. Moreover, Figure 7, where we plot the model implied path of inflation together with actual inflation, makes clear that under this monetary policy regime, the rise of inflation in the 1970s would have been avoided. Thus, our counterfactual exercise suggests that a change in the systematic response of monetary policy would have mattered greatly for inflation dynamics in the pre-Volcker era. Second, we find that output would not have been very different. This is because the slope of the Phillips curve is relatively steep in the pre-Volcker period and thus there was little short-run trade-off between output and inflation.

3.7 Discussion

We have so far presented various quantitative results, conditional on the best-fitting policy regimes given in Table 2. The model-fit result for the post-Volcker period is standard and conventional for any sub-sample estimation exercise. For the pre-Volcker period however, some previous studies – focusing on determinate policy regimes – suggest evidence for the PMAF regime.[33] Therefore, one may naturally ask what factors contribute to our result that the PMPF regime is preferred to the PMAF regime in the pre-Volcker period. This subsection addresses this question in a variety of ways. We also argue that including fiscal policy explicitly in the model and using fiscal variables

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the effect on inflation dynamics of a change in the systematic response of monetary policy. We did not shut down the inflation target shock $\hat{\pi}_t^*$, but our result is robust even when $\hat{\pi}_t^*$ is shut down because the estimated inflation target shock does not fluctuate much under PMPF, pre-Volcker. In other words, under PMPF in the pre-Volcker period, inflation dynamics with and without these shocks are virtually identical, as our earlier variance decomposition results make clear.

[33]Traum and Yang (2011) find evidence for PMAF using a different model and data. Moreover, in an interesting paper, Bianchi and Ilut (2015) use a regime switching set-up from an PMAF regime to a AMPF regime to explain the rise of inflation in the $1970s$. Compared to our split-sample estimation, they find the date of the switch endogenously and assess the effects of regime-switching, but do not conduct a formal model comparison exercise while allowing for indeterminacy. We leave it for future research to address these issues with a method that allows for both regime switching as well as equilibrium indeterminacy and enables a model comparison.

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in estimation indeed played an important role for our model-fit result. We finally conduct several robustness exercises.

3.7.1 Model fit

What features of the data, within the context of our estimated model, account for the model selection result in the pre-Volcker period? We find that the most significant discrepancies between the PMAF regime and the data lie in the joint dynamics of inflation, interest rates and debt, and this is precisely where the PMAF regime fares worse than the PMPF regime.

The poor performance of the PMAF regime is a result of the combination of the predominant role of monetary policy shocks and the wealth effects that arise under that policy regime.[34] While the monetary policy shock plays a minor role under PMPF as shown above, it is in fact the main driving force for the joint dynamics of inflation, interest rates and debt under PMAF. Monetary policy shock explains 33% of inflation and 96% of interest rate variation in the short-run and 52% of inflation and interest rate variation in the long-run. In addition, the same shock plays a significant role for debt dynamics, especially at longer horizon (40%). As discussed above, monetary policy shocks affect these variables through wealth effects – as the FTPL is operative under PMAF. The resulting model dynamics, however, are at odds with the data.

As can be seen from panel (a) of Figure 1, a monetary policy shock, under PMAF, moves inflation, interest rates and debt in the same direction due to the FTPL mechanism (i.e. the wealth effects caused by changes in interest rates). Moreover, the effect of the shock is highly persistent – as can also be seen clearly from the impulse responses – because a monetary policy shock generates such the wealth effects through its influence on debt, which itself moves sluggishly due to its dependence on the amount of debt carried over from the previous period (i.e. b_{t-1} is in the law of motion for debt b_t). Such long-lasting wealth effects lead to a large degree of autocorrelation of inflation and interest rates and also a large degree of cross-correlation between the two variables. These model dynamics, however, are at odds with the data as actual inflation and interest rates are much less persistent. Furthermore, the positive cross-correlation between interest rates and debt and also between inflation and debt implied by the PMAF regime is also problematic as the data

[34]Bhattarai, Lee, and Park (2014a) contains a detailed analysis of these wealth effects.

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clearly indicates that the correlations are negative. The online appendix (Section 8.1) provides more discussions and figures that compare autocorrelations and cross-correlations of the data to those implied by each of the policy regimes in the model.

Overall, we find that the wealth-effect-based mechanism of a significant size that is predicted by our estimated PMAF regime is not observed in the data in the pre-Volcker period. Thus, this mechanism and the PMAF regime do not seem to explain the joint dynamics of inflation, interest rates and debt.

3.7.2 External evidence on policy regimes

The previous subsection discusses why the PMAF regime is inferior to the PMPF in matching the data within our structural estimation framework. While there are benefits of estimating structural equilibrium models when assessing which policy regime in fact prevailed, this approach has an obvious shortcoming that one's finding inevitably depends on the model structure, at least partially.[35] We therefore supplement our exercise by providing external evidence for a passive fiscal policy regime during this period as well as for self-fulfilling beliefs, based on earlier empirical studies that impose less structure. First, we estimate single equation fiscal policy reaction functions of Bohn (1998) with quarterly data and also for the precise sample period considered in our paper. The details of the specification and estimation results are provided in the online appendix (Section 8.2). We indeed find that fiscal policy was passive in the pre-Volcker period.[36] Second, in a framework in the spirit of Leduc, Sill, and Stark (2007), we utilize the Livingston Survey data on

[35]Related to this point that the results are partly driven by model structure, Davig and Leeper (2007a) point out that the condition for (in)determinacy is different in models in which policy reaction coefficients evolve exogenously according to a Markov process. It will be interesting to develop a framework that can allow both for monetary/fiscal policy regime-switching as well as indeterminacy and to investigate whether model comparison results are different in such an alternative framework.

[36]In addition, our result on monetary policy is also consistent with earlier studies that use limited information approaches such as Clarida, Gali and Gertler (2000), Mavroeidis (2010) and Coibion and Gorodnichenko (2011). Our exercise reinforces their results in a general equilibrium setting.

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expected inflation (and the timing of the survey to motivate a recursive ordering) like them and align the data to be as close as possible to the one used in our DSGE model estimation. The details of the specification and VAR estimation procedure are in the online appendix (Section 8.3). We find that pre-Volcker, the shock to expected inflation was not stabilized and led to persistent effects on actual inflation. This thus suggests a role for self-fulfilling beliefs in the pre-Volcker era, as was the argument of Leduc, Sill, and Stark (2007).[37]

3.7.3 Role of fiscal policy

We now assess the role played by including fiscal policy explicitly in the model and using fiscal variables as observables in estimation on inference and identification in the pre-Volcker period. It is perhaps easy to see some direct benefits of including fiscal variables in the model and estimation. For example, without it, one would not be able to make a meaningful inference regarding the effects of fiscal policy changes on key aggregate variables such as inflation and output. We have shown that these effects were statistically significant in the pre-Volcker period. Moreover, dropping fiscal policy from the model would preclude the possibility of the PMAF regime, which potentially biases our inference towards indeterminacy. There are however, some additional benefits on which we focus next.

First, under PMPF and indeterminacy, excluding an explicit specification of fiscal policy can be a source of misspecification. For example, in Bhattarai, Lee, and Park (2014a), we show analytically in a simple sticky-price model with lump-sum taxes that $\Gamma^*_{0,\varepsilon}(\boldsymbol{\theta})$, the determined component of the solution under indeterminacy, depends both on monetary and fiscal policy parameters. Thus, dropping fiscal policy, even if fiscal policy is passive, is not innocuous. Second, we illustrate below that including fiscal variables in the model and estimation provides additional information about self-fulfilling beliefs of the agents, which in turn leads to a better identification of the matrix M and more robust inference regarding the propagation of monetary policy shocks under PMPF. This is because in a model with monetary and fiscal policy interactions, under PMPF, $M_{R\zeta}$ in M that corresponds to the monetary policy shock influences the impact of monetary policy shocks on not

[37]Post-Volcker, this shock does not have persistent effects on actual inflation, as shown in Leduc, Sill, and Stark (2007). To conserve space, we do not show a figure of this standard result.

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only output, inflation, and the interest rate but also, fiscal variables. Therefore, using data on fiscal variables can provide an additional source of identification. We show these results in the online appendix (Section 7.1) which clarify that only when we include fiscal variables in the model and estimation for the pre-Volcker period, as we discussed above, our results are robust to what prior we assign to M. In addition, we consider another experiment to highlight the role of fiscal variables in our model comparison results. In particular, we now include fiscal policy in the model but drop fiscal variables from estimation. Thus, while the model continues to have government debt and taxes, we do not use data on those variables. In the online appendix (Section 7.2), we show that our model comparison results continue to hold as in the baseline case: pre-Volcker, the PMPF regime fits the data best.[38]

3.7.4 Robustness

We conduct five major robustness exercises: a monetary aggregate is included in the monetary policy reaction function; we estimate the model without time-varying inflation and debt targets is estimated; we estimate the model with an ARMA specification for the shocks; looser priors are considered on the key policy parameters by increasing the standard deviation on the prior distributions of ϕ_π^*, ψ_b^*, and ϕ_Y; and we extend the post-Volcker sample to include the observations from the Volcker disinflation period (1979:Q3-1982:Q3). These alternative specifications do not affect the substantive results of our paper. The details of all the results from this section are provided in the online appendix (Section 9).

4 Conclusion

In this paper we have addressed some long-standing questions in macroeconomics using an estimated DSGE model that has an explicit description of both monetary and fiscal policies. Our main

[38]Note that we continue to use data on government spending as this variable features even on standard models that do not consider monetary and fiscal policy interactions. Moreover, using data on government spending while not on debt and taxes helps further clarify that even without matching data on debt, the PMAF regime still predicts joint dynamics of inflation and interest rates that is at odds with the data.

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result is that the monetary and fiscal policy regime combination in place has mattered historically for a host of issues: the prevalence of equilibrium indeterminacy, the transmission mechanism of monetary and fiscal policy, and the major sources of variation in inflation. That is, we find the nature of the systematic response of policy to the state of the economy to be paramount in the propagation mechanism of both policy and non-policy shocks.

In future research projects, we plan to extend and build on our current work on three fronts. First, we can conduct our analysis using a medium-scale DSGE model such as the one in Smets and Wouters (2007), Del Negro et al. (2007), and Justiniano, Primiceri, and Tambalotti (2010), with a detailed specification of fiscal policy such as distortionary taxes and long-term debt. Second, we can allow for time-varying volatility of shocks in our estimated DSGE model, along the lines of Justiniano and Primiceri (2008). Third, we can estimate a DSGE model with recurring regime switching in both monetary and fiscal policies, building on the methodology provided in Farmer, Waggoner, and Zha (2011) or Davig and Leeper (2007a). Another related approach we can adopt is the time-varying policy parameters set-up in Inoue and Rossi (2011) or Fernandez-Villaverde, Guerron-Quintana, and Rubio-Ramirez (2010).

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Figures and Tables

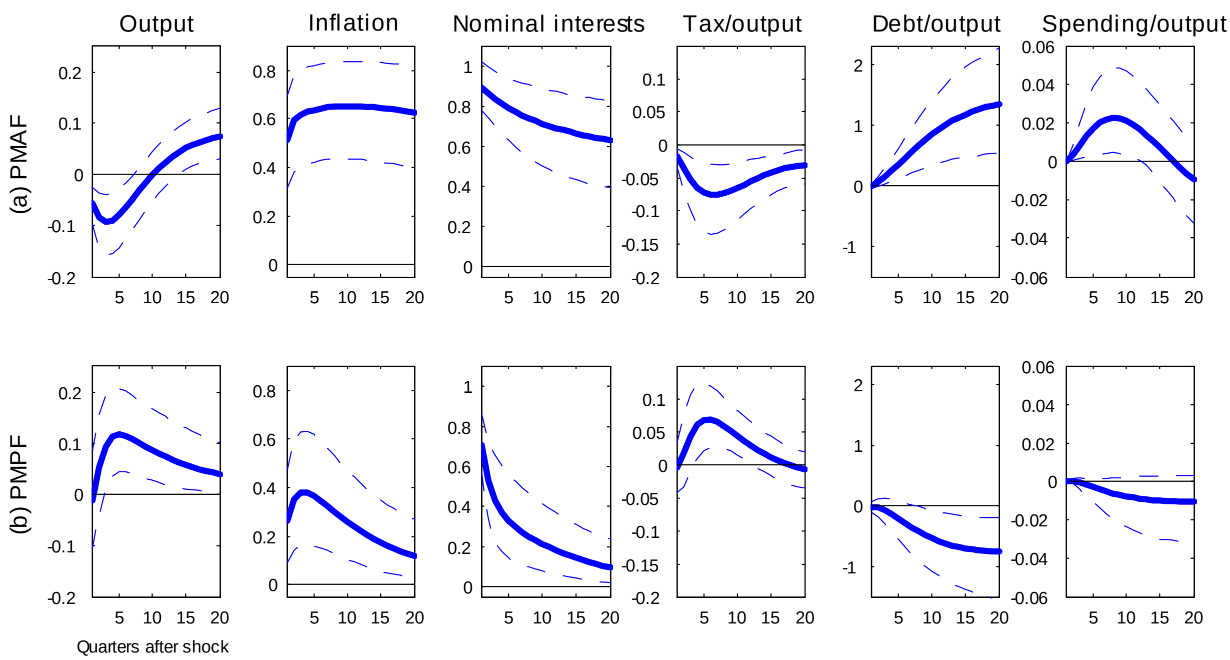

Figure 1: Impulse responses to monetary policy shocks in the pre-Volcker period

Note: Figure plots pointwise posterior means (solid lines) and 5th and 95th percentiles (dashed lines) for impulse responses to a one standard deviation shock to $\varepsilon_{R,t}$. Row (a) presents results of the PMAF regime, pre-Volcker, and row (b) presents results of the PMPF regime, pre-Volcker. The unit of the impulse responses is percentage deviations from the steady state for output and percentage point deviations from the steady state for the rest of the variables.

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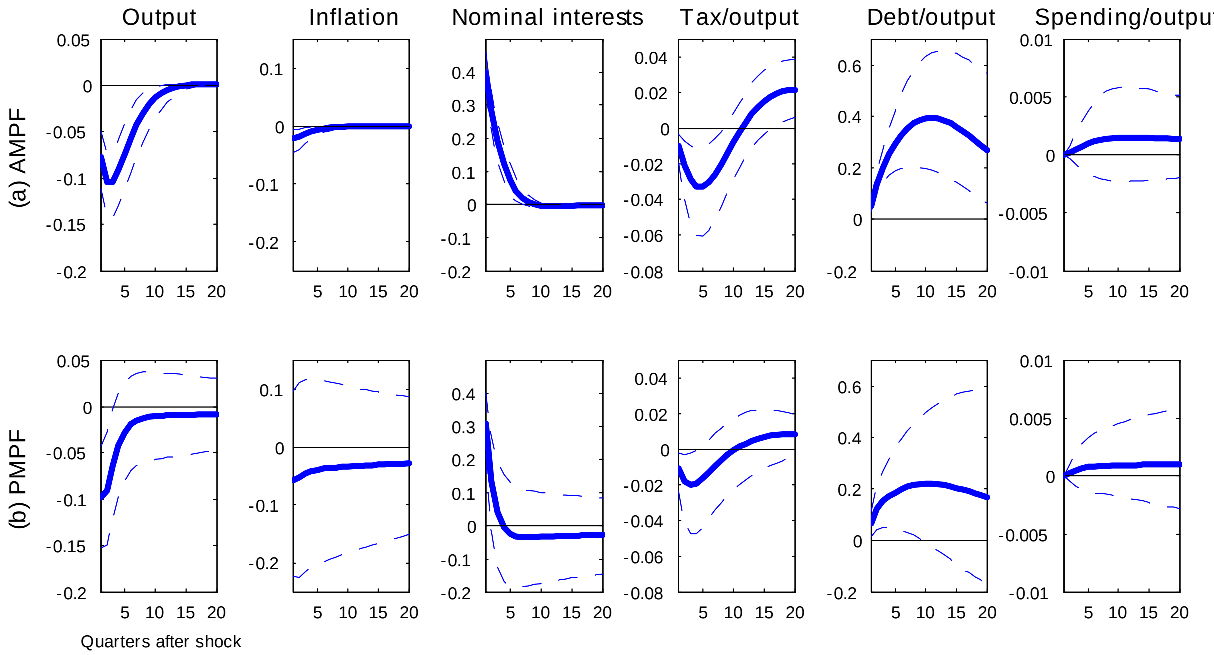

Figure 2: Impulse responses to monetary policy shocks in the post-Volcker period

Note: Figure plots pointwise posterior means (solid lines) and 5th and 95th percentiles (dashed lines) for impulse responses to a one standard deviation shock to $\varepsilon_{R,t}$. Row (a) presents results of the AMPF regime, post-Volcker, and row (b) presents results of the PMPF regime, post-Volcker. The unit of the impulse responses is percentage deviations from the steady state for output and percentage point deviations from the steady state for the rest of the variables.

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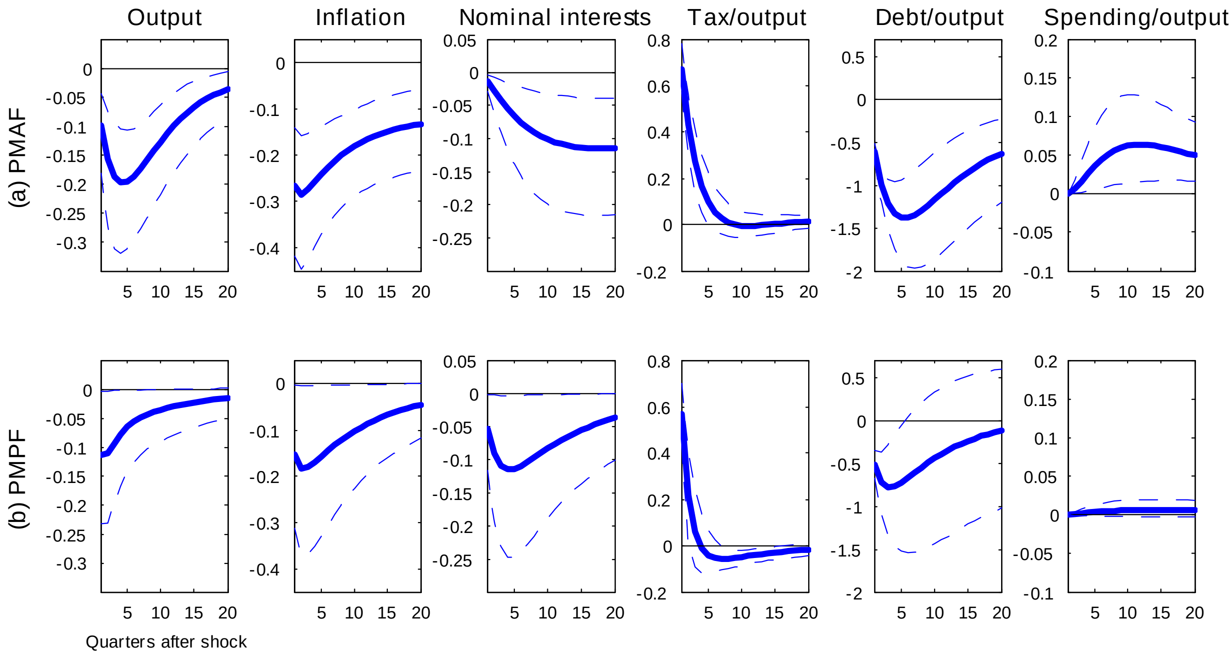

Figure 3: Impulse responses to fiscal policy shocks in the pre-Volcker period

Note: Figure plots pointwise posterior means (solid lines) and 5th and 95th percentiles (dashed lines) for impulse responses to a one standard deviation shock to $\varepsilon_{\tau,t}$. Row (a) presents results of the PMAF regime, pre-Volcker, and row (b) presents results of the PMPF regime, pre-Volcker. The unit of the impulse responses is percentage deviations from the steady state for output and percentage point deviations from the steady state for the rest of the variables.

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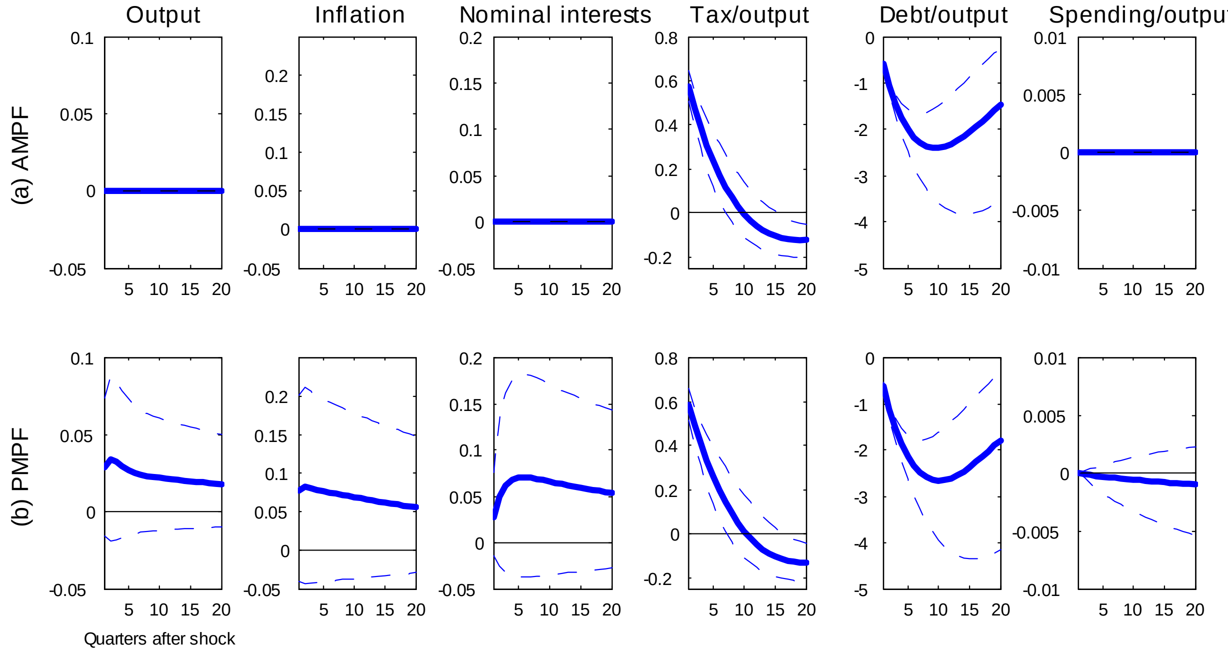

Figure 4: Impulse responses to fiscal policy shocks in the post-Volcker period

Note: Figure plots pointwise posterior means (solid lines) and 5th and 95th percentiles (dashed lines) for impulse responses to a one standard deviation shock to $\varepsilon_{\tau,t}$. Row (a) presents results of the AMPF regime, post-Volcker, and row (b) presents results of the PMPF regime, post-Volcker. The unit of the impulse responses is percentage deviations from the steady state for output and percentage point deviations from the steady state for the rest of the variables.

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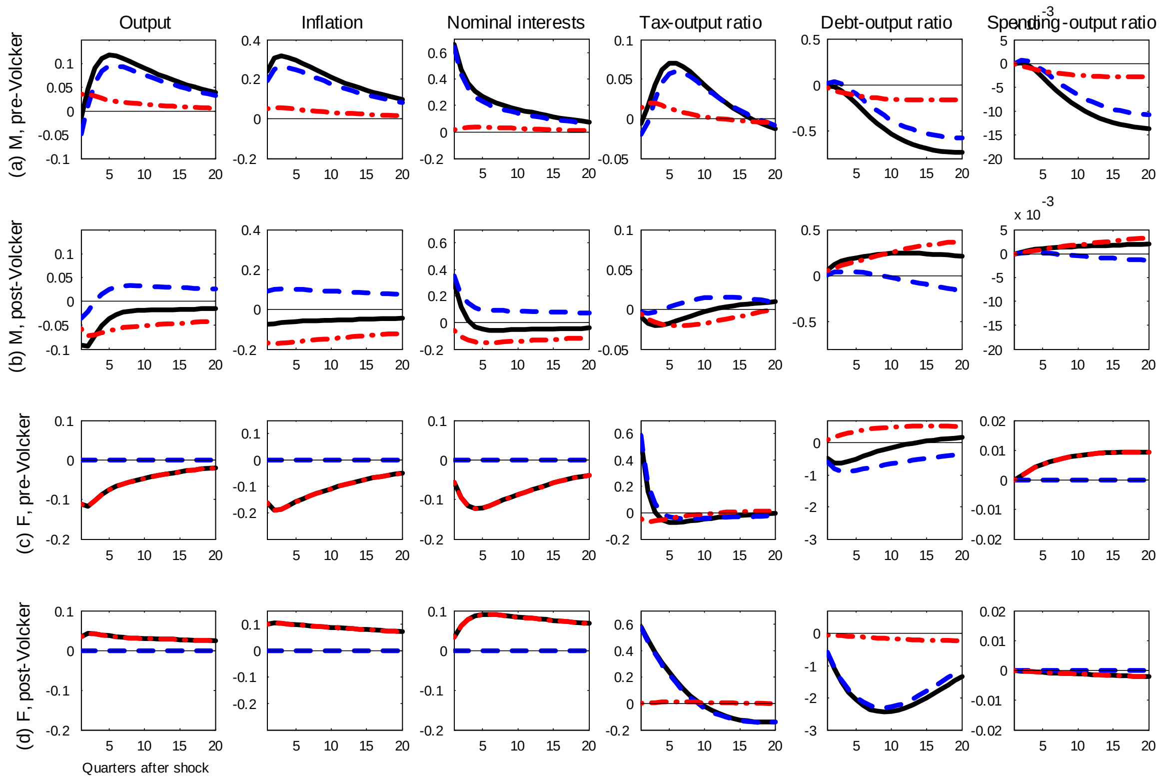

Figure 5: Decomposition of the impulse responses to monetary and fiscal policy shocks

Note: Row (a): the impulse responses to monetary policy shocks under PMPF, pre-Volcker; row (b): the impulse responses to monetary policy shocks under PMPF, post-Volcker; row (c): the impulse responses to fiscal policy shocks under PMPF, pre-Volcker; and row (d): the impulse responses to fiscal policy shocks under PMPF, post-Volcker. Each plot presents three impulse responses of each variable to one standard deviation shock to $\varepsilon_{R,t}$ and $\varepsilon_{\tau,t}$: 1) (dashed lines) impulse responses due to the determined part of initial impact of a shock, 2) (dashed-dotted lines) impulse responses due to the undetermined part of initial impact of a shock, and 3) (solid lines) the combined impulse responses of 1) and 2). The determined part of initial impact of a shock is uniquely pinned down by the structural parameters of the model while the undetermined part of initial impact of a shock is not uniquely pinned down by the structural parameters because of additional free parameters.

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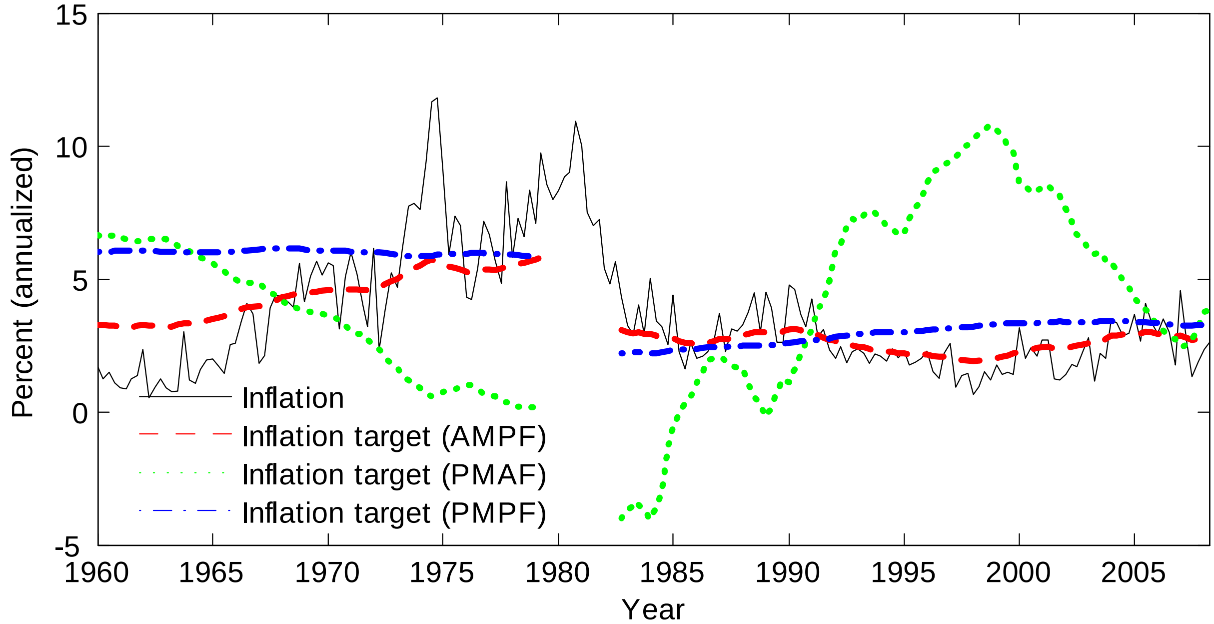

Figure 6: Smoothed inflation target and inflation

Note: Figure presents actual inflation and the point-wise mean of the smoothed values of the inflation target for the three policy regimes for both the pre- and the post-Volcker periods.

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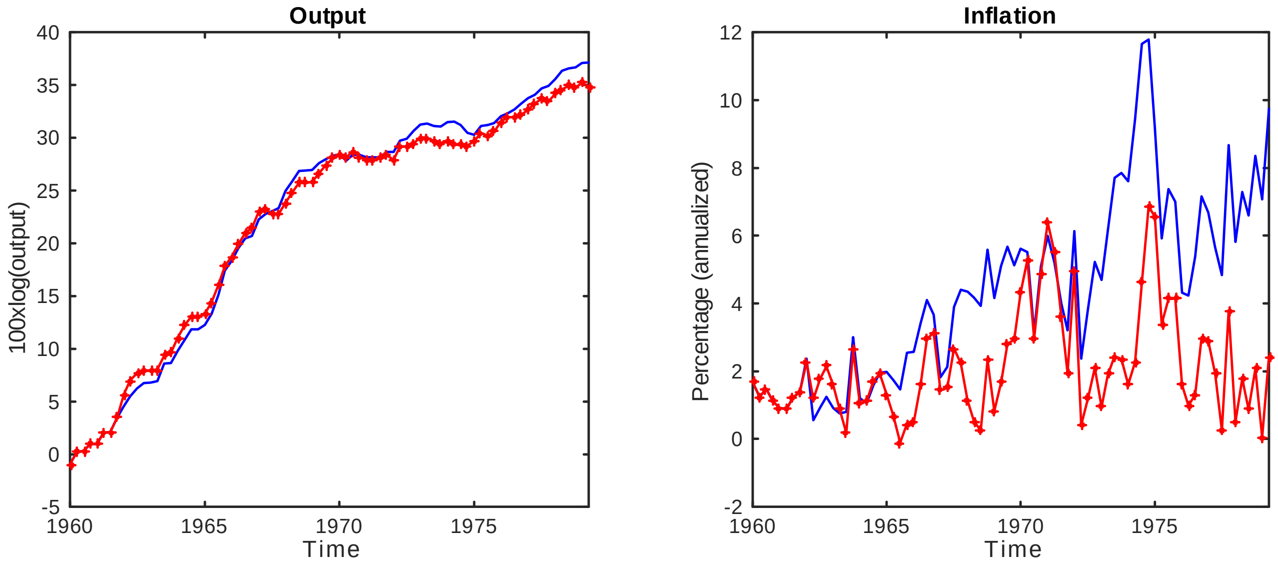

Figure 7: Counterfactual path of output and inflation

Note: Figure presents actual (solid) and counterfactual (solid with + marks) path of the two variables in the pre-Volcker period. The distribution of counterfactual paths was computed using the posterior distribution of the parameters except that ϕ_π and ϕ_Y are set to their respective posterior means 1.348 and 0.438 under the AMPF regime post-Volcker. We assumed that the Federal Reserve switched from PMPF to AMPF in 1962:Q1, using the observations before 1962:Q1 to initialize the Kalman filter in the counterfactual exercise. The presented counterfactual paths are point-wise mean of the distribution of counterfactual paths. The monetary policy shock was shut down.

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Table 1: Prior distribution of monetary and fiscal policy parameters

Parameters	Policy	Mean	St. Dev.	[5th, 95th]
ϕ_π	Active Monetary	1.499	0.200	[1.190, 1.812]
	Passive Monetary	0.512	0.181	[0.218, 0.806]
ψ_b	Active Fiscal	-0.047	0.040	[-0.101, 0.002]
	Passive Fiscal	0.052	0.040	[0.003, 0.106]

Note: The last column presents the 5th and 95th percentiles. The prior distribution of ϕ_π and ψ_b was obtained based on a simulation from the prior distribution of the structural parameters. Since the prior distribution of those parameters that determine the boundary condition of active and passive policy is identical pre-Volcker and post-Volcker, ϕ_π and ψ_b also have the same prior distribution across the subsamples.

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Table 2: Comparison of the marginal likelihood of alternate regimes

	Determinacy		Indeterminacy
	AMPF	PMAF	PMPF
Pre-Volcker	-541.7	-537.4	-521.8
Post-Volcker	-553.2	-564.1	-566.0

Note: Table reports log marginal likelihoods that are computed using the harmonic mean estimator proposed by John F. Geweke (1999).

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Table 3: Variance decompositions of inflation

	Pre-Volcker (PMPF)		Post-Volcker (AMPF)	
Shocks	Short-Run (4 Q)	Long-Run (40 Q)	Short-Run (4 Q)	Long-Run (40 Q)
Govt. spending	0.6	0.2	0.0	0.0
$\varepsilon_{g,t}$	[0.0, 2.4]	[0.0, 0.7]	[0.0, 0.0]	[0.0, 0.0]
Demand	19.4	46.7	5.8	1.9
$\varepsilon_{d,t}$	[3.4, 40.2]	[11.9, 90.4]	[1.0, 14.3]	[0.2, 5.8]
Technology	35.9	12.1	0.0	0.0
$\varepsilon_{a,t}$	[11.9, 60.1]	[0.6, 31.6]	[0.0, 0.1]	[0.0, 0.0]
Mark-up	19.7	21.0	71.2	15.5
$\varepsilon_{u,t}$	[7.3, 39.2]	[1.2, 53.9]	[53.2, 86.9]	[2.1, 38.5]
Transfer	1.0	0.3	0.0	0.0
$\varepsilon_{s,t}$	[0.0, 3.8]	[0.0, 1.4]	[0.0, 0.0]	[0.0, 0.0]
Monetary policy	10.7	5.7	0.1	0.0
$\varepsilon_{R,t}$	[1.7, 27.1]	[0.2, 18.8]	[0.0, 0.4]	[0.0, 0.1]
Tax revenues	2.7	0.9	0.0	0.0
$\varepsilon_{\tau,t}$	[0.1, 7.7]	[0.0, 3.1]	[0.0, 0.0]	[0.0, 0.0]
Inflation target	0.7	10.1	22.8	82.6
$\varepsilon_{\pi,t}$	[0.0, 2.9]	[0.1, 37.8]	[10.4, 37.9]	[58.3, 97.4]
Debt target	2.1	0.7	0.0	0.0
$\varepsilon_{b,t}$	[0.0, 7.8]	[0.0, 2.9]	[0.0, 0.0]	[0.0, 0.0]
Sunspot	7.2	2.3	0	0
$\varepsilon_{\zeta,t}$	[2.0, 16.1]	[0.1, 6.9]	-	-

Note: Means and [5th, 95th] posterior percentiles in percentage. The demand shock $\hat{d}_t$ and the cost-push shock $\hat{u}_t$ are a reparameterized shock of $\hat{\delta}_t$ and $\hat{\theta}_t$, respectively

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Table 4: Variance decompositions of output growth

	Pre-Volcker (PMPF)		Post-Volcker (AMPF)	
Shocks	Short-Run (4 Q)	Long-Run (40 Q)	Short-Run (4 Q)	Long-Run (40 Q)
Govt. spending	15.0	14.5	12.5	12.0
$\varepsilon_{g,t}$	[6.3, 25.2]	[6.1, 24.5]	[8.8, 17.0]	[8.4 , 16.3]
Demand	17.9	17.8	57.5	57.7
$\varepsilon_{d,t}$	[1.8, 37.1]	[2.0, 36.9]	[41.7, 71.3]	[41.7, 71.5]
Technology	9.6	10.5	25.5	25.9
$\varepsilon_{a,t}$	[2.8, 23.7]	[3.5, 24.0]	[12.3, 42.2]	[12.8, 42.7]
Mark-up	34.0	34.2	0.4	0.5
$\varepsilon_{u,t}$	[15.9, 54.6]	[16.2, 54.7]	[0.1, 1.0]	[0.1, 1.1]
Transfer	1.6	1.6	0.0	0.0
$\varepsilon_{s,t}$	[0.0, 5.5]	[0.0, 5.4]	[0.0, 0.0]	[0.0, 0.0]
Monetary policy	1.6	1.6	2.5	2.5
$\varepsilon_{R,t}$	[0.4, 4.3]	[0.4, 4.3]	[1.0, 4.9]	[1.0, 4.9]
Tax revenues	4.7	4.6	0.0	0.0
$\varepsilon_{\tau,t}$	[0.1, 14.0]	[0.1, 13.6]	[0.0, 0.0]	[0.0, 0.0]
Inflation target	0.8	0.7	1.5	1.5
$\varepsilon_{\pi,t}$	[0.0, 3.2]	[0.0, 3.1]	[0.6, 3.0]	[0.5, 2.9]
Debt target	3.5	3.4	0.0	0.0
$\varepsilon_{b,t}$	[0.0, 12.8]	[0.0, 12.4]	[0.0, 0.0]	[0.0, 0.0]
Sunspot	11.4	11.1	0	0
$\varepsilon_{\zeta,t}$	[3.9, 23.2]	[3.9, 22.7]	-	-

Note: Means and [5th, 95th] posterior percentiles in percentage. The demand shock $\hat{d}_t$ and the cost-push shock $\hat{u}_t$ are a reparameterized shock of $\hat{\delta}_t$ and $\hat{\theta}_t$, respectively