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Active or Passive? Revisiting the Role of Fiscal Policy During High Inflation

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Abstract

We investigate the interplay of the monetary-fiscal policy mix during times of crisis by drawing insights from the Great Inflation of the 1960s and 1970s. We use a Sequential Monte Carlo (SMC) algorithm to estimate a DSGE model with three distinct monetary/fiscal policy regimes. We show that in such a model SMC outperforms standard sampling algorithms because it is better suited to deal with multimodal posteriors, an outcome that is highly likely in a DSGE model with monetary-fiscal policy interactions. From the estimation with SMC a differentiated perspective results: pre-Volcker macroeconomic dynamics were similarly driven by passive monetary/passive fiscal policy and fiscal dominance. We apply these insights to study the post-pandemic inflation period.

JEL classification: C11, C15, E63, E65

Keywords: Bayesian Analysis, DSGE Models, Monetary-Fiscal Policy Interactions, Monte Carlo Methods

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1 Introduction

In advanced economies, sovereign debt levels have increased to record highs due to fiscal stimulus and rescue packages in response to the pandemic and the war in Ukraine. This has eroded the fiscal authorities' credibility in stabilizing the accumulated fiscal imbalances (Bianchi and Melosi, 2022). At the same time, inflation has been surging, ending decades of generally stable prices. Navigating through this complex environment requires coordinated fiscal and monetary policy actions and a sound understanding of macroeconomic policy interactions derived from model-based evaluations.

This paper aims to contribute to this debate along three dimensions. First, we provide methodological guidance on how to estimate DSGE models with distinct monetary-fiscal policy regimes. We show that in such a model setup the Sequential Monte Carlo (SMC) algorithm outperforms standard posterior sampling algorithms and should be the preferred choice. Using SMC, we revisit the still open role of fiscal policy during the historical episode of the Great Inflation in the U.S. In a last step, we transfer the insights from the pre-Volcker period to the recent period of post-pandemic inflation and discuss appropriate monetary and fiscal responses.

It is well established in the literature that any discussion of potential causes of inflation and appropriate policy actions to contain them must be accompanied by an assessment of the fiscal-monetary policy mix in place.[1] For one historical episode, which is very instructive for all these aspects, the debate about the fiscal-monetary policy mix is still unsettled. This episode is usually referred to as the Great Inflation of the 1960s and 1970s in the U.S. In our study, we revisit the role of fiscal policy during the Great Inflation to obtain insights for potential policy options in the post-pandemic inflation regime. We estimate a DSGE model

[1] The insight that monetary and fiscal policy are not independent from each other and must be studied jointly has a long tradition in modern macroeconomics, going back to Sargent and Wallace (1981), Leeper (1991), Sims (1994), Woodford (1996), and Cochrane (2001). Cochrane (2011), Davig and Leeper (2011) and Bianchi and Melosi (2017) study the interaction of monetary and fiscal policy in a recession. Ascari et al. (2020) call for a new taxonomy for studying the interactions of monetary and fiscal policy. Bianchi et al. (2020) propose a concrete policy that involves coordination between the monetary and fiscal authorities in response to the COVID-19 pandemic.

with three distinct monetary/fiscal policy regimes using a SMC algorithm - a posterior sampler established in the DSGE literature by Herbst and Schorfheide (2014, 2015). The SMC is able to deal with multimodal posterior surfaces and enables us to estimate a fixed-regime DSGE model with distinct monetary/fiscal policy regimes over its entire parameter space.

We find that the macroeconomic dynamics during the pre-Volcker period were almost similarly driven by a passive monetary/passive fiscal policy regime and a regime of fiscal dominance. From a historical standpoint, a regime of fiscal dominance emerges as a plausible explanation for several reasons. First, the fiscal authority notably operated with deficits to fund initiatives such as the "Great Society" program, initiated by President Johnson in 1964, the Vietnam War until 1973, and the tax reductions implemented by President Ford's administration in 1975. Concurrently, Arthur Burns, who served as the chairman of the Federal Reserve from 1970 to 1978, frequently interacted with the White House — described by Alan Meltzer as a "junior partner" to the fiscal authority Meltzer (2003). Moreover, in a similar vein, research by Drechsel (2023) supports the notion that President Nixon applied political pressure on Fed Chairman Burns. The result that regime F and indeterminacy were almost equally likely calls for a more differentiated perspective on the causes of the Great Inflation. Not only did non-policy shocks create inflationary pressure, but fiscal policy actions, in particular government spending, were also an equally important driver of U.S. inflation in the 1960s and 1970s.

Through the lens of the model, we analyze the current period. Present times are marked by post-pandemic inflation and a fiscal authority grappling with increased government spending to address pandemic fallout, adapt to climate change-induced transformations, and respond to escalating global tensions necessitating heightened military investments or expanded aid packages to countries like Ukraine, Israel, or Taiwan. These expenditures have been increasingly financed by the issuance of government debt, which led the IMF to warn the US that its massive fiscal deficits have stoked inflation and pose "significant risks" for the global economy (International Monetary Fund, 2024). Against this background, we illustrate the interplay of the policy regime by filtering U.S. data from 2020:Q1 - 2022:Q4 through the model, separately for each of the three estimated monetary-fiscal policy regimes. Although the smoothed shocks are similar in each parameterization, the contribution of each shock to inflation varies significantly across policy regimes. In a regime of monetary dominance, the main drivers of post-pandemic inflation are mark-up shocks. In a regime with two passive authorities, inflation is mainly driven by preference and tax shocks. In contrast, under fiscal dominance, transfers are the main source of inflation. Consequently, while fiscal policy would be the main instrument to curb inflation in the indeterminacy and fiscal-led regime, fiscal policy measures would not be effective in reducing inflation in a regime of monetary dominance. This discrepancy arises from the regime-specific effectiveness of macroeconomic policy instruments. While nominal interest rate hikes effectively dampen inflation in a monetary-led regime, they fuel inflationary pressures in fiscal-led and passive monetary/passive fiscal regimes. Therefore, it is of utmost relevance that policymakers are aware of the regime when formulating policy decisions.

Our analysis provides methodological guidance on how to estimate DSGE models with monetary-fiscal policy interactions and therefore different policy regimes. Models that account for different monetary and fiscal policy interactions played a pertinent role in the debate on escaping the efficient lower bound (Bianchi and Melosi, 2017) and, more recently, in the debate on how to deal with high public debt (Bianchi and Melosi, 2022; Bianchi et al., 2023). Estimating these models is challenging because each policy regime introduces a potential mode into the posterior distribution. As demonstrated by Herbst and Schorfheide (2014, 2015) and Cai et al. (2020), the SMC sampler outperforms the standard RWMH algorithm in the presence of multimodal posteriors, an outcome that is highly likely in a DSGE model with monetary-fiscal policy interactions. The model's different policy regimes exhibit different model dynamics and, hence, lead to discontinuous likelihood functions around the policy regimes. Compared to models with a single policy regime, this feature makes it harder for posterior samplers to transition between areas of the parameter space with similar fit. We contrast the RWMH's and SMC's performance in such a model and show that the choice of the posterior sampler determines the estimation outcome. While the SMC sampler can deal with the irregular posterior surface and can navigate through the entire parameter space, the RWMH produces posterior regime probabilities that highly depend on the sampler's starting value.

Related literature With our finding that there was not one prevailing fiscal-monetary policy mix, and thus no single explanation for the observed inflation dynamics in the pre-Volcker period, we can reconcile opposing strands in the literature.

One strand of the literature on the monetary policy stance during the Great Inflation estimates monetary policy functions but does not consider an explicit role for fiscal policy. More specifically, the studies either do not include a fiscal policy sector in the model or do not include observable variables such as public debt and deficits in the estimation. This strand of the literature therefore focuses on distinguishing between determinacy of the model resulting from active monetary policy and indeterminacy resulting from passive monetary policy. It largely agrees on the latter, with some notable exceptions. Among the studies finding evidence for passive monetary policy, Clarida et al. (2000) and Mavroeidis (2010) estimate monetary policy reaction functions. In addition, Lubik and Schorfheide (2004) obtain this result for a small New Keynesian DSGE model. Boivin and Giannoni (2006) combine evidence from vector autoregressive and general equilibrium analysis to confirm these results. More recently, Nicolò (forthcoming) re-examines the question of the policy stance during the Great Inflation using the sampling algorithm proposed by Bianchi and Nicolò (2021). This sampling algorithm allows the estimation of the multimodal posterior surfaces. His findings confirm that monetary policy was most likely passive during the Great Inflation.

In the strand of the literature that focuses solely on the role of monetary policy, a number of features have been introduced that affect the size of the indeterminacy region. First, following Ascari and Ropele (2009), several studies have shown that even an active monetary policy can be associated with indeterminacy when trend inflation is positive. These studies include Coibion and Gorodnichenko (2011), Ascari and Sbordone (2014), and more recently Hirose et al. (2020). The latter study uses an SMC algorithm to estimate the multimodal posterior surface. Interestingly, using a similar model and sampling method, Haque et al. (2021) find that there was a unique equilibrium during the Great Inflation, i.e., monetary policy stabilized the economy. Key to their finding is not only trend inflation, but also its interaction with commodity price shocks and real wage rigidities. Their estimate of a unique equilibrium connects to the second noteworthy feature that changes the indeterminacy properties of a model, the inclusion of hand-to-mouth consumers or limited asset market participation (Bilbiie and Straub, 2013). In their model, a passive monetary authority stabilizes the economy. Estimating the model, they show that this can be one explanation for a passive monetary authority. A third avenue is pursued by Ascari et al. (2019). Their analysis explains the Great Inflation with temporary unstable inflation dynamics due to expectations that were independent of monetary policy behavior. The study also finds evidence of passive monetary policy in the pre-Volcker period. However, not all studies have confirmed passive monetary policy during the Great Inflation. The exceptions are Orphanides (2004, 2002). Both papers argue that considering real-time data instead of ex-post data can overturn the consensus of passive monetary policy. More recently, Nicolò (forthcoming) estimates a DSGE model with real-time data and finds that the monetary policy stance can best be described as passive.

The strand of the literature that considers an explicit role for fiscal policy can be split into studies that consider a fixed regime approach and studies that model regime switches using a Markov-switching model approach. The former approach has been taken by Bhattarai et al. (2016) to estimate a fixed-regime DSGE model with monetary and fiscal policy interactions. They find that fiscal policy has been passive, confirming the result of indeterminacy. In an earlier study, Traum and Yang (2011) find no evidence of an active U.S. fiscal authority in the pre-Volcker period. Interestingly, their estimates support the evidence for an active monetary policy. However, they do not consider the possibility of non-unique equilibria in their analysis. Leeper et al. (2017) estimate a medium-scale DSGE model with either monetary or fiscal dominance. Their estimation results lead them to conclude that these two regimes are equally likely. On the contrary, Kliem et al. (2024) show that the inclusion of a financial sector and the introduction of financial repression leads to a regime of fiscal dominance as the most likely one. All these studies have in common that the fixed-regime DSGE model is estimated by applying a random walk Metropolis-Hastings sampling. While the evidence on the role of fiscal policy during the Great Inflation from the estimation of fixed-regime models is mixed, the evidence from the estimation of Markov-switching models favors an active fiscal policy. Davig and Leeper (2006), Davig and Leeper (2011), Bianchi (2012), Bianchi and Ilut (2017), and Chen et al. (2022) all find evidence for an active fiscal policy in 1970s.

Our paper contributes to the literature in the following way: in line with the research strand that considers an explicit role for fiscal policy, we incorporate a fiscal sector and fiscal variables into our analysis. However, unlike existing studies in this strand of the literature, we employ a technique capable of sampling from a multimodal posterior surface. Consistent with the findings of Bhattarai et al. (2016), we confirm that equilibrium indeterminacy indeed played a significant role pre-Volcker. However, echoing the conclusion of regime-switching DSGE models, regime F, at 37 % posterior probability, mattered as well. Consequently, through re-estimating the fixed-regime model proposed by Bhattarai et al. (2016) using the more appropriate SMC posterior sampler, we reconcile the previously existing dissonance between these two model classes.

The remainder of this paper is as follows. Section 2 describes the DSGE model with monetary-fiscal policy interactions and in Section 3, we outline our empirical approach. In Section 4 we present the estimation results. In light of our findings, we re-examine in Section 5 what caused the build-up of U.S. inflation in the 1960s and 1970s and link the findings on the pre-Volcker monetary-fiscal policy mix to the post-pandemic high inflation period. The final section concludes the study.

2 A DSGE model with monetary-fiscal policy interactions

In this section, we outline the fixed-regime DSGE model with monetary-fiscal policy interactions of Bhattarai et al. (2016), our reference model, characterize its distinct monetary-fiscal policy regimes, and present the solution method for the model.

2.1 Model description

We use the fixed-regime DSGE model set up in Bhattarai et al. (2016). It features a complete description of fiscal policy, a time-varying inflation and debt-to-output target, partial dynamic price indexation, and external habit formation in consumption. Here, we only present the first-order approximations of the model equations that determine equilibrium dynamics. For a detailed analysis of the model's characteristics, we refer the reader to the original study.

Consumption behavior of households is given by the consumption Euler equation:

$$\begin{aligned}\hat{C}_t = \frac{\bar{a}}{\bar{a}+\eta}E_t\hat{C}_{t+1} + \frac{\eta}{\bar{a}+\eta}\hat{C}_{t-1} - \left(\frac{\bar{a}-\eta}{\bar{a}+\eta}\right)\left(\hat{R}_t - E_t\hat{\pi}_{t+1}\right) + \frac{\bar{a}}{\bar{a}+\eta}E_t\hat{a}_{t+1} - \\ -\frac{\eta}{\bar{a}+\eta}\hat{a}_t + \left(\frac{\bar{a}-\eta}{\bar{a}+\eta}\right)\hat{d}_t,\end{aligned} \tag{1}$$

where $\hat{C}_t$ is aggregate consumption, $\hat{R}_t$ is the interest rate on government bonds, $\hat{a}_t$ is the growth rate of technology, $\hat{\pi}_t$ is the inflation rate, and $\hat{d}_t$ stands for preferences.[2] The param-

[2] We define the log-linear deviation of a detrended variable from its corresponding steady state as $\hat{X}_t = lnX_t - ln\bar{X}$. Only the fiscal variables $\hat{b}_t = b_t - \bar{b}$, $\hat{g}_t = g_t - \bar{g}$, $\hat{\tau}_t = \tau_t - \bar{\tau}$, and $\hat{s}_t = s_t - \bar{s}$ are normalized by output and linearized around their steady states.

eters $\bar{a}$ and η denote the steady-state value of a_t and external habit formation, respectively.

The New Keynesian Phillips curve is denoted by

$$\begin{aligned}\hat{\pi}_t = \frac{\beta}{1+\gamma\beta}E_t\hat{\pi}_{t+1} + \frac{\gamma}{1+\gamma\beta}\hat{\pi}_{t-1} + \kappa\Bigg[\left(\varphi + \frac{\bar{a}}{\bar{a}-\eta}\right)\hat{Y}_t - \frac{\eta}{\bar{a}-\eta}\hat{Y}_{t-1} + \frac{\eta}{\bar{a}-\eta}\hat{a}_t - \\ - \left(\frac{\bar{a}}{\bar{a}-\eta}\right)\left(\frac{1}{1-\bar{g}}\right)\hat{g}_t + \left(\frac{\eta}{\bar{a}-\eta}\right)\left(\frac{1}{1-\bar{g}}\right)\hat{g}_{t-1}\Bigg] + \hat{u}_t,\end{aligned} \tag{2}$$

where $\hat{Y}_t$ is aggregate output, $\hat{g}_t$ represents the government spending-to-output ratio, and $\hat{u}_t$ can be interpreted as cost-push shock. The parameters β, γ, φ, and $\bar{g}$ are, respectively, the discount factor, the degree of price indexation, the inverse of the Frisch elasticity of labor supply, and the steady-state value of government spending. Furthermore, $\kappa := \frac{(1-\alpha\beta)(1-\alpha)}{\alpha\left(1+\varphi\bar{\theta}\right)(1+\gamma\beta)}$. α stands for the degree of price rigidity in the economy and $\bar{\theta}$ for the steady-state value of the elasticity of substitution between intermediate goods.

Monetary policy is characterized by the following rule:

$$\hat{R}_t = \rho_R\hat{R}_{t-1} + (1-\rho_R)\left[\phi_\pi(\hat{\pi}_t - \hat{\pi}_t^*) + \phi_Y(\hat{Y}_t - \hat{Y}_t^*)\right] + \epsilon_{R,t}. \tag{3}$$

$\hat{\pi}_t^*$ is the inflation target and $\hat{Y}_t^*$ is potential output. The idiosyncratic monetary policy shock $\epsilon_{R,t}$ is assumed to evolve as i.i.d. $N(0, \sigma_R^2)$. The parameters ρ_R, ϕ_π, and ϕ_Y represent, respectively, interest rate smoothing, responses to deviations of inflation from its target, and responses to deviations of output from its natural level.

The fiscal authority sets lump-sum taxation by a rule:

$$\hat{\tau}_t = \rho_\tau\hat{\tau}_{t-1} + (1-\rho_\tau)\left[\psi_b(\hat{b}_{t-1} - \hat{b}_{t-1}^*) + \psi_Y(\hat{Y}_t - \hat{Y}_t^*)\right] + \epsilon_{\tau,t}. \tag{4}$$

$\hat{\tau}_t$ stands for the tax-revenue-to-output ratio, $\hat{b}_t$ is the debt-to-output ratio, and $\hat{b}_t^*$ is the debt-to-output ratio target. The non-systematic tax policy shock $\epsilon_{\tau,t}$ is assumed to evolve as i.i.d. $N(0, \sigma_\tau^2)$. The tax policy rule features tax smoothing (ρ_τ), systematic reactions of tax revenues to deviations of lagged debt from its target (ψ_b), and to deviations of output from natural output (ψ_Y).

The government spending rule is modeled as

$$\hat{g}_t = \rho_g \hat{g}_{t-1} - (1 - \rho_g)\chi_Y \left(\hat{Y}_{t-1} - \hat{Y}^*_{t-1}\right) + \epsilon_{g,t}. \tag{5}$$

$\hat{g}_t$ stands for the government spending-to-output ratio. The exogenous shock to government spending $\epsilon_{g,t}$ is assumed to follow an i.i.d.-process with $N(0, \sigma_g^2)$. ρ_g represents smoothing in government purchases and χ_Y is the response of government spending to the lagged output gap. Under the assumption of flexible prices, the natural level of government spending is:

$$\hat{g}^*_t = \rho_g \hat{g}^*_{t-1} + \epsilon_{g,t}. \tag{6}$$

The government budget constraint is given by:

$$\hat{b}_t = \frac{1}{\beta}\hat{b}_{t-1} + \frac{\bar{b}}{\beta}\left(\hat{R}_{t-1} - \hat{\pi}_t - \hat{Y}_t + \hat{Y}_{t-1} - \hat{a}_t\right) + \hat{g}_t - \hat{\tau}_t + \hat{s}_t. \tag{7}$$

$\hat{s}_t$ is the ratio of government transfers to output and the parameter $\bar{b}$ is the steady-state value of the debt-to-output ratio.

The aggregate resource constraint is given by:

$$\hat{Y}_t = \hat{C}_t + \frac{1}{1 - \bar{g}}\hat{g}_t. \tag{8}$$

The natural level of output is:

$$\hat{Y}^*_t = \frac{\eta}{\varphi\left(\bar{a} - \eta\right) + \bar{a}}\hat{Y}^*_{t-1} + \frac{\bar{a}}{\left[\varphi\left(\bar{a} - \eta\right) + \bar{a}\right]\left(1 - \bar{g}\right)}\hat{g}^*_t - \frac{\eta}{\left[\varphi\left(\bar{a} - \eta\right) + \bar{a}\right]\left(1 - \bar{g}\right)}\hat{g}^*_{t-1} - \frac{\eta}{\varphi\left(\bar{a} - \eta\right) + \bar{a}}\hat{a}_t. \tag{9}$$

Finally, six additional exogenous shocks drive economic fluctuations. These are all assumed to evolve according to univariate AR(1) processes.

Preferences evolve as

$$\hat{d}_t = \rho_d \hat{d}_{t-1} + \epsilon_{d,t} \qquad \text{with } \epsilon_{d,t} \sim i.i.d.\ N(0, \sigma_d^2). \tag{10}$$

Technology evolves as

$$\hat{a}_t = \rho_a \hat{a}_{t-1} + \epsilon_{a,t} \qquad \text{with } \epsilon_{a,t} \sim i.i.d.\ N(0, \sigma_a^2). \tag{11}$$

Markup shocks are assumed to follow

$$\hat{u}_t = \rho_u \hat{u}_{t-1} + \epsilon_{u,t} \qquad \text{with } \epsilon_{u,t} \sim i.i.d.\ N(0, \sigma_u^2). \tag{12}$$

Government transfers are given by

$$\hat{s}_t = \rho_s \hat{s}_{t-1} + \epsilon_{s,t} \qquad \text{with } \epsilon_{s,t} \sim i.i.d.\ N(0, \sigma_s^2). \tag{13}$$

The inflation target evolves as

$$\hat{\pi}_t^* = \rho_\pi \hat{\pi}_{t-1}^* + \epsilon_{\pi,t} \qquad \text{with } \epsilon_{\pi,t} \sim i.i.d.\ N(0, \sigma_\pi^2). \tag{14}$$

The debt-to-output ratio target follows

$$\hat{b}_t^* = \rho_b \hat{b}_{t-1}^* + \epsilon_{b,t} \qquad \text{with } \epsilon_{b,t} \sim i.i.d.\ N(0, \sigma_b^2). \tag{15}$$

2.2 Model solution under different policy regimes

A unique equilibrium of the economy arises if either monetary policy is active while fiscal policy is passive (regime M or AMPF) or monetary policy is passive while fiscal policy is active (regime F or PMAF). If both monetary and fiscal policy are passive, multiple equilibria exist (PMPF). No stationary equilibrium exists if both authorities act actively (AMAF). The boundaries of the distinct policy regimes can be characterized analytically in Bhattarai et al. (2016)'s model. In particular, monetary policy is active if

$$\phi_\pi > 1 - \phi_Y \left(\frac{1 - \tilde{\beta}}{\tilde{\kappa}} \right), \tag{16}$$

where $\tilde{\beta} = \frac{\gamma+\beta}{1+\gamma\beta}$ and $\tilde{\kappa} = \frac{(1-\alpha\beta)(1-\alpha)}{\alpha(1+\varphi\theta)(1+\gamma\beta)} \left(1 + \varphi + \frac{\chi_Y}{1-\bar{g}}\right)$, while fiscal policy is active if

$$\psi_b < \frac{1}{\beta} - 1. \tag{17}$$

We collect the parameters of the loglinearized model in the vector ϑ with domain Θ and solve the system of equations for its state-space representation.[3] Under determinacy (regime F, regime M), we employ the solution algorithm for linear rational expectations models of Sims (2002), which expresses the model solution as

$$z_t = \Gamma_1^*(\vartheta) z_{t-1} + \Psi^*(\vartheta)\epsilon_t, \tag{18}$$

where z_t is a vector of state variables, ϵ_t is a vector of exogenous variables, while both Γ_1^* and Ψ^* are coefficient matrices that depend on the model parameters collected in the vector ϑ. Under indeterminacy, we apply the generalization of this procedure suggested by Lubik and Schorfheide (2003, 2004):

$$z_t = \Gamma_1^*(\vartheta) z_{t-1} + \left[\Gamma_{0,\epsilon}^*(\vartheta) + \Gamma_{0,\zeta}^*(\vartheta)\tilde{M} \right] \epsilon_t + \Gamma_{0,\zeta}^*(\vartheta) M_\zeta \zeta_t. \tag{19}$$

Under indeterminacy, the transmission of fundamental shocks ϵ_t is no longer uniquely determined as it depends not only on the coefficient matrix $\Gamma_{0,\epsilon}^*$, but also on the matrices $\tilde{M}$

[3]More details on the implementation of the model solution are given in Appendix A.1.

and $\Gamma^*_{0,\zeta}$.[4] Second, an exogenous sunspot shock ζ_t, unrelated to the fundamental shocks ϵ_t, potentially affects the dynamics of the model variables z_t. This effect depends on the coefficient matrices $\Gamma^*_{0,\zeta}$ and M_ζ.

3 Empirical Strategy

In this section, we present the Bayesian empirical strategy. We describe the prior distributions and the dataset, and motivate the procedures for posterior sampling we choose to determine the monetary-fiscal policy mix in the pre-Volcker period.

Prior distributions and calibrated parameters

In line with Bhattarai et al. (2016), we fix a few model parameters. We calibrate the inverse of the Frisch elasticity of labor supply to $\varphi = 1$ and the steady-state value of the elasticity of substitution between goods to $\bar{\theta} = 8$, since these cannot be separately identified from the Calvo parameter α. We also fix the parameters measuring the persistence of the time-varying policy targets to $\rho_\pi = \rho_b = 0.995$. Our prior distributions extend over a broad range of parameter values.[5] As we initialize the SMC algorithm from the prior, we used prior predictive analysis to carefully tailor a prior that results in realistic model implications, but nevertheless remains agnostic about the prevailing policy regime.[6] In the following, we discuss only the key parameters of our analysis.

Specifically, the policy parameters in the monetary and fiscal policy rule, ϕ_π and ψ_b, play a central role in our analysis as they determine the policy regime. Table 1 summarizes the

[4] In accordance with Lubik and Schorfheide (2004), we replace $\tilde{M}$ with $\tilde{M} = M^*(\vartheta) + M$ to prevent that the transmission of fundamental shocks changes drastically when the boundary between the determinacy regimes and the indeterminacy regime is crossed. We choose $M^*(\vartheta)$ such that the impulse responses $\partial z_t / \partial \epsilon_t'(\vartheta, M)$ become continuous on the boundary and estimate the vector M. Appendix A.2 describes the approach in more detail.

[5] Table 4 in Appendix B.1 specifies the prior distributions of all model parameters.

[6] In Appendix B.2 we show results from the prior predictive analysis. Specifically, we take 20,000 draws from the prior, simulate the model's observables and plot these simulated time series against the actual data from 1960:Q1 to 1979:Q2 that we use for estimating the model.

Table 1: Prior distributions of monetary and fiscal policy parameters

Parameter	Range	Distribution	Mean	SD	90 percent int.
ϕ_π, active / passive monetary policy	$\mathbb{R}^+$	N	0.8	0.6	$[0.14, 1.84]$
ψ_b, active / passive fiscal policy	$\mathbb{R}$	N	0	0.1	$[-0.16, 0.16]$

details. For ϕ_π, we choose a Normal distribution restricted to the positive domain with an implied 90 % probability interval from 0.14 to 1.84, while the interval extends from -0.16 to 0.16 for ψ_b. Our choice is motivated by the consideration to construct prior distributions that yield more or less equal probabilities for regime F and the PMPF regime. In particular, as we initialize the SMC algorithm from the prior, we do not want to impose artificially a certain policy regime before confronting the model with the data. The implied prior probabilities of the policy regimes presented in Table 2 support our choice. Regime F and the PMPF regime receive almost identical support.[7]

Table 2: Prior probability of pre-Volcker policy regimes

	AMPF	PMAF	PMPF
Probability	25.64	37.88	36.48

Note: The prior probabilities of the policy regimes are obtained from a prior predictive analysis. We drew ϑ 20,000 times from the priors specified in Table 4, solved the model with each draw, and computed the shares of each policy regime.

A second group of parameters we want to highlight are those necessary to characterize the indeterminacy model solution. For the parameters in the vector M, representing agents' self-fulfilling beliefs, we choose, as Bhattarai et al. (2016), priors centered around zero in

[7] The estimation results are sensitive to the choice of the prior distribution. For example, a prior that favors regime F will also increase the regime's share in the posterior distribution. Therefore, it is important that the two main candidate regimes have equal prior weights.

order to let the data decide if and how indeterminacy changes the propagation mechanism of the fundamental shocks.

Data

We use the dataset of Bhattarai et al. (2016).[8] We fit the loglinearized DSGE model to six quarterly U.S. time series and estimate the model for the pre-Volcker sample 1960:Q1 to 1979:Q2. The list of observables includes real per capita output, annualized inflation, annualized nominal interest rates, the real tax-revenue-to-output ratio, the real market value of the government debt-to-output ratio, and the real government spending-to-output ratio.

RWMH vs. SMC posterior sampling

Posterior inference in DSGE models relies on sampling techniques as the moments of the posterior cannot be characterized in closed forms. Compared to Bhattarai et al. (2016), our reference study, we do not estimate each regime separately with a RWMH, but choose the SMC algorithm introduced to the DSGE literature by Creal (2007), then further enhanced and theoretically justified by Herbst and Schorfheide (2014, 2015).[9] As shown by Herbst and Schorfheide (2014, 2015), and Cai et al. (2020), the SMC algorithm outperforms the workhorse RWMH sampler in cases of multimodal posteriors, an outcome that is highly likely in the case of the DSGE model with monetary-fiscal policy interactions with a discontinuous likelihood function.[10] Due to this feature, neither are we obliged to estimate the model separately, nor must we compare model fit across regimes. Rather, we let the SMC algorithm explore the entire parameter space such that the probability of each policy regime is directly

[8] The dataset is downloadable from the supplemental material of their study `https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/OHUWKM`. More details on the data and the corresponding measurement equations are given in Appendix C.

[9] Chopin (2002), Del Moral et al. (2006), and Creal (2012), among others, provide further details on SMC algorithms. Cai et al. (2020) advance the tuning of the algorithm in the context of DSGE model estimation.

[10] In short, the RWMH is an iterative simulator that belongs to the class of Markov chain Monte Carlo (MCMC) techniques. Herbst and Schorfheide (2015, pp. 52-99), for instance, explain the sampler in detail.

determined by the data.[11]

To evaluate the RWMH's and SMC's performance explicitly in a model with monetary-fiscal policy interactions, for comparison, we estimate the model over its unrestricted parameter space using RWMH and contrast the two samplers' findings. We choose a set-up that *a priori* puts the RWMH algorithm on equal grounds. In particular, we initialize (i) two chains à ten million draws at the mode of regime F and the indeterminacy regime, respectively, and pool these draws with (ii) four chains à ten million draws departing from a random value in the parameter space region of regime F and indeterminacy. Using the double number of draws from the randomly chosen starting values compared to the mode initialization, attributes the sampler a higher chance to explore the entire parameter space without getting stuck at a local mode and, hence, works in favor of the RWMH sampler. From this procedure, we obtain a total of 120 million posterior draws - an number much greater than usually computed for estimating medium-sized DSGE models.[12]

4 The monetary-fiscal policy mix in the pre-Volcker period

In this section, we determine the monetary-fiscal policy mix in the pre-Volcker period separately with the RWMH and the SMC and compare the performance of the two samplers. In the final discussion, we argue that the SMC, our preferred approach, is able to reconcile the empirical findings of the fixed-regime and regime-switching DSGE model literature, while also providing some intuition why restricting or not restricting the parameter space during estimation matters.

[11]The SMC algorithm generates weighted draws from a sequence of easy-to-sample proposal densities. The weighted draws are called particles. Appendix D includes a more detailed description of the SMC algorithm and our choice of tuning parameters.

[12]From each chain we discard seven million draws as burn-in and use from the remainder each eighth draw to compute posterior results. In comparison, in Bhattarai et al. (2016), our reference study, a total of 21.6 million draws over all regimes is computed.

Posterior estimates

Figure 1 presents the posterior densities of the policy parameters ϕ_π and ψ_b from the unrestricted estimation with RWMH.[13] The values of ϕ_π and ψ_b determine the monetary-fiscal policy mix. $\phi_\pi < 1 - \phi_Y \left(\frac{1-\tilde{\beta}}{\tilde{\kappa}}\right)$ corresponds to a passive monetary authority, while $\phi_\pi > 1 - \phi_Y \left(\frac{1-\tilde{\beta}}{\tilde{\kappa}}\right)$ corresponds to an active central bank. The boundary of fiscal policy lies around zero. $\psi_b < \frac{1}{\beta} - 1$ refers to an active fiscal policy, while $\psi_b > \frac{1}{\beta} - 1$ is associated with a passive fiscal authority.

To evaluate the RWMH's performance, it is instructive to distinguish the posterior draws according to the initialization method described in Section 3. The blue solid and the blue dashed lines show the posterior draws obtained from initializing the RWMH at the mode of regime F and indeterminacy, respectively. The red solid line depicts the marginal posterior densities obtained from the runs started at random points in the parameter space of regime F and PMPF. The plot makes three points obvious. First, considering all draws jointly, the marginal posterior distribution of the policy parameters exhibit pronounced bimodalities. However, each initialization method taken individually generates a unimodal marginal posterior density that corresponds to a distinct policy regime. Second, starting the sampler at the mode of regime F results in posterior estimates corresponding to regime F, while starting the sampler at the mode of the indeterminacy regime produces draws exclusively from the indeterminacy region of the parameter space. Hence, initializing the RWMH at the mode of the policy regimes leads to posterior estimates that highly depend on the starting value as the sampler does not transition between regimes. Last, all runs started at random values, no matter if in regime F or PMPF, let the sampler draw uniquely from the indeterminacy region. This characteristic could lead to the conclusion that the indeterminacy region is the prevailing regime.

[13] For the RWMH, we monitored convergence by computing recursive means. Appendix E.2 provides the corresponding plots.

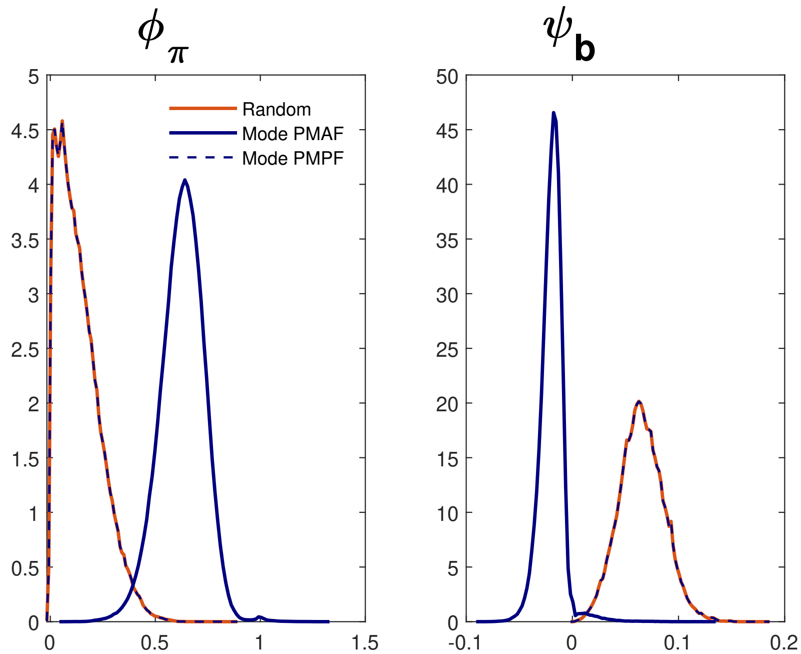


Figure 1: Posterior densities of the policy parameters obtained from RWMH sampling. The blue solid line depicts the posterior density obtained from initializing the sampler on the mode of regime F, the blue dashed line from initializing the sampler on the mode of regime PMPF, and the red solid line shows the posterior density obtained from the random initialization.

In Figure 2, we compare the marginal posterior densities of ϕ_π and ψ_b across the SMC and the RWMH samplers. The red dashed line corresponds to the posterior density obtained from SMC sampling,[14] while the blue solid line is the posterior density obtained from the pooled runs of the RWMH sampler. The black line shows the marginal prior distribution. Similar to the RWMH, the posterior densities of ϕ_π and ψ_b from SMC sampling display pronounced bimodalities around the policy regimes. However, while the RWMH generates draws mainly in the immediate vicinity of the policy regimes' modes, the SMC sampler transitions more frequently between regimes and assigns more probability mass to parameter values between the two modes of ϕ_π and ψ_b.[15] It is also noticeable that the probability mass below each

[14] To ensure convergence of the SMC, we follow the practical recommendations given in Herbst and Schorfheide (2014) and produced 50 independent runs with the SMC sampler. We pooled the draws over the 50 runs to compute parameter means, standard errors, and credible sets.

[15] Appendix E.1 shows posterior estimates from an estimation in which we restrict the parameter space and apply SMC sampling to estimate each policy regime sequentially. The purpose of this exercise is to show (i) that the SMC sampler is able to replicate the RWMH estimation results of Bhattarai et al. (2016), our reference study, that the PMPF regime was the dominant regime pre-Volcker, and (ii) that our prior specification does not affect the probability of policy regimes in the posterior. Appendix E.2 contains the

mode is unequally distributed across the samplers.

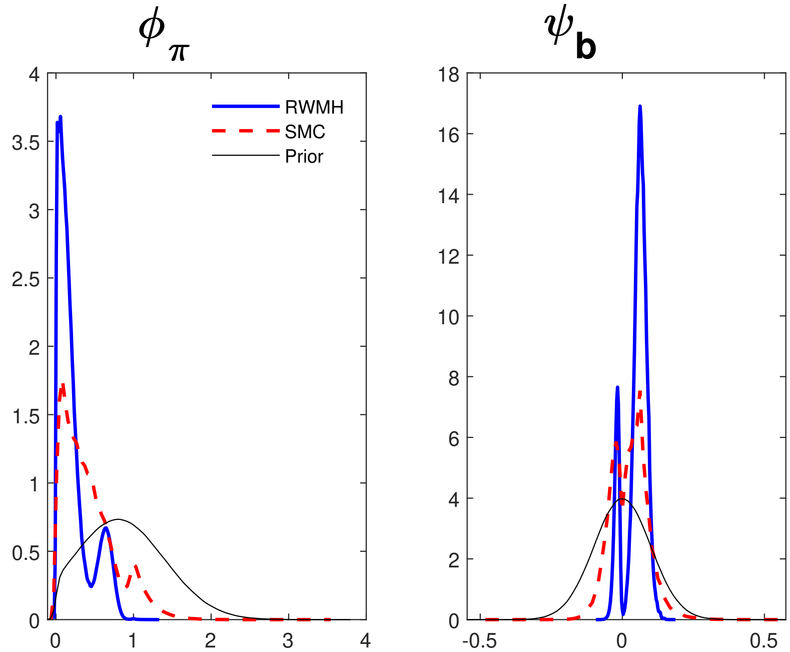


Figure 2: Posterior densities of the policy parameters obtained from SMC and RWMH sampling and prior densities. The blue solid line depicts the RWMH posterior density, the red dashed line the SMC posterior density, and the black line the prior density.

To shed more light on the estimated monetary-fiscal policy mix, we present the posterior probabilities of the policy regimes in the pre-Volcker period (Table 3). The two samplers agree that the dominant monetary-fiscal regime in the pre-Volcker period was the indeterminacy regime. However, while the RWMH attributes PMPF a posterior probability of 83.33 %, the SMC assigns the indeterminacy regime at 43.54 %, considerablye less. In contrast, regime F, receives in the SMC estimation, at 36.81 %, more than twice as much posterior probability as than in the RWMH estimation (16.32 %). In line with the literature, regime M obtaines for both samplers the least support from the data.[16]

The contrasting regime probabilities for the monetary-led regime highlight once again

density plots of the remaining parameters from the unrestricted estimation as well as tables with estimated means, standard deviations, and credible bands for all parameters.

[16]The finding that monetary policy in the pre-Volcker period was mainly passive, is also widely established in the literature. Therefore, in the following, we focus our discussion in the main text entirely on the still open role of fiscal policy and look exclusively on regime F and the PMPF regime. In Appendix E.4 we show a historical decomposition for pre-Volcker inflation conditional on regime M.

the superior performance of the SMC algorithm compared to the RWMH in DSGE models with distinct fiscal-monetary policy regimes. While the SMC assigns a posterior probability of approximately 20 % to regime M, the RWMH assigns regime M a posterior probability of zero. This discrepancy can be attributed to the tendency of the RWMH to remain fixed at the mode for passive monetary policy, thereby failing to transition frequently enough to regions of the parameter space corresponding to active monetary policy. The empirical finding resulting from the SMC estimation, indicating a positive regime probability for regime M in the pre-Volcker period, aligns with existing literature. Bianchi (2013) estimates a high probability of active monetary policy from 1955 to 1974. While Bianchi (2013) does not consider an explicit role for fiscal policy, Bianchi (2012) considers the interaction between the policies and estimates a sizeable probability (approximately 10 %) of active monetary and passive fiscal policy from 1955 to 1965 and a small probability for this regime in the 70s.

Table 3: Posterior probability of pre-Volcker policy regimes

	AMPF	PMAF	PMPF
SMC	19.65	36.81	43.54
RWMH	0.35	16.32	83.33

Note: To obtain the posterior probabilities from SMC, we solved the model with each of the 20,000 particles obtained from the last SMC stage and computed the shares of each policy regime over 50 independent runs of the algorithm. For the RWMH, the posterior regime probabilities are computed over 4.5 million draws.

Discussion

The comparison of posterior estimates between the RWMH and the SMC reveals that the choice of sampler significantly impacts the estimation results in DSGE models characterized by interactions between monetary and fiscal policies, especially during periods marked by the coexistence of distinct regimes.[17] While the RWMH produces estimates that depend on the starting value and fails to transition between the policy regimes' distinct posterior modes, the SMC can deal with irregular-shaped posterior surfaces and explores the entire parameter space. Although the two sampler coincide in finding indeterminacy to be the dominant regime in the pre-Volcker period, the general conclusion drawn from the sampler comparison is that the RWMH overstates the posterior probability of the dominant regime and underrepresents the other regimes. For that reason, the SMC is our preferred sampler to estimate DSGE models with monetary-fiscal policy interactions, like the model of Bhattarai et al. (2016).

Compared to the restricted estimation in Bhattarai et al. (2016), using SMC to estimate the model over its unrestricted parameter space allows us to draw a more differentiated conclusion on the fiscal-monetary policy mix during the Great Inflation. In line with Bhattarai et al. (2016), we find that the regime with the highest posterior probability in the pre-Volcker period is the PMPF regime. However, in contrast to their analysis, we find that regime F scores only slightly worse. Based on our findings, we argue that regime F also matters for the macroeconomic dynamics in the pre-Volcker period. First, in our analysis, regime F receives, at 36.81 %, considerable probability that is only seven percentage points less than, on average, the dominant PMPF regime. Due to this significant empirical support, regime F should not simply be neglected. Second, our results complement a range of studies that already convincingly discuss quantitative or narrative evidence for a leading fiscal authority during particular periods in the pre-Volcker era. Sims (2011), for instance, refers to the emerging primary deficits in the U.S. related to President Ford's tax cuts and rebates in 1975. Bianchi and Ilut (2017), in a regime-switching DSGE model, even provide empirical

[17] To strengthen our argument regarding the divergent performance of the two samplers in periods characterized by distinct regimes, we conducted estimations using data from the post-Volcker period spanning from 1982:Q4 to 2008:Q2, widely acknowledged in the literature as being governed by a monetary-led regime. We initialized the SMC sampler from (i) the prior outlined in Section 3, and (ii) a prior that yields equal shares of regime F, regime M and indeterminacy. For each of these two cases, we derived posterior probabilities from the SMC by solving the model with the 20,000 particles of the posterior, and then calculated the proportion of each policy regime across ten independent runs of the algorithm. This exercise yielded in both cases a 100 % probability for regime M.

evidence for fiscal dominance in the U.S. during the 1960s and 1970s, outlining the fiscal expansion due to the Vietnam War and Lyndon B. Johnson's Great Society reforms.[18] Our findings support their view that an active U.S. fiscal policy played a substantial role in the build-up of pre-Volcker inflation.

The merit of our chosen SMC approach is that it can create new perspectives in a fixed-regime model environment. Since we can estimate the model over its entire parameter space, we remain agnostic and strictly let the data determine each policy regime's probability. In contrast, in our application, using RWMH sampling to estimate the model in one step overrepresents the posterior probability of the dominant PMPF regime as the sampler takes draws mainly around the associated mode and does not transition frequently enough to other regions of the parameter space with less likelihood. Comparably, restricting the parameter space and estimating the model sequentially for each regime with RWMH would force us to take a zero-one decision. As the model comparison results from the restricted estimation in Table 5 in Appendix E.1 show, we would conclude that, like Bhattarai et al. (2016), only the PMPF regime was in place pre-Volcker. The other policy regimes would not be considered. Instead, our analysis allows us to draw a more nuanced conclusion: although the PMPF regime receives slightly more posterior probability throughout the 1960:Q1 to 1979:Q2 sample, regime F also mattered.

5 Lessons from revisiting the Great Inflation

The estimation in the previous section shows that the macroeconomic dynamics in the pre-Volcker period are similarly driven by a passive monetary/passive fiscal policy regime and fiscal dominance. In light of these results, we revisit one of the most pressing macroeconomic questions of this episode, namely, what caused the Great Inflation. In a second step, we link the findings on the pre-Volcker monetary-fiscal policy mix to the post-pandemic period to

[18]Further references that provide evidence for fiscal dominance in the U.S. in the pre-Volcker period include, among others, Davig and Leeper (2006), Bianchi (2012), and Chen et al. (2022). All these studies employ regime-switching model frameworks.

gain insights on causes and policy options in the recent inflation build-up.

Revisiting the causes of the Great Inflation

We use our findings to carry out a historical shock decomposition of pre-Volcker inflation and conduct a counterfactual analysis to quantify the importance of fiscal policy actions in the inflation build-up. We partition the draws from the posterior according to the corresponding policy regimes determined by the SMC and conduct the historical decomposition for the PMPF regime and regime F separately.[19] Figure 3 shows the results for the PMPF regime. In line with the findings in Bhattarai et al. (2016), we find that, in the PMPF regime, pre-Volcker inflation was mainly driven by non-policy shocks, in particular, preference, markup, and technology shocks. Importantly, sunspot shocks played only a minor role in the pre-Volcker inflation build-up.[20]

[19]Specifically, we focus on the 20,000 particles generated in the final stage of the SMC algorithm, representing the posterior distribution. With each of these draws, we solve the model and ascertain its region by calculating the respective regime boundaries outlined in Equations 16 and 17. Using this classification, we segment the posterior draws. This process is iterated across each of the 50 algorithm runs, resulting in partitioned draws from regime F and indeterminacy from 50 distinct posteriors. Appendix E.4 contains the historical decomposition conditional on regime M.

[20]The fact that sunspot shocks did not play a substantial role in the pre-Volcker inflation build-up is, for instance, also confirmed in Nicolò (forthcoming).

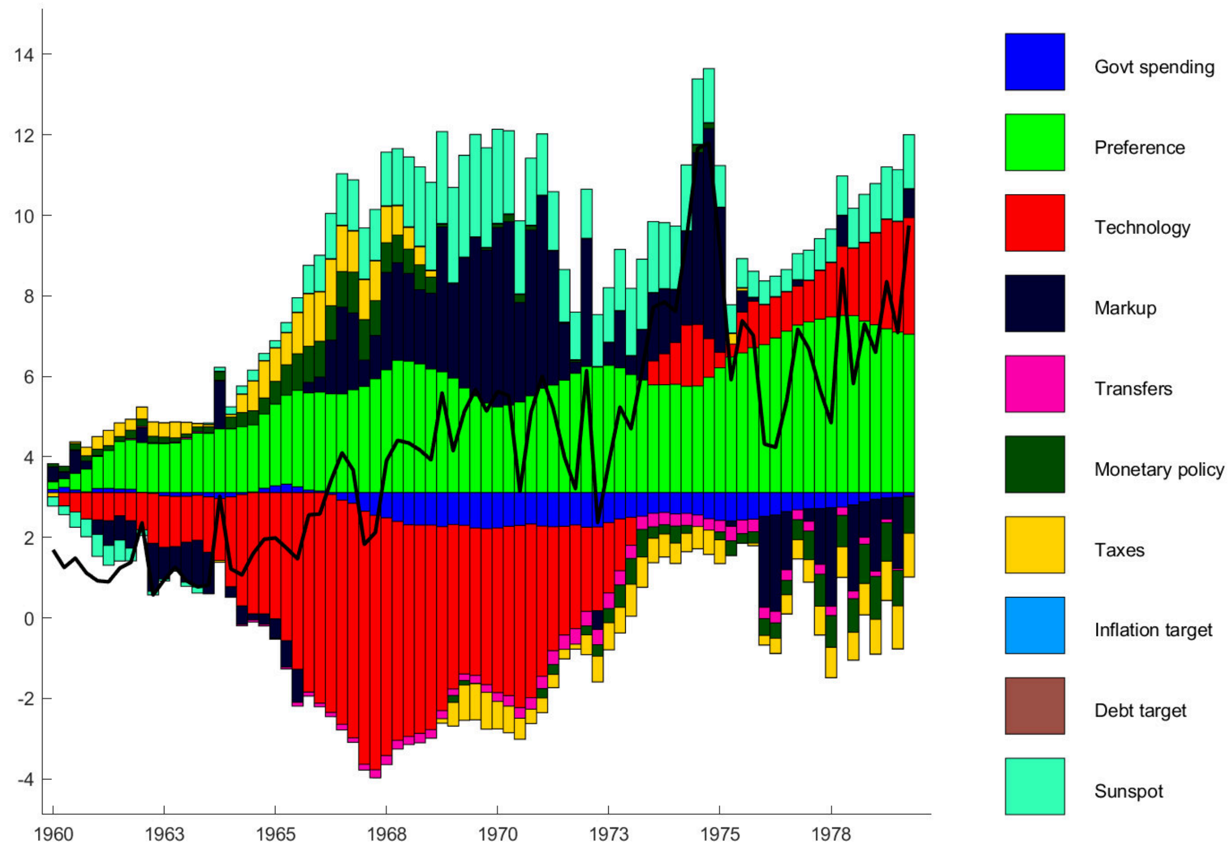


Figure 3: Contribution of each shock to annualized inflation (percentage points) in the PMPF regime. The bold black line shows observed inflation. The historical decomposition is conducted at the posterior mean of the PMPF regime.

In regime F, the picture looks different. Figure 4 summarizes the findings. Technology and demand shocks played only a minor role in regime F. Instead, the mechanism of the fiscal theory of the price level (FTPL) is clearly present: fiscal actions, government spending in particular, lead to the build-up of inflation.

Summarizing our analysis, we find empirical evidence for the two most widely acknowledged explanations for the rising U.S. inflation in the pre-Volcker period in the literature. First, fundamental non-policy shocks generated persistent inflationary pressure. Sunspot disturbances played no substantial role. Second, fiscal actions, in particular government spending, were an important driver of inflation.

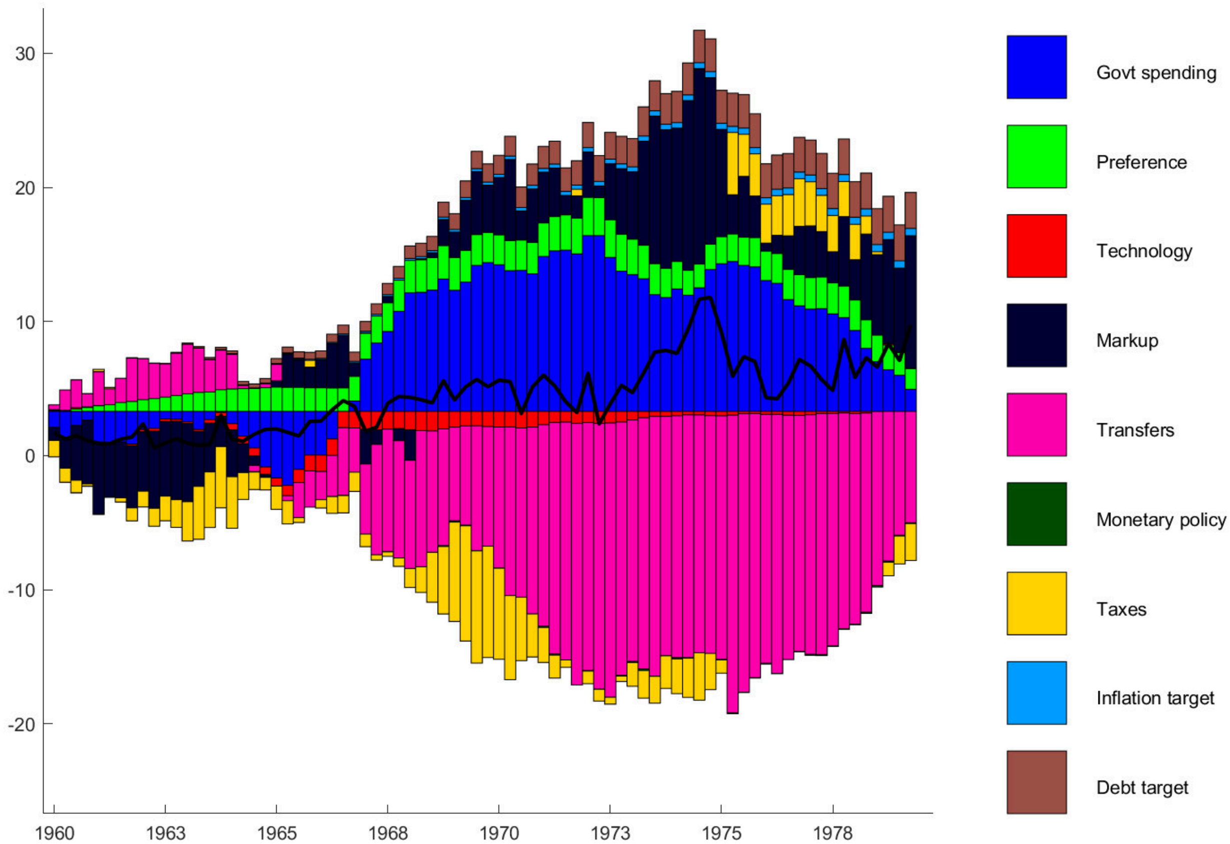


Figure 4: Contribution of each shock to annualized inflation (percentage points) in regime F. The bold black line shows observed inflation. The historical decomposition is conducted at the posterior mean of regime F.

To further elaborate the role of government spending for pre-Volcker inflation, we carry out a counterfactual analysis. We set the contribution of government spending shocks in each regime to zero and simulate inflation with the remaining shocks. Figure 5 shows the result. In regime F, counterfactual inflation lies considerably below the observed time series. In the PMPF regime, on the other hand, the difference between actual and counterfactual inflation is almost negligible.

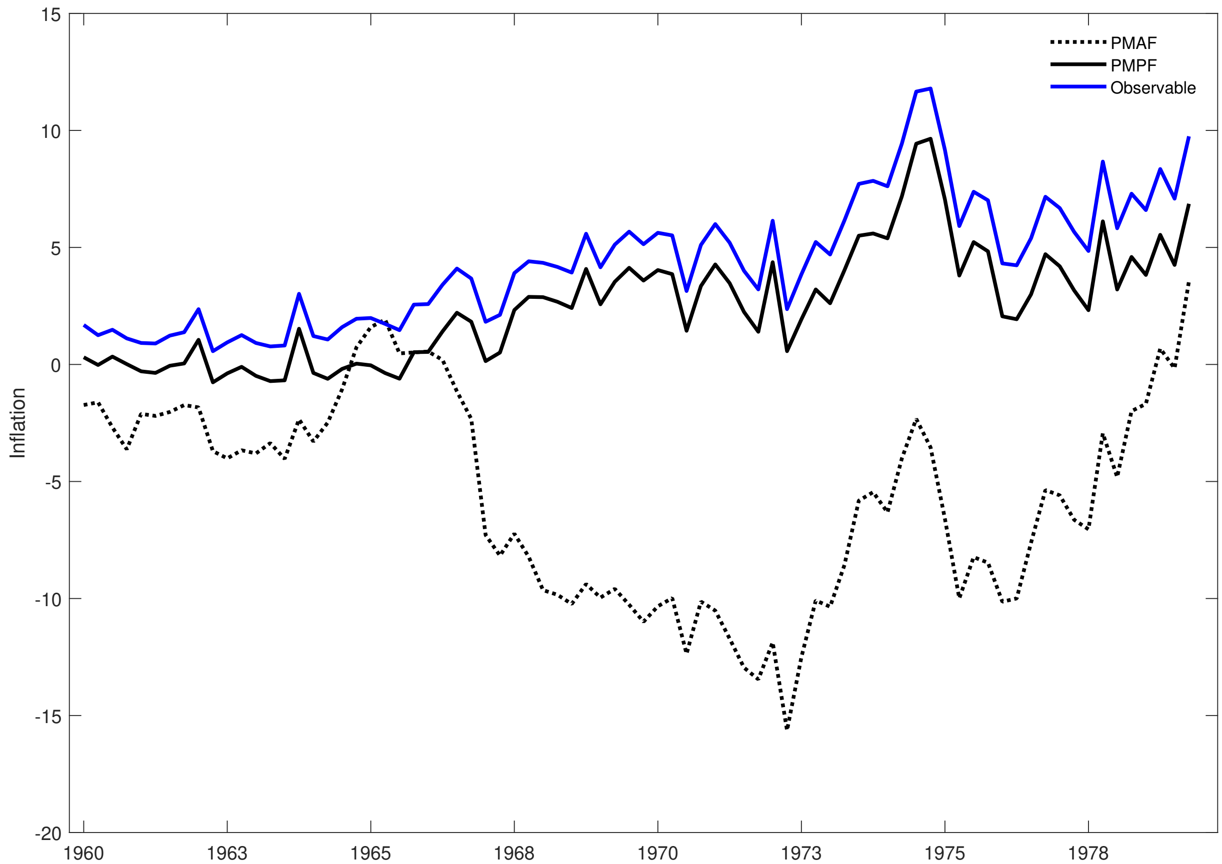


Figure 5: Evolution of annualized inflation (in percentage points) without government spending shock in the PMPF regime and regime F. The counterfactual analysis is conducted at the posterior mean of each policy regime.

We can exclude that the trend of pre-Volcker inflation in regime F and the PMPF regime is due to the sheer size of the government spending shocks. Figure 6 shows that, pre-Volcker, the smoothed government spending shocks of regime F and the PMPF regime are nearly congruent.[21] Hence, the differing evolution of inflation is induced by the regimes themselves.

[21] Appendix F shows plots of the remaining smoothed shocks for regime F and the PMPF regime, respectively.

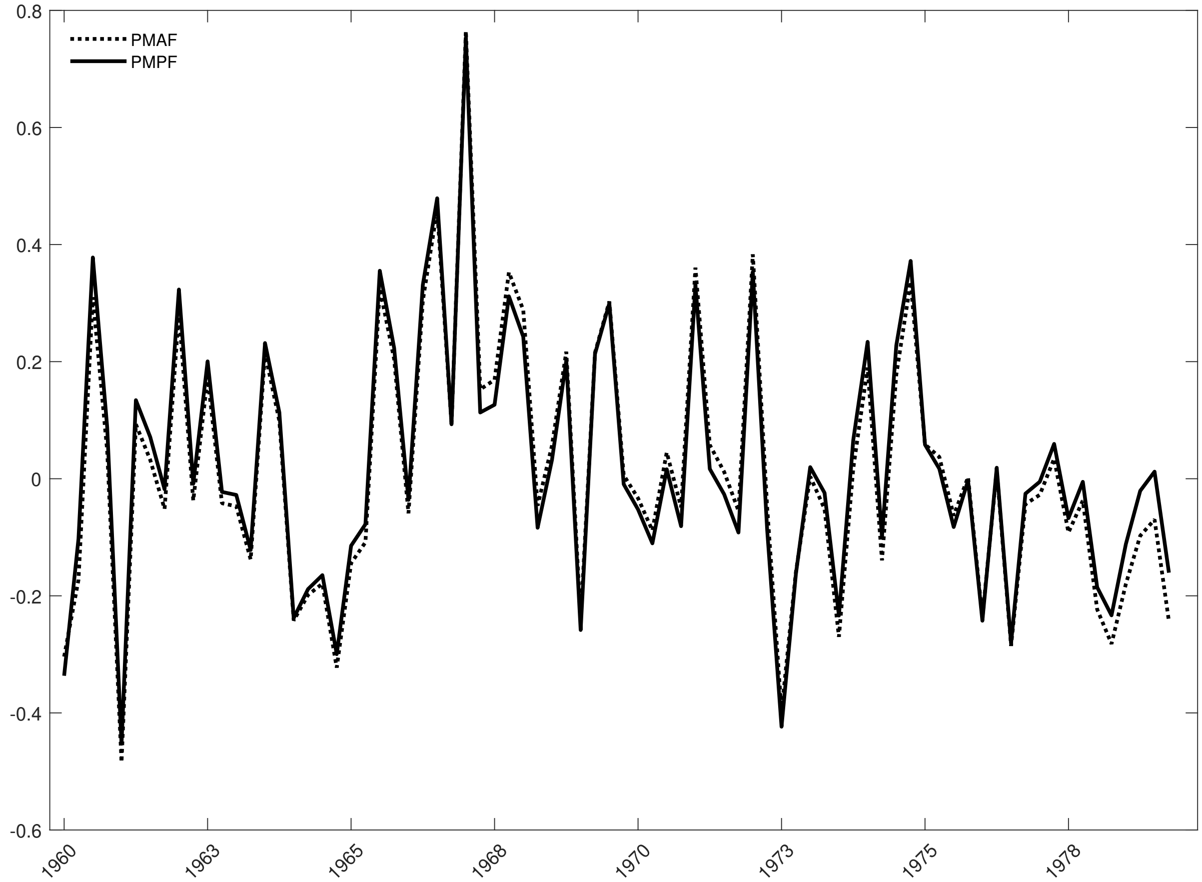


Figure 6: Smoothed government spending shock for 1960:Q1 to 1979:Q2 for regime F and the PMPF regime. The dotted line shows the shock computed at the posterior mean of regime F. The solid line shows the shock computed at the posterior mean of the PMPF regime.

The results of the counterfactual analysis are instructive for evaluating policy measures that effectively brought down pre-Volcker inflation. The Volcker action surely was one possible way to go. By increasing interest rates drastically, the central bank credibly signaled that it will take the lead role. Reagan complied and backed the monetary policy actions. As a result, the monetary-fiscal policy mix switched to regime M. However, conditional on the results in Figure 5, an alternative policy response crystallizes. Less consumption on the part of the fiscal authority during the 1970s would have also reduced the government spending-to-output ratio and, hence, countered the rising inflation.

Lessons for today

After decades of generally stable prices, the post-pandemic era marked a turning point with a global surge in inflation. In the U.S., shocks to energy prices and heavy fiscal stimulus in response to the pandemic, most notably U.S. President Biden's $ 1.9 trillion of federal government spending included in the American Rescue Plan Act, have evoked memories of the Great Inflation in the 1970s. In the last part of the study, we link our analysis of pre-Volcker inflation dynamics to the recent rise in inflation.

As the study of the Great Inflation has shown, it is crucial to determine the correct regime in which the economy is operating, and one could argue that there are signs that the U.S. is moving into a regime where the fiscal authority is active. Bianchi and Melosi (2022) use a Markov switching model estimated on the 1954:Q4-2022:Q1 sample. The authors conclude that, given the unprecedented fiscal intervention in response to the pandemic, a regime of fiscal dominance is more likely. However, the authors also point out the methodological limitations of obtaining robust predictions from models at the end of the estimation sample. This point is underlined by Bergholt et al. (2023), who state that even disentangling the systematic and stochastic components in a VAR model is difficult for this time period. Therefore, we do not take a position on the likelihoods of the different regimes. Instead, we consider each regime equally likely and treat them equally in the rest of the paper.

For each regime we use the insights from the estimated model in the previous sections to analyze causes and policy options in the inflation build-up since 2020. In particular, we construct the six observables for the period spanning from 2020Q1 to 2022Q4 in the same way we did for the pre-Volcker period. We use the posterior mean of each regime from the pre-Volcker period as parametrizations to carry out the historical decomposition of U.S. inflation from 2020:Q1 - 2022:Q4. More precisely, the observables are filtered through the model to derive the smoothed shocks for the post-pandemic period. Figure 7 illustrates the drivers of post-pandemic inflation under an assumed regime of fiscal dominance. Over the period 2020:Q1 - 2022:Q4, positive transfer shocks are the main cause of inflation, echoing the conclusions in Bianchi and Melosi (2022) that the recent surge in inflation has a fiscal nature. Under a regime of monetary dominance, fiscal policy shocks play no role. Instead, Figure 8 shows that the main driver of post-pandemic inflation are mark-up (i.e., cost-push) shocks. Under assumed indeterminacy, post-pandemic inflation is mainly caused by preference and tax shocks (Figure 9). To summarize, in line with the recent narrative, the historical decomposition attributes mainly cost-push and fiscal shocks the role of driving post-pandemic inflation. Yet, depending on the regime, the quantitative importance of the shocks differ starkly.

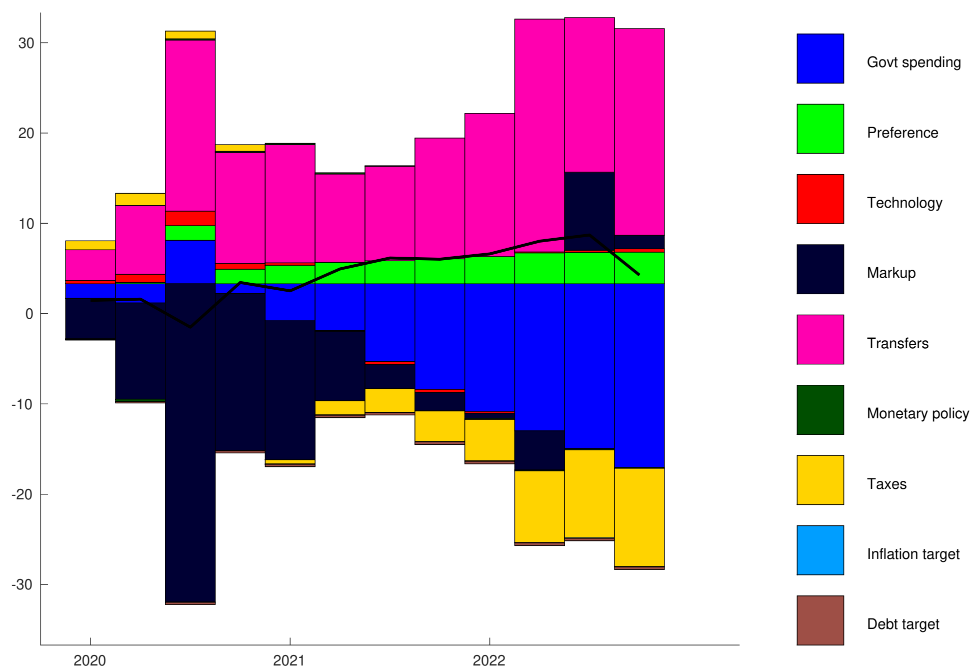


Figure 7: Contribution of each shock to post-pandemic inflation (annualized, percentage points) in regime F. The bold black line shows observed inflation. The historical decomposition is conducted at the posterior mean of draws from regime F in the pre-Volcker estimation.

It is well known in the literature that the recipe for bringing inflation back under control depends on the policy regime in place (Leeper and Leith, 2016). This is due to the different policy transmission mechanism in each regime. To illustrate the differences, we provide the effects of monetary and fiscal policy in the three different regimes. Figure 10 shows the responses of output, annualized inflation, and the debt-to-output ratio to a monetary policy shock (panel a) and to a transfer shock (panel b). The impulse responses show the well-known pattern that both a contractionary monetary policy shock and a positive transfer shock are inflationary in regime F.

Less studied in the literature are the impulse response functions in the indeterminacy regime and the role of the additional parameters (M) which potentially change the shock transmission mechanism. To shed light on this issue, Figure 11 contrasts the estimated impulse response functions in the indeterminacy regime with the impulse response functions when all elements in M are set to zero. The parameters in M are quantitatively important for the response of inflation to both a monetary and a transfer shock. For the debt-to-output ratio, the additional parameters even lead to a qualitatively different response to a monetary policy shock. A drawback of the exercise is that the parameters, and hence the differences in the impulse response functions, lack an economic interpretation.

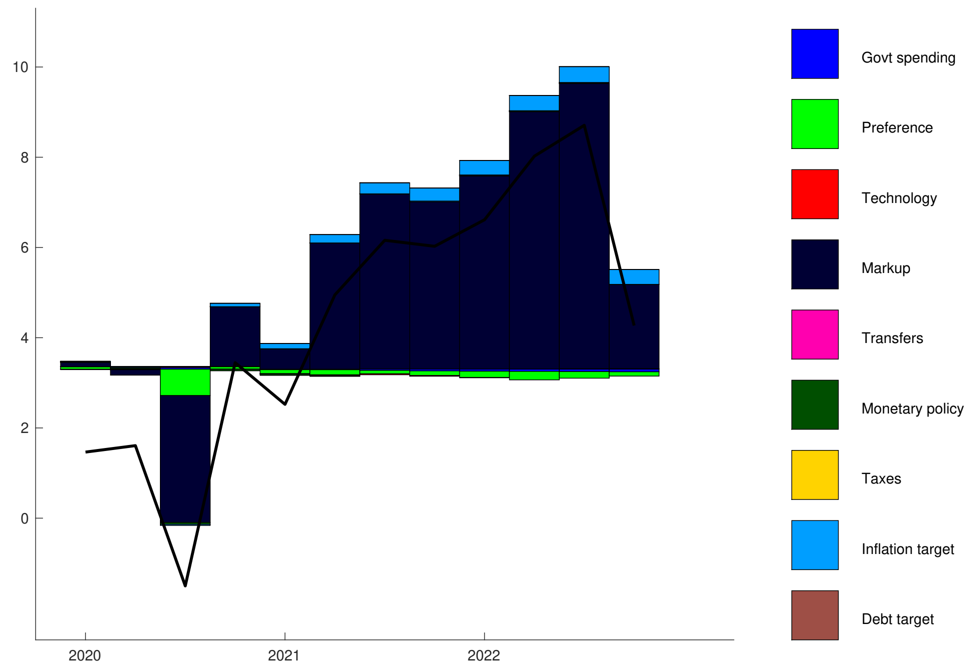


Figure 8: Contribution of each shock to post-pandemic inflation (annualized, percentage points) in regime M. The bold black line shows observed inflation. The historical decomposition is conducted at the posterior mean of draws from regime M in the pre-Volcker estimation.

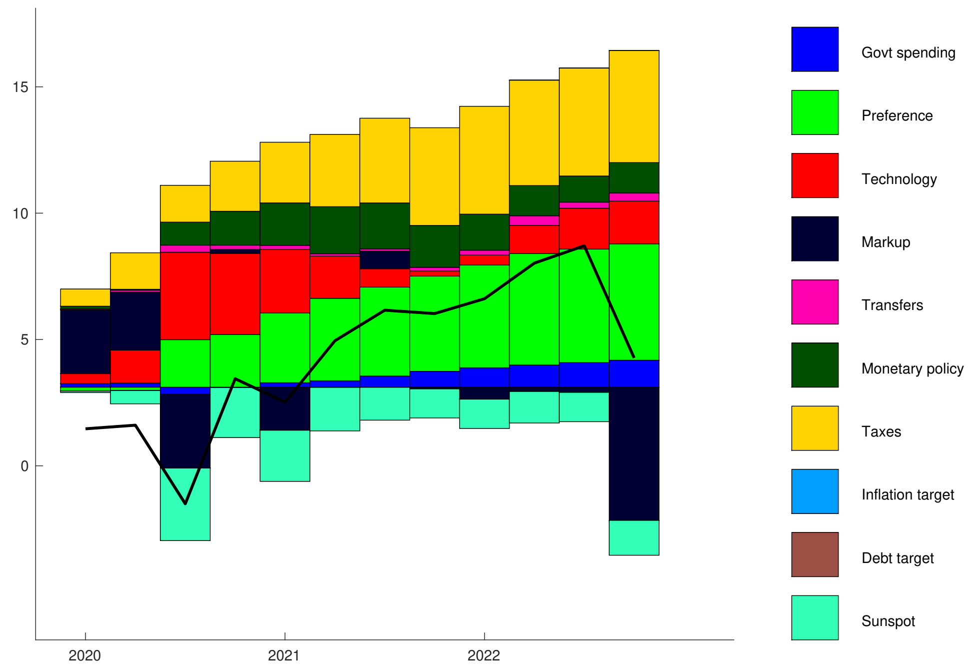
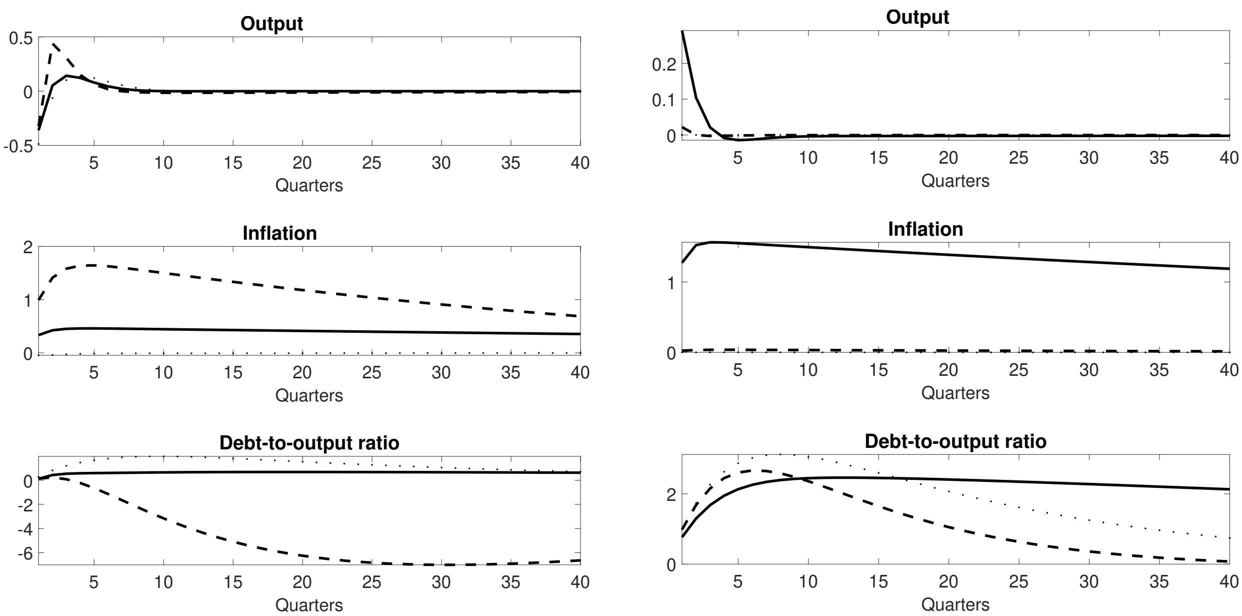


Figure 9: Contribution of each shock to post-pandemic inflation (annualized, percentage points) in the indeterminacy regime. The bold black line shows observed inflation. The historical decomposition is conducted at the posterior mean of draws from the indeterminacy regime in the pre-Volcker estimation.

6 Conclusion

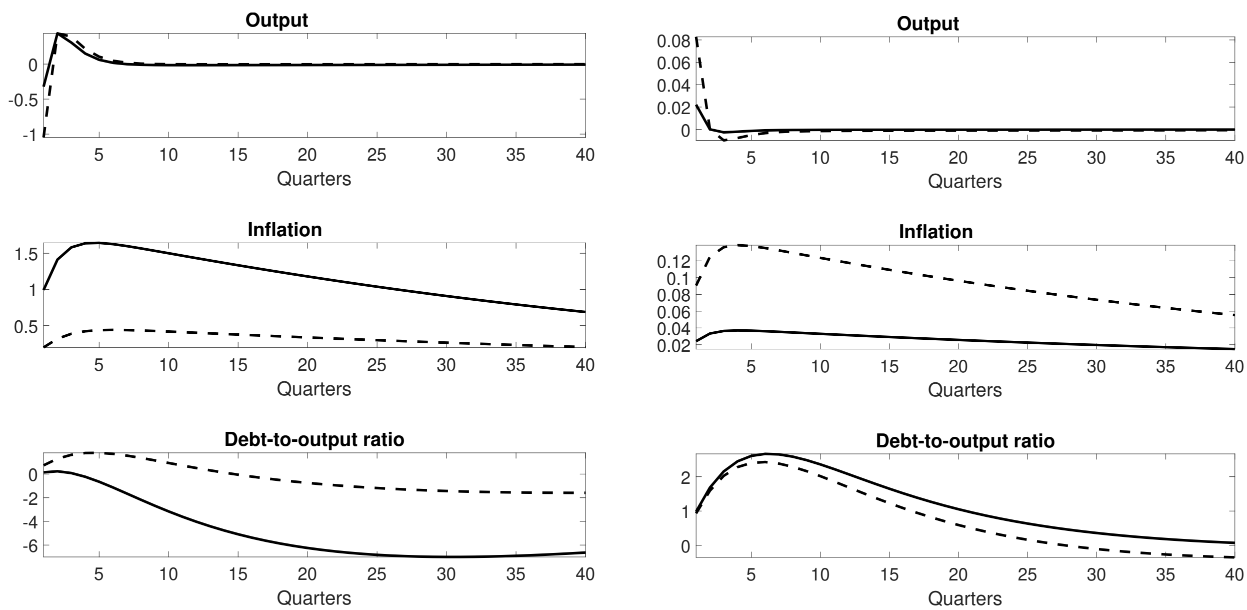
Guidance on managing high public debt and addressing inflationary pressures remains crucial in today's economic landscape. It is widely recognized that the interplay between fiscal and monetary policies is central to addressing these issues. This paper seeks to enrich this discourse across three dimensions. First, we offer methodological insights into the estimation of DSGE models featuring distinct monetary-fiscal policy regimes. We show that in such a model setup the SMC algorithm outperforms standard posterior sampling algorithms and should be the preferred choice because it is better suited to transition between the model's



(a) Monetary policy shock

(b) Transfer shock

Figure 10: Impulse response functions to a monetary policy and a transfer shock. The dashed line corresponds to the indeterminacy regime, the dotted line to regime M, and the bold line to regime F. The unit of the impulse responses is percentage deviations from the steady state for output and percentage point deviations from the steady state for inflation and the debt-to-output ratio.



(a) Monetary policy shock

(b) Transfer shock

Figure 11: Impulse response functions to a monetary policy and a transfer shock in the indeterminacy regime. The bold line depicts the response in the indeterminacy regime (identical to Figure 10) as a reference. The dashed line shows how the transmission mechanism changes when all elements in M are set to zero. The unit of the impulse responses is percentage deviations from the steady state for output and percentage point deviations from the steady state for inflation and the debt-to-output ratio.

different regions of the parameter space. Second, using SMC, we revisit the still open role of fiscal policy during the historical episode of the Great Inflation in the U.S. We demonstrate that there was not one prevailing fiscal-monetary policy mix, and thus no single explanation for the observed inflation dynamics in the pre-Volcker period. Last, we transfer the insights from the pre-Volcker period to the recent period of post-pandemic inflation and discuss appropriate monetary and fiscal responses.

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Appendix A Model solution

Appendix A.1 Implementation of the model solution

The linear rational expectation form of the DSGE model presented in Section 2 is given by

$$\Gamma_0(\vartheta)z_t = \Gamma_1(\vartheta)z_{t-1} + \Psi(\vartheta)\epsilon_t + \Pi(\vartheta)\eta_t. \tag{20}$$

z is the vector of state variables, the vector ϵ includes the exogenous variables, and η is a vector of expectation errors. To apply the solution algorithm of Sims (2002), we define, for a generic variable $\hat{x}_t$, the corresponding one-step-ahead rational expectations forecast error as $\eta_{x,t} = \hat{x}_t - E_{t-1}[\hat{x}_t]$. In our application, the vectors of the general model form are defined as:

$$z_t = [\hat{c}_t\ \hat{\pi}_t\ \hat{a}_t\ \hat{R}_t\ \hat{d}_t\ \hat{Y}_t\ \hat{g}_t\ \hat{u}_t\ \hat{\pi}^*_t\ \hat{Y}^*_t\ \hat{\tau}_t\ \hat{b}_t\ \hat{b}^*_t\ \hat{s}_t\ \hat{g}^*_t\ \hat{c}_{t-1}\ \hat{\pi}_{t-1}\ \hat{g}_{t-1}\ \hat{Y}_{t-1}]',$$

$$\epsilon_t = [\epsilon_{g,t}\ \epsilon_{d,t}\ \epsilon_{a,t}\ \epsilon_{u,t}\ \epsilon_{s,t}\ \epsilon_{R,t}\ \epsilon_{\tau,t}\ \epsilon_{\pi,t}\ \epsilon_{b,t}]', \text{ and}$$

$$\eta_t = [\eta_{c,t}\ \eta_{\pi,t}]'.$$

Appendix A.2 Transmission mechanism around the regime boundaries

Equation 19 illustrates that indeterminacy changes the nature of the solution in two dimensions. First, the transmission of fundamental shocks ϵ_t is no longer uniquely determined as it additionally depends on the matrix $\tilde{M}$. Second, an exogenous sunspot shock ζ_t, unrelated to the fundamental shocks ϵ_t, potentially affects the dynamics of the model variables z_t. Thus, indeterminacy introduces additional parameters.

We denote the standard deviation of the sunspot shock as σ_ζ and normalize as Lubik and Schorfheide (2004) M_ζ to unity. Additionally, in accordance with Lubik and Schorfheide

(2004), we replace $\tilde{M}$ with $\tilde{M} = M^*(\vartheta) + M$ to prevent that the transmission of fundamental shocks changes drastically when the boundary between the determinacy regimes and the indeterminacy regime is crossed. Around this boundary, small changes in ϑ should rather leave the propagation mechanism of structural shocks unaffected. That is why we choose $M^*(\vartheta)$ such that the impulse responses $\partial z_t / \partial \epsilon_t'$ become continuous on the boundary. Vector M, in contrast, which determines the relationship between fundamental shocks and forecast errors, is estimated. It can be interpreted as capturing agents' self-fulfilling beliefs and consists of the following entries: $M = \left[M_{g_\zeta}, M_{d_\zeta}, M_{a_\zeta}, M_{u_\zeta}, M_{s_\zeta}, M_{R_\zeta}, M_{\tau_\zeta}, M_{\pi_\zeta}, M_{b_\zeta}\right]$. For the parameters in M, we choose priors centered around zero and, thus, strictly let the data decide how indeterminacy changes the transmission mechanism of structural shocks.

To compute the matrix $M^*(\vartheta)$ that guarantees continuous model dynamics on the boundary, we proceed in several steps. First, we construct for every parameter vector $\vartheta \in \Theta^I$ (indeterminacy) a reparametrized vector $\vartheta^* = g^*(\vartheta)$ that lies on the boundary between the indeterminacy and the determinacy regimes. Then, $M^*(\vartheta)$ is chosen by a least-squares criterion such that the impulse responses $\frac{\partial z_t}{\partial \epsilon_t'}(\vartheta, M)$ conditional on ϑ resemble the impulse responses conditional on the vector on the boundary $\frac{\partial z_t}{\partial \epsilon_t'}(g^*(\vartheta))$. However, the DSGE model, with monetary-fiscal policy interactions presented in subsection 2, gives rise to two different determinate solutions (regime F and regime M) that are generally characterized by different transmission mechanisms. To deal with this ambiguity, we proceed as follows:

1. For every $\vartheta \in \Theta^I$, we construct a vector $\vartheta^M = g^M(\vartheta)$ that demarks the boundary between regime M and the indeterminacy regime and a vector $\vartheta^F = g^F(\vartheta)$ that lies on the boundary to regime F. The function $g^M(\vartheta)$ is obtained by replacing ϕ_π in the vector ϑ with

$$\tilde{\phi_\pi} = 1 - \phi_Y \left(\frac{1 - \tilde{\beta}}{\tilde{\kappa}} \right). \tag{21}$$

The function $g^F(\vartheta)$ is obtained by replacing ψ_b in the vector ϑ with

$$\tilde{\psi}_b = \frac{1}{\beta} - 1. \tag{22}$$

2. We solve the model successively with the reparametrized vectors ϑ^M and ϑ^F, then compute

$$M^M(\vartheta) = \left[\Gamma^M_{0,\zeta}(\vartheta)'\Gamma^M_{0,\zeta}(\vartheta)\right]^{-1} \Gamma^M_{0,\zeta}(\vartheta)' \left[\Gamma^M_{0,\epsilon}(g^M(\vartheta)) - \Gamma^M_{0,\epsilon}(\vartheta)\right], \text{ and} \tag{23}$$

$$M^F(\vartheta) = \left[\Gamma^F_{0,\zeta}(\vartheta)'\Gamma^F_{0,\zeta}(\vartheta)\right]^{-1} \Gamma^F_{0,\zeta}(\vartheta)' \left[\Gamma^F_{0,\epsilon}(g^F(\vartheta)) - \Gamma^F_{0,\epsilon}(\vartheta)\right]. \tag{24}$$

3. To choose the $M^*(\vartheta)$ that minimizes the discrepancy between $\frac{\partial z_t}{\partial \epsilon_t'}(\vartheta, M)$ and $\frac{\partial z_t}{\partial \epsilon_t'}(g^*(\vartheta))$, we compute the distances to the respective boundaries as

$$D^M = \left[\Gamma^M_{0,\epsilon}(g^M(\vartheta)) - \Gamma^M_{0,\epsilon}(\vartheta)\right] - \Gamma^M_{0,\zeta}(\vartheta)M^M(\vartheta), \text{ and} \tag{25}$$

$$D^F = \left[\Gamma^F_{0,\epsilon}(g^F(\vartheta)) - \Gamma^F_{0,\epsilon}(\vartheta)\right] - \Gamma^F_{0,\zeta}(\vartheta)M^F(\vartheta). \tag{26}$$

4. As, in our model, all fundamental shocks are assumed to be independent from each other, we compute the Euclidean norm of each column in D^*, sum them up, and, finally, choose the $M^*(\vartheta)$ that corresponds with[22]

$$min \left[\sum_{j=1}^{9} ||d_j^M||_2, \sum_{j=1}^{9} ||d_j^F||_2\right].$$

Here we show plots to demonstrate that our approach delivers effectively continuous impulse response functions on the boundary between policy regimes. We draw 20,000 times

[22]For matrix $D^* = (d^*_{ij})$, its i-th row and j-th column are denoted by d^*_i and d^*_j, respectively.

from the prior distribution outlined in Section 3 and, with each draw, solve the model. If a draw lies in the indeterminacy region, we first determine with the least-square criterion if it is closer to the monetary (regime M) or the fiscal boundary (regime F) of the determinacy region. Then we conduct the following steps:

If the draw's position in the parameter space is closer to the monetary boundary, we reparametrize the parameter vector to lie on the monetary boundary.

1. We solve the model on the boundary and compute impulse responses.

2. We step numerically from the boundary into the indeterminacy region, solve the model and compute impulse responses.

3. To check if the transmission mechanism changes when crossing the boundary, we compute the difference between the impulse responses on the boundary and the impulse responses from the indeterminacy region.

We repeat the three steps for the draws that are located closer to the fiscal boundary. Figures 12 and 13 show that the impulse responses (IRFs) are nearly congruent.

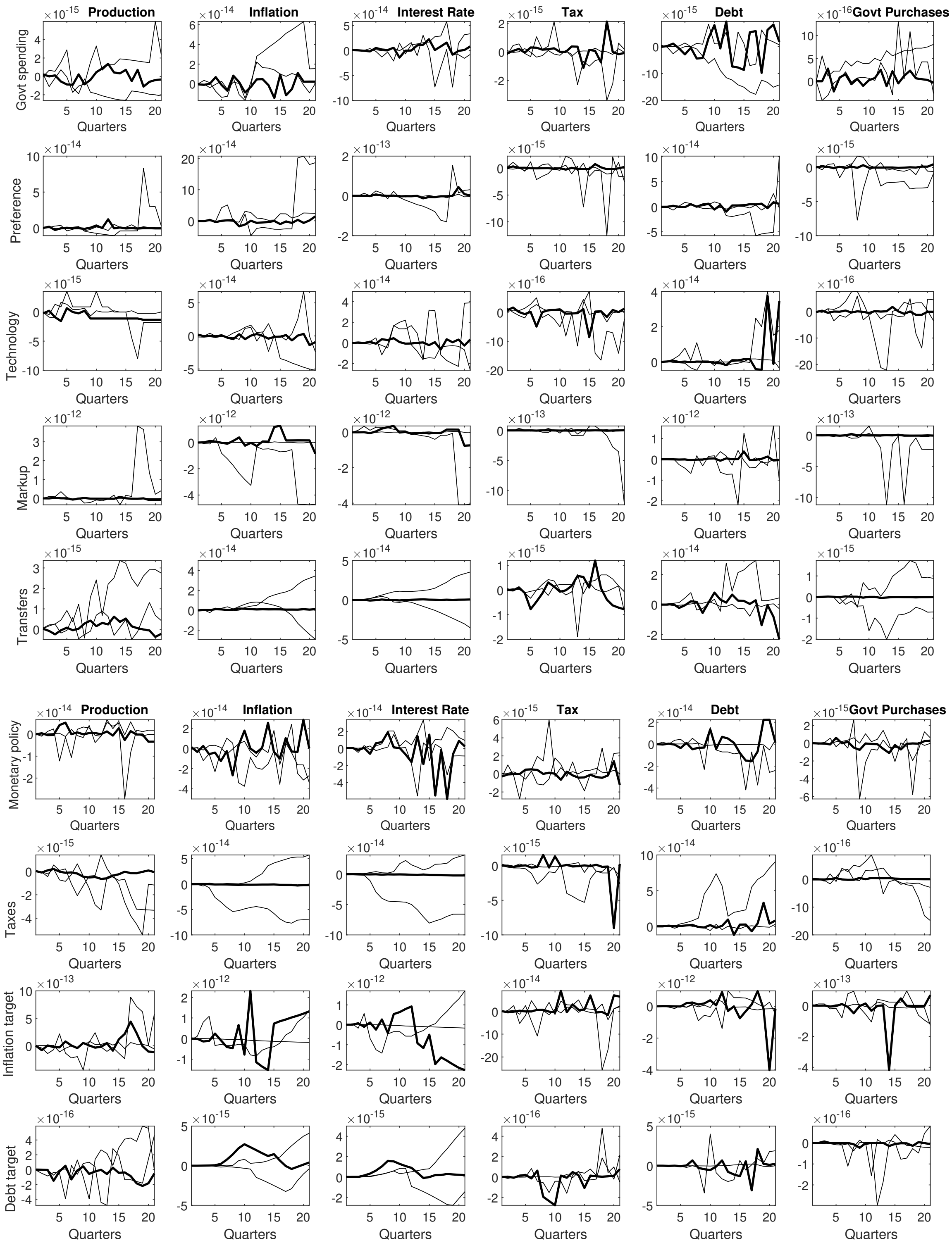


Figure 12: Difference of IRFs computed in the determinacy and the indeterminacy region around the monetary boundary. The bold line shows posterior means and the solid line 90 % credible sets.

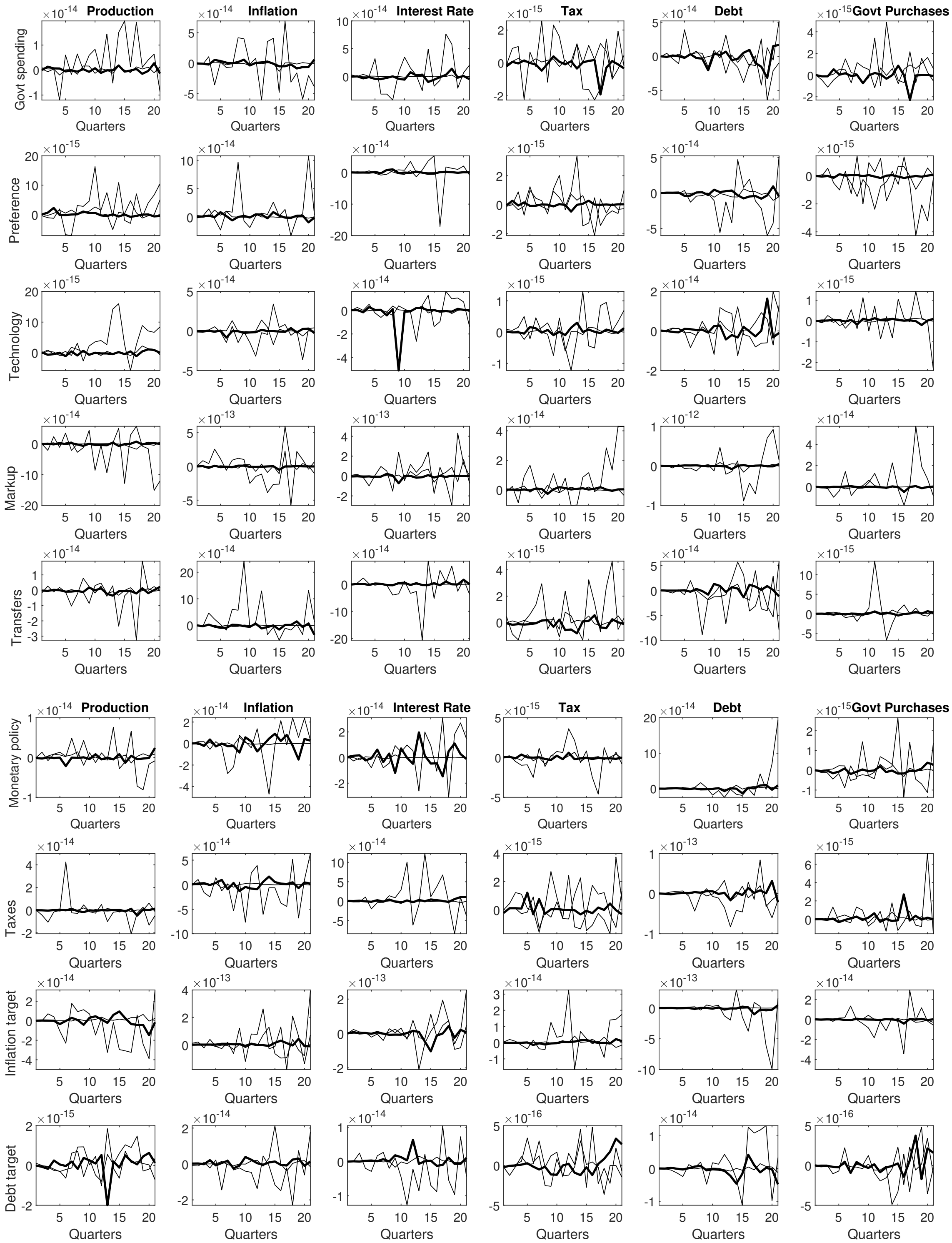


Figure 13: Difference of IRFs computed in the determinacy and the indeterminacy region around the fiscal boundary. The bold line shows posterior means and the solid line 90 % credible sets.

Appendix B Prior

In this appendix, we summarize the details of our prior distribution and show results of a prior predictive analysis.

Appendix B.1 Prior distribution

Table 4: Prior distributions

Parameter	Prior				
	Range	Distribution	Mean	SD	90 percent int.
Monetary policy					
ϕ_π, interest rate response to inflation	$\mathbb{R}^+$	N	0.8	0.6	$[0.14, 1.84]$
ϕ_Y, interest rate response to output	$\mathbb{R}^+$	G	0.3	0.1	$[0.16, 0.5]$
ρ_R, response to lagged interest rate	$[0, 1)$	B	0.6	0.2	$[0.24, 0.9]$
Fiscal policy					
ψ_b, tax response to lagged debt	$\mathbb{R}$	N	0	0.1	$[-0.16, 0.16]$
ψ_Y, tax response to output	$\mathbb{R}$	N	0.4	0.3	$[-0.1, 0.9]$
χ_Y, govt spending response to lagged output	$\mathbb{R}$	N	0.4	0.3	$[-0.1, 0.9]$
ρ_g, response to lagged govt spending	$[0, 1)$	B	0.6	0.2	$[0.24, 0.9]$
ρ_τ, response to lagged taxes	$[0, 1)$	B	0.6	0.2	$[0.24, 0.9]$
Preference and HHs					
η, habit formation	$[0, 1)$	B	0.5	0.2	$[0.17, 0.83]$
$\mu := 100(\beta^{-1} - 1)$, discount factor	$\mathbb{R}^+$	G	0.25	0.1	$[0.11, 0.44]$
Frictions					
α, price stickiness	$[0, 1)$	B	0.5	0.2	$[0.17, 0.83]$
γ, price indexation	$[0, 1)$	B	0.6	0.2	$[0.24, 0.9]$
Shocks					
ρ_d, preference	$[0, 1)$	B	0.6	0.2	$[0.24, 0.9]$
ρ_a, technology	$[0, 1)$	B	0.4	0.2	$[0.1, 0.76]$
ρ_u, cost-push	$[0, 1)$	B	0.6	0.2	$[0.24, 0.9]$
ρ_s, transfers	$[0, 1)$	B	0.6	0.2	$[0.24, 0.9]$
σ_g, govt spending	$\mathbb{R}^+$	Inv. Gamma	0.1	4	$[0.07, 0.24]$
σ_d, preference	$\mathbb{R}^+$	Inv. Gamma	0.3	4	$[0.19, 0.72]$
σ_a, technology	$\mathbb{R}^+$	Inv. Gamma	0.5	4	$[0.32, 1.17]$
σ_u, cost-push	$\mathbb{R}^+$	Inv. Gamma	0.04	4	$[0.026, 0.094]$
σ_s, transfers	$\mathbb{R}^+$	Inv. Gamma	0.08	4	$[0.052, 0.188]$

Table 4: Prior distributions - continued

Parameter	Prior				
	Range	Distribution	Mean	SD	90 percent int.
σ_R, monetary policy	$\mathbb{R}^+$	Inv. Gamma	0.15	4	$[0.098, 0.353]$
σ_τ, tax	$\mathbb{R}^+$	Inv. Gamma	0.2	4	$[0.13, 0.48]$
σ_π, inflation target	$\mathbb{R}^+$	Inv. Gamma	0.003	4	$[0.002, 0.007]]$
σ_b, debt/output target	$\mathbb{R}^+$	Inv. Gamma	0.05	4	$[0.033, 0.118]$
Steady state					
$a := 100(\bar{a}-1)$, technology	$\mathbb{R}$	N	0.55	0.1	$[0.38, 0.71]$
$\pi := 100(\bar{\pi}-1)$, inflation	$\mathbb{R}$	N	0.8	0.1	$[0.63, 0.96]$
$b := 100\bar{b}$, debt/output	$\mathbb{R}$	N	35	2	$[31.71, 38.3]$
$\tau := 100\bar{\tau}$, tax/output	$\mathbb{R}$	N	25	2	$[21.73, 28.27]$
$g := 100\bar{g}$, govt spending/output	$\mathbb{R}$	N	22	2	$[18.81, 25.31]$
Indeterminacy					
σ_ζ, sunspot shock	$\mathbb{R}^+$	Inv. Gamma	0.2	4	$[0.13, 0.48]$
$M_{g\zeta}$	$\mathbb{R}$	N	0	1	$[-1.64, 1.64]$
$M_{d\zeta}$	$\mathbb{R}$	N	0	1	$[-1.64, 1.64]$
$M_{a\zeta}$	$\mathbb{R}$	N	0	1	$[-1.64, 1.64]$
$M_{u\zeta}$	$\mathbb{R}$	N	0	1	$[-1.64, 1.64]$
$M_{s\zeta}$	$\mathbb{R}$	N	0	1	$[-1.64, 1.64]$
$M_{R\zeta}$	$\mathbb{R}$	N	0	1	$[-1.64, 1.64]$
$M_{\tau\zeta}$	$\mathbb{R}$	N	0	1	$[-1.64, 1.64]$
$M_{\pi\zeta}$	$\mathbb{R}$	N	0	1	$[-1.64, 1.64]$
$M_{b\zeta}$	$\mathbb{R}$	N	0	1	$[-1.64, 1.64]$

Note: The Inverse Gamma prior distributions have the form $p(x|\nu, s) \propto x^{-\nu-1}e^{-\nu s^2/2x^2}$, where $\nu = 4$ and s is given by the value in the column denoted as "Mean".

Appendix B.2 Prior implications

Here we show results of a prior predictive analysis for the prior specification outlined in Section 3. Specifically, we take 20,000 draws from the prior and simulate with these draws 20,000 times the model's observables.

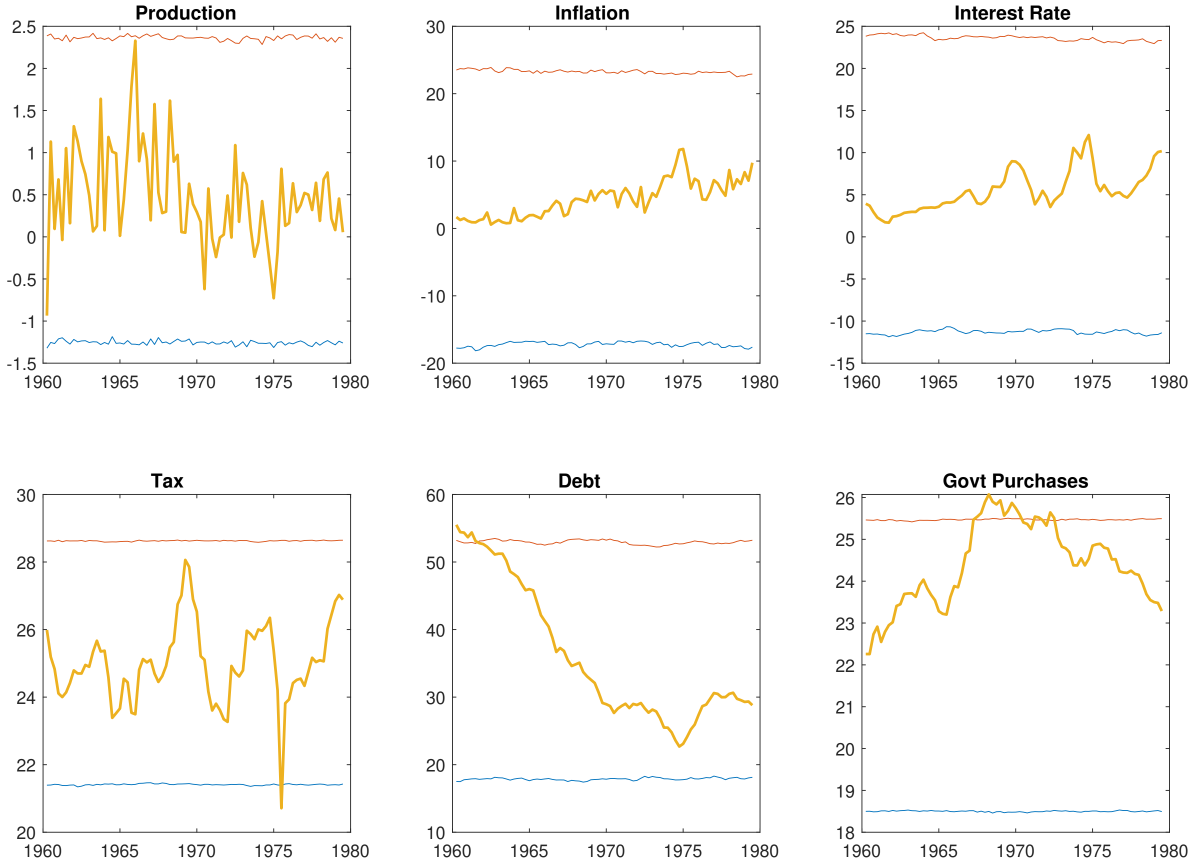


Figure 14: Simulated model observables vs. real data for 1960:Q1 to 1979:Q2. The bold yellow line shows the actual time series we use for estimating the model. The blue and the red line show the 90 % interval of the simulated time series.

Appendix C Data description

We use the dataset of Bhattarai et al. (2016). Unless otherwise noted, the data is retrieved from the National Income and Product Accounts Tables published by the Bureau of Economic Analysis. All time series in nominal values are converted to real values by dividing them by the GDP deflator. For the period 2020:Q1 to 2022:Q4, we update the dataset of Bhattarai et al. (2016) from the same sources.

Per capita output: Per capita output is the sum of personal consumption of nondurables and services, and government consumption divided by civilian noninstitutional population. Civilian noninstitutional population is taken from the FRED database of the Federal Reserve Bank of St. Louis.

Inflation: The gross inflation rate is the annualized GDP deflator.

Interest rate: The annualized nominal interest rate is the effective federal funds rate from the FRED database of the Federal Reserve Bank of St. Louis.

Tax revenues: The tax-revenues-to-output ratio is defined as the sum of current tax receipts and contributions for government social insurance divided by output.

Government debt: Government debt corresponds to the market value of privately held gross federal debt, retrieved from the Federal Reserve Bank of Dallas. The government debt-to-output ratio is obtained by dividing the series by output.

Government spending: The government spending-to-output ratio is defined as government consumption divided by output.

The relationship between observables and model variables is given by

$$\begin{bmatrix} 100 \times \Delta\text{ln Production}_t \\ \text{Inflation}_t \ (\%) \\ \text{Interest}_t \ (\%) \\ \text{TaxRev}_t \ (\%) \\ \text{GovtDebt}_t \ (\%) \\ \text{GovtPurch}_t \ (\%) \end{bmatrix} = \begin{bmatrix} a \\ 4\pi \\ 4(a + \pi + \mu) \\ \tau \\ b \\ g \end{bmatrix} + \begin{bmatrix} \hat{Y}_t - \hat{Y}_{t-1} + \hat{a}_t \\ 4\hat{\pi}_t \\ 4\hat{R}_t \\ \hat{\tau}_t \\ \hat{b}_t \\ \hat{g}_t \end{bmatrix}. \tag{27}$$

Appendix D SMC algorithm

This appendix gives a technical description of the implemented SMC algorithm. In terms of exposition and notation it draws heavily on Herbst and Schorfheide (2014, 2015), and Bognanni and Herbst (2018).

Appendix D.1 SMC with likelihood tempering - intuition

The basic concept of the SMC relies on importance sampling, which means that the posterior $p(\vartheta, M|Y)$ is approximated by an easy-to-sample proposal, or source density. However, in the high-dimensional parameter space of DSGE models, good proposal densities are difficult to obtain. This is why the SMC constructs proposal densities sequentially. More precisely, the algorithm draws from a sequence of bridge densities that link a known starting distribution with the targeted posterior density. A meaningful starting distribution constitutes the prior $p(\vartheta, M)$. The bridge distributions, in contrast, differ in the amount of information from the likelihood they contain. At each stage of the algorithm, an increment of the likelihood is added to the proposal density. At the moment the full information from the likelihood has been released, an approximation of the posterior is obtained. In particular, the sequence of n distributions is given by

$$p_n(\vartheta, M|Y) = \frac{[p(Y|\vartheta, M)]^{\delta_n} p(\vartheta, M)}{\int [p(Y|\vartheta, M)]^{\delta_n} p(\vartheta, M) d\vartheta dM}, \quad n = 1, ..., N_\delta. \tag{28}$$

We follow Herbst and Schorfheide (2014) and choose the tuning parameter δ_n as an increasing sequence of values such that $\delta_1 = 0$ and $\delta_{N_\delta} = 1$. The length of this sequence coincides with the number of importance samplers. At the first stage of the algorithm, $p_1(\vartheta, M|Y)$ is the prior density $p(\vartheta, M)$. At the last stage, the final proposal density $p_{N_\delta}(\vartheta, M|Y)$ constitutes the posterior $p(\vartheta, M|Y)$. In particular, our tempering schedule $\{\delta_n\}_{n=1}^{N_\delta}$ is given by $\delta_n = (n - 1/N_\delta - 1)^\lambda$. The tuning parameter λ determines how much information from the likelihood is incorporated in each proposal density.

In a nutshell, the SMC draws in N_δ stages sequentially N parameter vectors $\vartheta^i, i = 1, ..., N$ from the proposal densities and assigns them with importance weights $\tilde{W}^i$. Each of the i pairs $(\vartheta^i, \tilde{W}^i)$ is known as a particle and the set of particles $\{(\vartheta^i, \tilde{W}^i)\}_{i=1}^N$ approximates the density in iteration. Each stage of the SMC consists of three steps. First, in the *correction* step of stage n, the particles of the previous stage $\{(\vartheta^i_{n-1}, \tilde{W}^i_{n-1})\}_{i=1}^N$ are reweighted to correct for the difference between $p_{n-1}(\vartheta, M|Y)$ and $p_n(\vartheta, M|Y)$. The second step, the *selection* step, controls the accuracy of the particle approximation. Whenever the distribution of weights becomes too uneven, systematic resampling restores a well-balanced set of particles. In the last step, the *mutation* step, the particle values are propagated around in the parameter space by M_{MH} iterations of a RWMH algorithm with N_{blocks} random blocks. The particles' new location determines the updated density $p_n(\vartheta, M|Y)$.

To estimate the model, we choose the following tuning parameters for the SMC. We use $N = 20,000$ particles, $N_\delta = 600$ stages, $\lambda = 2.4$, $N_{blocks} = 10$, $M_{MH} = 2$. As suggested by Herbst and Schorfheide (2014), λ is determined by examining the particle degeneracy after the first piece of information of the likelihood was added to the prior density in $n = 1$. We increased λ until at least 80% of the total number of particles (16,000) was retained. To choose N_{blocks} and M_{MH}, we monitored the acceptance rate in the mutation step in preliminary runs. $N_{blocks} = 10$ and $M_{MH} = 2$ insured a stable acceptance rate of 25% without down-scaling the proposal variance too much.

Appendix D.2 SMC with likelihood tempering - the algorithm

1. The SMC is **initialized** by drawing the particles of the first stage ($n = 1$; $\delta_1 = 0$) from the prior density.[23]

$$\vartheta^i_1 \overset{i.i.d.}{\sim} p(\vartheta) \quad i = 1, ..., N.$$

   In the first stage, each particle receives equal weight such that $W^i_1 = 1$.

[23]To ease notation in Appendix D, we assume that the parameters in M are part of ϑ.

2. **Recursions:**

`for n=2:`N_δ

1. *Correction:* Reweight the particles from stage $n-1$ by defining the incremental and normalized weights as

$$\tilde{w}_n^i = \left[p(Y|\vartheta_{n-1}^i)\right]^{\delta_n - \delta_{n-1}}, \quad \tilde{W}_n^i = \frac{\tilde{w}_n^i W_{n-1}^i}{\frac{1}{N}\sum_{i=1}^N \tilde{w}_n^i W_{n-1}^i}, \ i = 1, ..., N.$$

2. *Selection:* Check particle degeneracy by computing the effective sample size

$$ESS_n = \frac{N}{\frac{1}{N}\sum_{i=1}^N (\tilde{W}_n^i)^2}.$$

The ESS monitors the variance of the particle weights. The larger this variance, the more inefficient runs the sampler. If the distribution of particle weights becomes too uneven, resampling the particles helps to improve accuracy.

`if` $ESS_n < N/2$

Resample the particles via systematic resampling and set the weights to uniform

$$W_n^i = 1, \quad \hat{\vartheta}_n^i \sim \{\vartheta_{n-1}^j, \tilde{W}_n^j\}_{j=1,...,N} \quad i = 1, ..., N.$$

`else`

$$W_n^i = \tilde{W}_n^i, \quad \hat{\vartheta}_n^i = \vartheta_{n-1}^i, \quad i = 1, ..., N$$

`end if`

3. *Mutation:* Propagate each particle $\{\tilde{\vartheta}_N^i, W_n^i\}$ via M_{MH} steps of a RWMH with N_{blocks} random blocks. See Appendix D.3 for further details.

`end for`

3. Process **posterior draws**.

Appendix D.3 Mutation step

In this section, we specify the RWMH sampler we use for particle mutation. In accordance with Herbst and Schorfheide (2014) and Bognanni and Herbst (2018), the RWMH steps in our application are characterized by two features. First, we reduce the dimensionality of the parameter vector ϑ by splitting it into N_{blocks} blocks, thus making it easier to approximate the target density in each of the RWMH's M_{MH} steps.[24] Second, we scale the variance of the proposal density adaptively. Let $\hat{\Sigma}_n$ be the estimate of the covariance of $p_n(\vartheta|Y)$ after the selection step and c_n be a scaling factor. We set c_n as a function of the previous stage's scaling factor c_{n-1} and the average empirical acceptance rate of the previous stage's mutation step $\hat{A}_{n-1}$. We target an acceptance rate of 25 % and, hence, increase c_n if the acceptance rate in stage $n-1$ was too high or decrease c_n if it was too low. In particular, the functional form is given by $\hat{c}_n = \hat{c}_{n-1} f(\hat{A}_{n-1})$, where $f(x) = 0.95 + 0.1\frac{e^{16(x-0.25)}}{1+e^{16(x-0.25)}}$.

1. In every n stage after the *selection* step, create a **random partitioning** of the parameter vector ϑ into N_{blocks}. b denotes the block of the parameter vector such that $\vartheta^i_{b,n}$ refers to the b elements of the ith particle, and $\vartheta^i_{<b,n}$ denotes the remaining partitions.

2. **Compute** an estimate of the **covariance** of the parameters as

$$\hat{\Sigma}_n = \sum_{i=1}^{N} W^i_n(\hat{\vartheta}^i_n - \hat{\mu}_n)(\hat{\vartheta}^i_n - \hat{\mu}_n)' \quad \text{with} \quad \hat{\mu}_n = \sum_{i=1}^{N} W^i_n \hat{\vartheta}^i_n.$$

   The covariance for the bth block is given by

$$\hat{\Sigma}_{b,n} = [\hat{\Sigma}_n]_{b,b} - [\hat{\Sigma}_n]_{b,-b}[\hat{\Sigma}_n]^{-1}_{-b,-b}[\hat{\Sigma}_n]_{-b,b},$$

   where $[\hat{\Sigma}_n]_{b,b}$ refers to the bth block of $\hat{\Sigma}_n$.

3. **MH steps:**

[24] Chib and Ramamurthy (2010) and Herbst (2012) provide evidence that parameter blocking is beneficial for estimating DSGE models.

for m=1:M_{MH}

for b=1:N_{blocks}

1. Draw a proposal density $\vartheta_b^* \sim N(\vartheta^i_{m-1,b,n}, c_n^2 \hat{\Sigma}_{b,n})$.

$\vartheta^* = [\vartheta^i_{m,<b,n}, \vartheta^*_b, \vartheta^i_{m-1,>b,n}]$ and $\vartheta^i_{m,n} = [\vartheta^i_{m,<b,n}, \vartheta^i_{m-1,\geq b,n}]$.

2. With probability

$$\alpha = \min \left\{ \frac{[p(Y|\vartheta^*)]^{\delta_n} p(\vartheta^*)}{[p(Y|\vartheta^i_{m,n})]^{\delta_n} p(\vartheta^i_{m,n})}, 1 \right\},$$

set $\vartheta^i_{m,b,n} = \vartheta^*_b$. Otherwise, set $\vartheta^i_{m,b,n} = \vartheta^i_{m-1,b,n}$.

end for

end for

Appendix E Posterior estimates

Appendix E.1 Restricted estimation

In this appendix, we show results of estimations in which we restrict the parameter space and apply SMC sampling to estimate each policy regime sequentially. The purpose of this exercise is to show (i) that the SMC sampler is able to replicate the RWMH estimation results of Bhattarai et al. (2016), our reference study, and (ii) that our prior specification does not affect the probability of policy regimes in the posterior. Hence, potential differences in findings are driven neither by the prior specification nor the sampling technique, but rather induced by restricting or not restricting the parameter space.

Restricted estimation - prior as in Bhattarai et al. (2016)

To understand how changing the posterior sampler influences the estimation results, we apply the SMC algorithm and replicate, in a first step, the study of Bhattarai et al. (2016). For this exercise, we follow strictly the approach of Bhattarai et al. (2016). We use the same dataset, and the same prior distributions.[25] It is only in terms of posterior sampling that we do not rely on RWMH sampling; rather we apply the SMC algorithm instead. We restrict the parameter space and estimate each policy regime 50 times with the SMC sampler.

Looking at the estimated marginal data densities of each regime, presented in Table 5, we come to the same conclusion as Bhattarai et al. (2016): the US-economy in the pre-Volcker period was in the PMPF regime. In this estimation, regime F and regime M receive no support from the data.

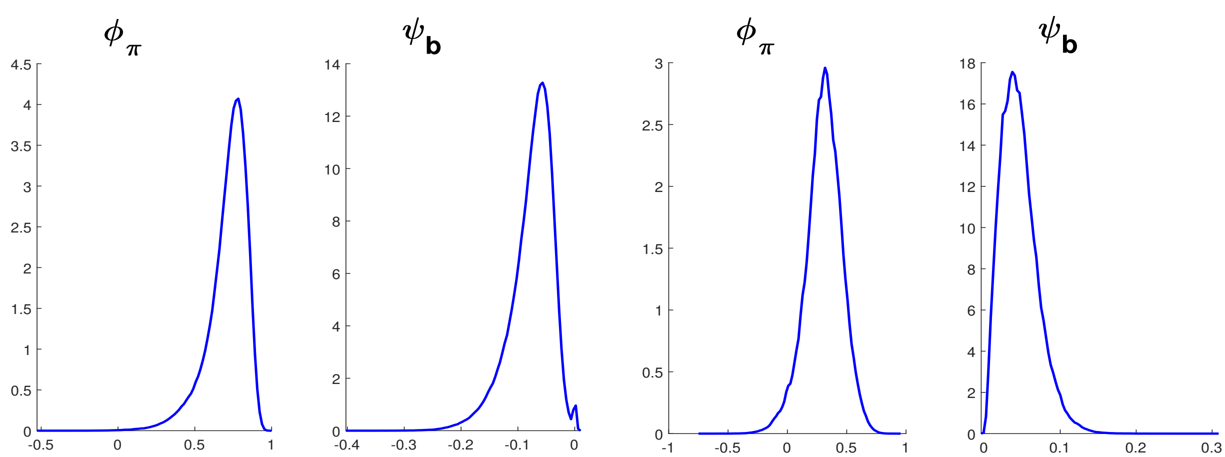
[25] For details on this prior specification, we refer the reader to the Online Appendix of the original study.

Table 5: Log marginal data densities for each policy regime from restricted estimation

	AMPF	PMAF	PMPF
Log MDD	-541.85	-537.54	-521.41

Note: The log marginal data density is obtained as a by-product during the correction step of the SMC algorithm, see Herbst and Schorfheide (2014) for further details. For each regime, its mean is computed over 50 independent runs of the SMC algorithm.

Figure 15 shows plots of the posterior densities of the policy parameters for regime F and the PMPF regime. The mean estimates for the Taylor-coefficient ϕ_π (regime F: 0.71; PMPF: 0.31) and ψ_b (regime F: -0.08; PMPF: 0.05) are in line with the findings of Bhattarai et al. (2016). Hence, using the SMC instead of the RWMH algorithm for posterior sampling does not influence the estimation results.

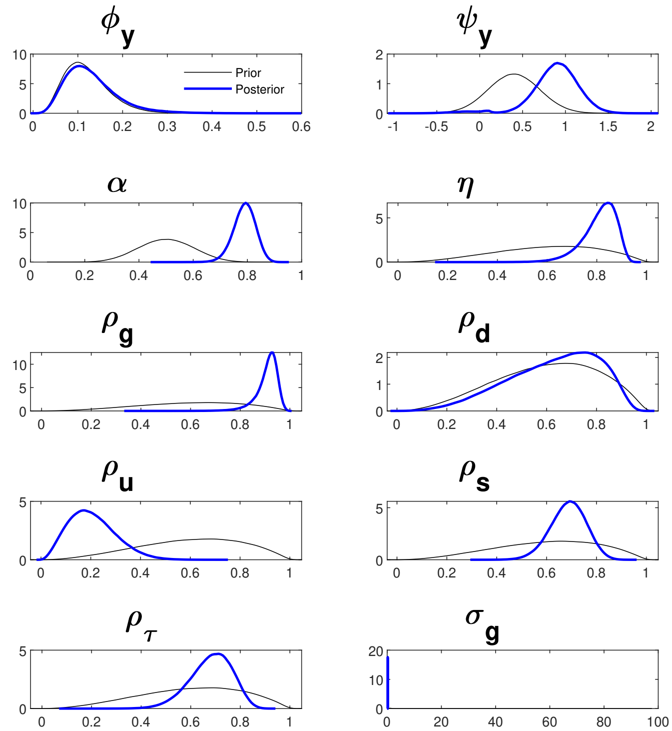


(a) Regime F (b) PMPF regime

Figure 15: Posterior densities of the policy parameters ϕ_π and ψ_b for regime F and the PMPF regime.

In the following, we show plots of the prior and posterior densities for the remaining parameters.

Regime F



ϕ_y
Prior
Posterior
ψ_y
χ_y
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η
γ
ρ_g
ρ_d
ρ_a
ρ_u
ρ_s
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ρ_τ
σ_g
σ_d

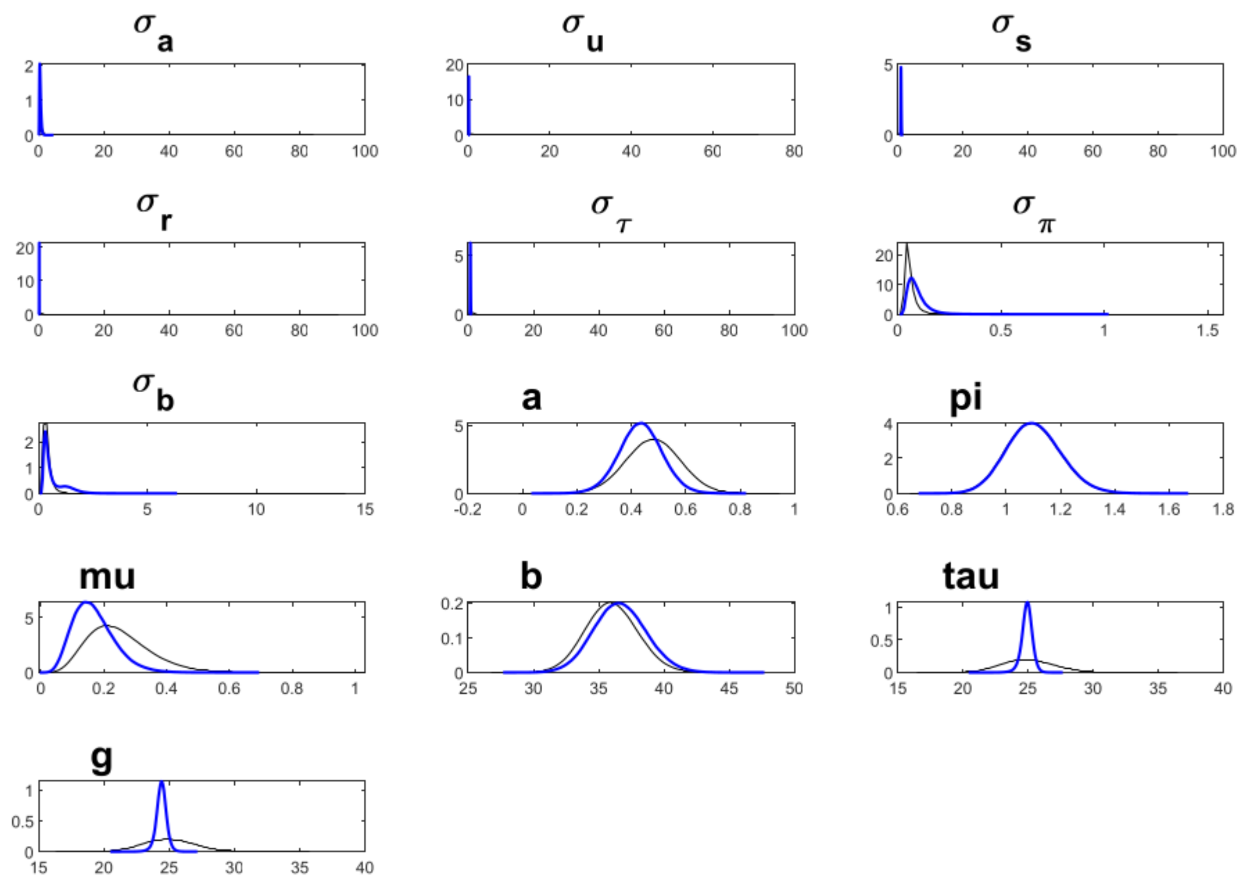


Figure 16: Prior and posterior densities of the estimated model parameters for regime F. The blue bold line depicts the posterior density, the black line the prior density. The prior densities are specified as in Bhattarai et al. (2016).

Table 6: Posterior distributions for estimated parameters (Regime F)

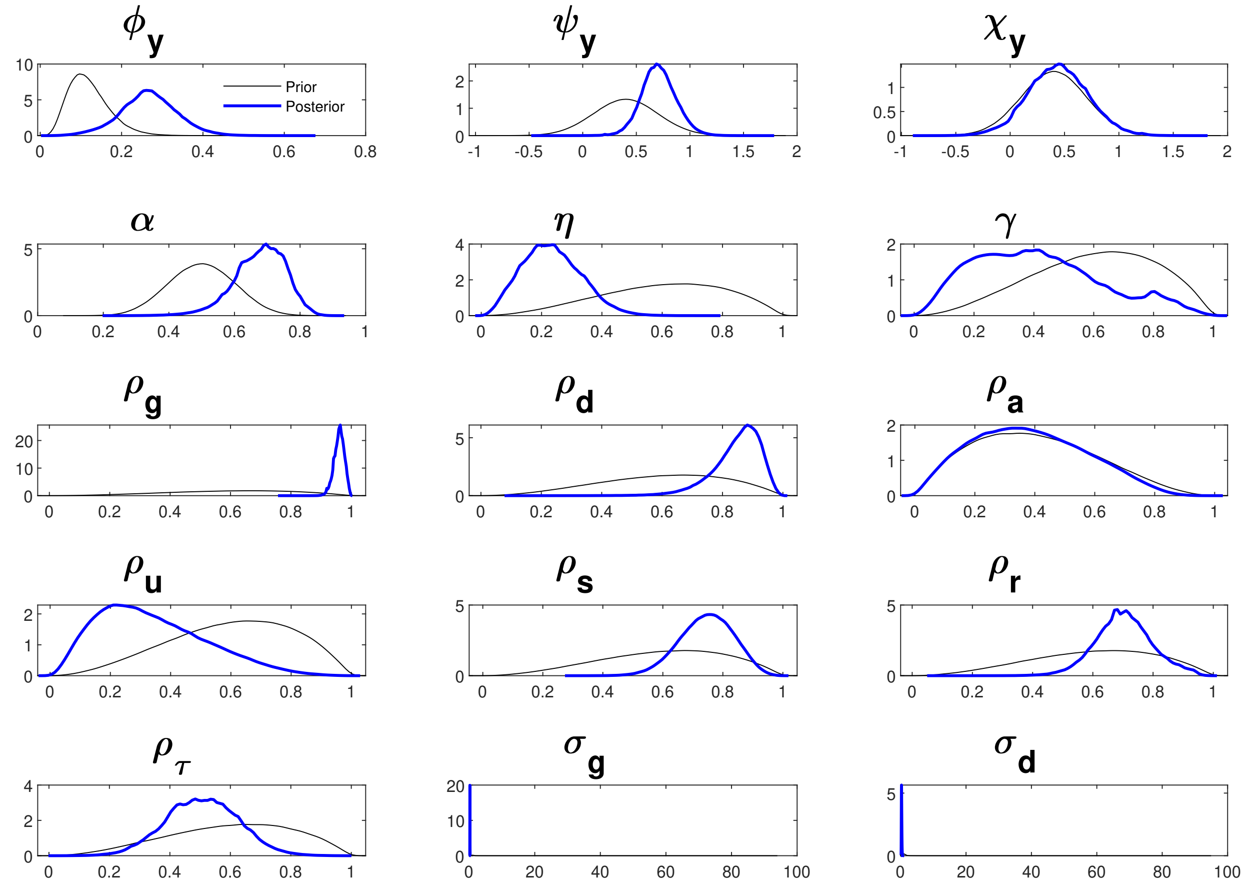
Parameter	Posterior Mean	Posterior SD	Posterior 90 percent credible set
Monetary policy			
ϕ_π, interest rate response to inflation	0.71	0.13	[0.53, 0.9]
ϕ_π^*, distance to monetary boundary	0.27	0.13	[0.09, 0.46]
ϕ_Y, interest rate response to output	0.13	0.06	[0.04, 0.21]
ρ_R, response to lagged interest rate	0.93	0.07	[0.9, 0.99]
Fiscal policy			
ψ_b, tax response to lagged debt	-0.08	0.04	[-0.14, -0.02]
ψ_b^*, distance to fiscal boundary	0.08	0.04	[0.02, 0.14]
ψ_Y, tax response to output	0.87	0.3	[0.49, 1.33]
χ_Y, govt spending response to lagged output	0.63	0.31	[0.24, 1.11]
ρ_g, response to lagged govt spending	0.91	0.04	[0.85, 0.97]
ρ_τ, response to lagged taxes	0.68	0.08	[0.55, 0.82]
Preference and HHs			
η, habit formation	0.81	0.07	[0.71, 0.91]
$\mu \coloneqq 100(\beta^{-1}-1)$, discount factor	0.17	0.07	[0.06, 0.27]
Frictions			
α, price stickiness	0.79	0.04	[0.72, 0.86]
γ, price indexation	0.15	0.08	[0.03, 0.27]
Shocks			
ρ_d, preference	0.63	0.18	[0.35, 0.91]
ρ_a, technology	0.58	0.21	[0.24, 0.9]
ρ_u, cost-push	0.21	0.09	[0.05, 0.35]
ρ_s, transfers	0.69	0.07	[0.57, 0.8]
σ_g, govt spending	0.21	0.02	[0.18, 0.25]
σ_d, preference	1.71	0.89	[0.41, 3.03]
σ_a, technology	0.54	0.25	[0.19, 0.89]
σ_u, cost-push	0.18	0.02	[0.14, 0.22]
σ_s, transfers	1.01	0.09	[0.87, 1.15]
σ_R, monetary policy	0.22	0.02	[0.19, 0.25]
σ_τ, tax	0.7	0.07	[0.59, 0.81]
σ_π, inflation target	0.09	0.05	[0.3, 0.15]
σ_b, debt/output target	0.65	0.49	[0.17, 1.44]
Steady state			
$a \coloneqq 100(\bar{a}-1)$, technology	0.43	0.08	[0.31, 0.56]
$\pi \coloneqq 100(\bar{\pi}-1)$, inflation	1.1	0.1	[0.94, 1.26]

Table 6: Posterior distributions for estimated parameters (Regime F) - continued

Parameter	Posterior Mean	SD	90 percent credible set
$b \coloneqq 100\bar{b}$, debt/output	36.63	2.01	[33.33, 39.93]
$\tau \coloneqq 100\bar{\tau}$, tax/output	24.92	0.42	[24.26, 25.6]
$g \coloneqq 100\bar{g}$, govt spending/output	24.4	0.4	[23.78, 25.05]

Note: Means and standard deviations are over 50 independent runs of the SMC algorithm with $N = 14,000$, $N_\delta = 500$, $\lambda = 2.5$, $N_{blocks} = 6$, and $M_{MH} = 1$. We compute 90 % highest posterior density intervals.

PMPF regime



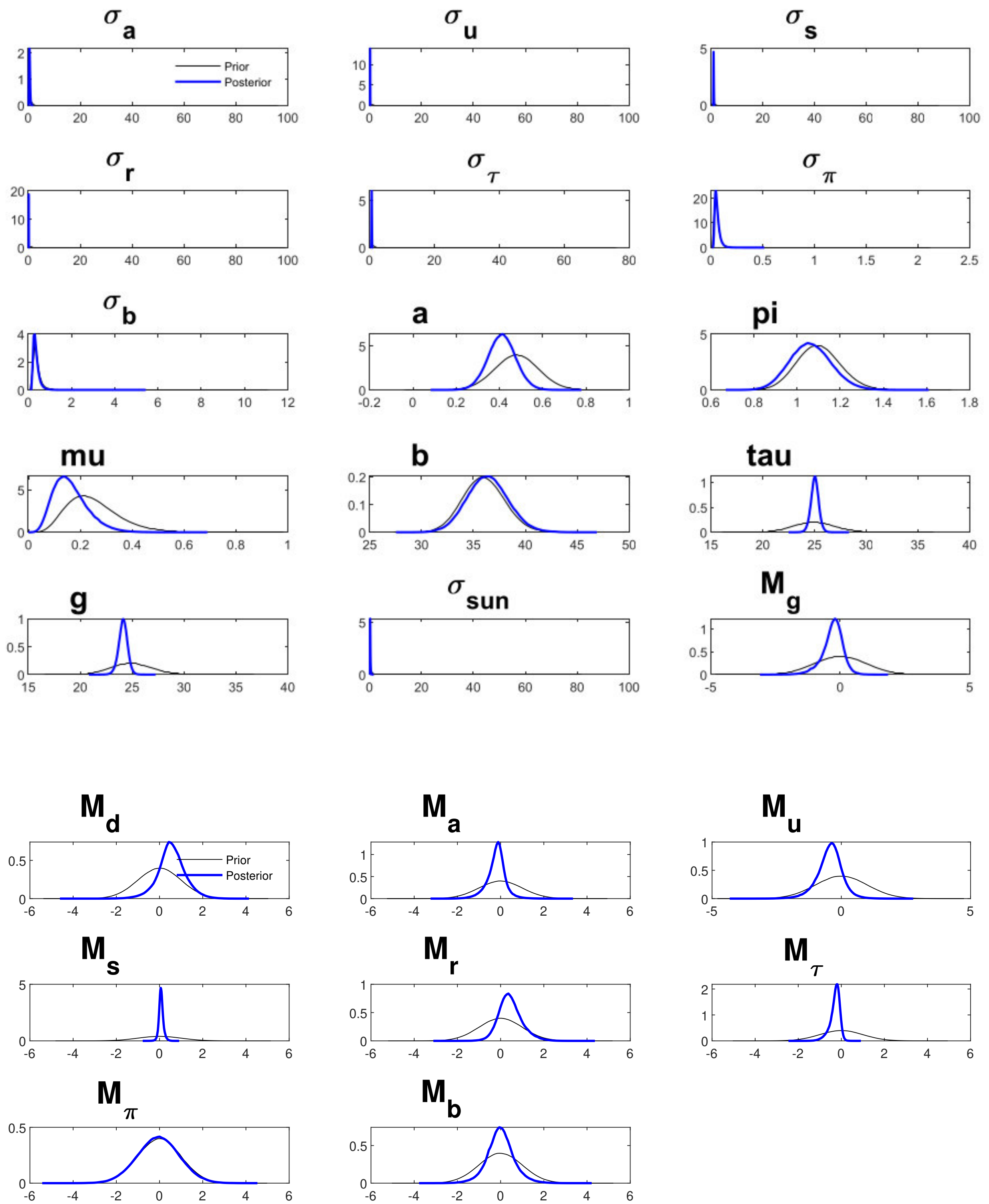


Figure 17: Prior and posterior densities of the estimated model parameters for the PMPF regime. The blue bold line depicts the posterior density, the black line the prior density. The prior densities are specified as in Bhattarai et al. (2016).

Table 7: Posterior distributions for estimated parameters (PMPF regime)

Parameter	Posterior Mean	SD	90 percent credible set
Monetary policy			
ϕ_π, interest rate response to inflation	0.31	0.15	[0.06, 0.56]
ϕ_π^*, distance to monetary boundary	0.71	0.05	[0.66, 0.79]
ϕ_Y, interest rate response to output	0.28	0.02	[0.25, 0.31]
ρ_R, response to lagged interest rate	0.7	0.03	[0.66, 0.74]
Fiscal policy			
ψ_b, tax response to lagged debt	0.05	0.02	[0.008, 0.08]
ψ_b^*, distance to fiscal boundary	0.05	0.01	[0.039, 0.055]
ψ_Y, tax response to output	0.71	0.03	[0.66, 0.77]
χ_Y, govt spending response to lagged output	0.44	0.07	[0.33, 0.54]
ρ_g, response to lagged govt spending	0.96	0.004	[0.957, 0.967]
ρ_τ, response to lagged taxes	0.5	0.03	[0.44, 0.54]
Preference and HHs			
η, habit formation	0.23	0.02	[0.21, 0.28]
$\mu := 100(\beta^{-1} - 1)$, discount factor	0.16	0.01	[0.14, 0.18]
Frictions			
α, price stickiness	0.68	0.02	[0.65, 0.72]
γ, price indexation	0.4	0.08	[0.3, 0.49]
Shocks			
ρ_d, preference	0.85	0.02	[0.82, 0.88]
ρ_a, technology	0.37	0.06	[0.27, 0.44]
ρ_u, cost-push	0.33	0.05	[0.27, 0.41]
ρ_s, transfers	0.75	0.02	[0.73, 0.77]
σ_g, govt spending	0.23	0.002	[0.226, 0.23]
σ_d, preference	0.29	0.02	[0.26, 0.32]
σ_a, technology	0.52	0.07	[0.42, 0.61]
σ_u, cost-push	0.21	0.006	[0.2, 0.21]
σ_s, transfers	1.02	0.008	[1, 1.03]
σ_R, monetary policy	0.18	0.006	[0.17, 0.19]
σ_τ, tax	0.62	0.01	[0.6, 0.64]
σ_π, inflation target	0.06	0.004	[0.05, 0.06]
σ_b, debt/output target	0.36	0.02	[0.32, 0.39]
Steady state			
$a := 100(\bar{a} - 1)$, technology	0.41	0.01	[0.39, 0.42]
$\pi := 100(\bar{\pi} - 1)$, inflation	1.06	0.02	[1.03, 1.07]

Table 7: Posterior distributions for estimated parameters (PMPF regime) - continued

	Posterior		
Parameter	Mean	SD	90 percent credible set
$b \coloneqq 100\bar{b}$, debt/output	36.4	0.31	[35.97, 36.77]
$\tau \coloneqq 100\bar{\tau}$, tax/output	25.06	0.09	[24.94, 25.17]
$g \coloneqq 100\bar{g}$, govt spending/output	24.13	0.08	[24.04, 24.28]
Indeterminacy			
σ_ζ, sunspot shock	0.26	0.05	[0.22, 0.3]
$M_{g\zeta}$	-0.29	0.11	[-0.43, -0.13]
$M_{d\zeta}$	0.6	0.2	[0.42, 0.92]
$M_{a\zeta}$	-0.2	0.08	[-0.34, -0.1]
$M_{u\zeta}$	-0.44	0.15	[-0.59, -0.25]
$M_{s\zeta}$	0.08	0.03	[0.03, 0.12]
$M_{R\zeta}$	0.43	0.18	[0.22, 0.68]
$M_{\tau\zeta}$	-0.3	0.1	[-0.46, -0.2]
$M_{\pi\zeta}$	-0.05	0.16	[-0.28, 0.26]
$M_{b\zeta}$	-0.006	0.13	[-0.18, 0.12]

Note: Means and standard deviations are over 50 independent runs of the SMC algorithm with $N = 14,000$, $N_\delta = 500$, $\lambda = 2.5$, $N_{blocks} = 6$, and $M_{MH} = 1$. We compute 90 % highest posterior density intervals.

Restricted estimation - prior as in Section 3 with renormalized policy parameters

In a next step, we conduct the restricted SMC estimation with the prior specification as outlined in Section 3. One exception is the prior specifications for the policy parameters ϕ_π and ψ_b. To ensure that we completely impose a particular policy regime during estimation, we again follow Bhattarai et al. (2016) and estimate the model with the reparameterized policy parameters ϕ_π^* and ψ_b^*. ϕ_π^* follows a Gamma distribution with a mean of 0.5 and a standard deviation of 0.2. ψ_b^* is also Gamma-distributed and has a mean of 0.05 and a standard deviation of 0.04. The prior densities of the remaining parameters are specified as in Section 3.

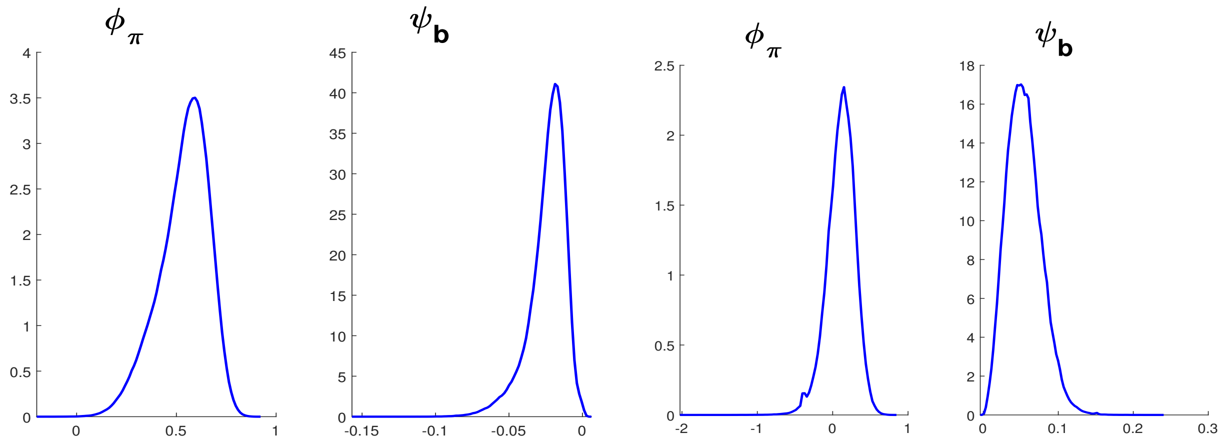
Table 8 shows the estimated marginal data densities of each regime. Also, with the prior specification of Section 3, we come to the conclusion, that in the US, in the pre-Volcker period, the PMPF regime receives the best support from the data.

Table 8: Log marginal data densities for each policy regime from restricted estimation

	AMPF	PMAF	PMPF
Log MDD	-548.72	-542.72	-523.17

Note: The log marginal data density is obtained as a by-product during the correction step of the SMC algorithm, see Herbst and Schorfheide (2014) for further details. For each regime, its mean is computed over 50 independent runs of the SMC algorithm.

Figure 18 shows plots of the posterior densities of the policy parameters for regime F and the PMPF regime. The shapes of the posterior densities are comparable to the findings in the previous subsection. The mean estimates for the Taylor-coefficient ϕ_π (regime F: 0.54; PMPF: 0.11) and ψ_b (regime F: -0.02; PMPF: 0.05) change only slightly. Hence, using, a for our exercise more suitable, prior specification together with SMC posterior sampling does not influence the estimation results.

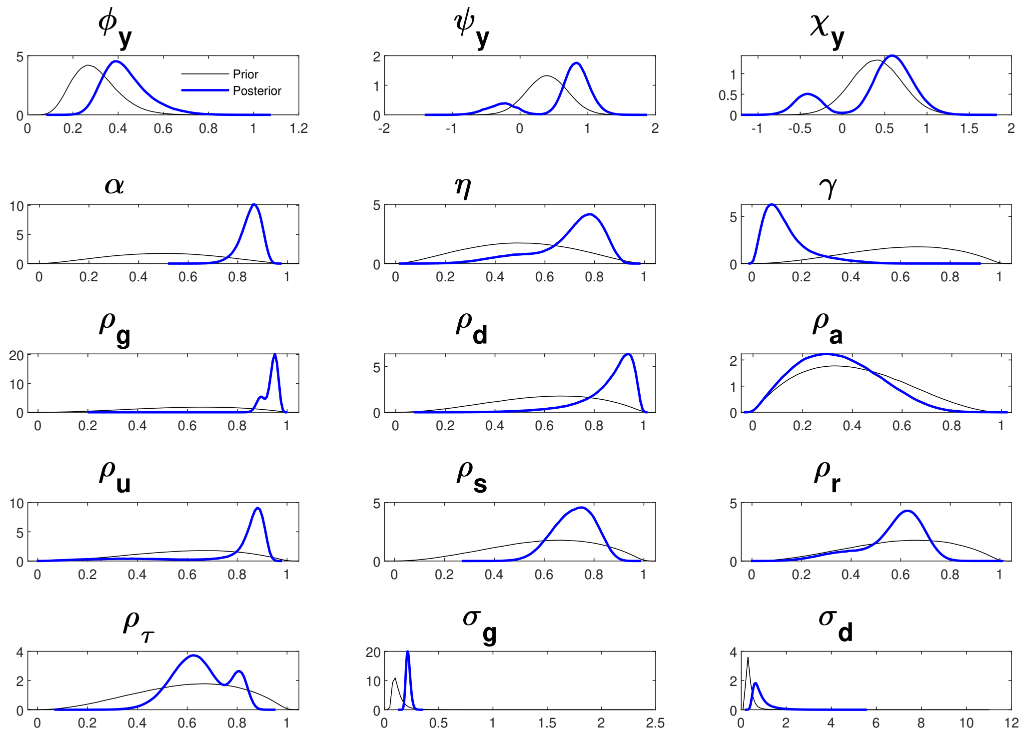


(a) Regime F (b) PMPF regime

Figure 18: Posterior densities of the policy parameters ϕ_π and ψ_b for regime F and the PMPF regime.

To make the results of the restricted estimation more comparable to the unrestricted estimation, we renormalized the policy parameters ϕ_π^* and ψ_b^* to ϕ_π and ψ_b in the density plots.

Regime F



ϕ_y
Prior
Posterior
ψ_y
χ_y
α
η
γ
ρ_g
ρ_d
ρ_a
ρ_u
ρ_s
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ρ_τ
σ_g
σ_d

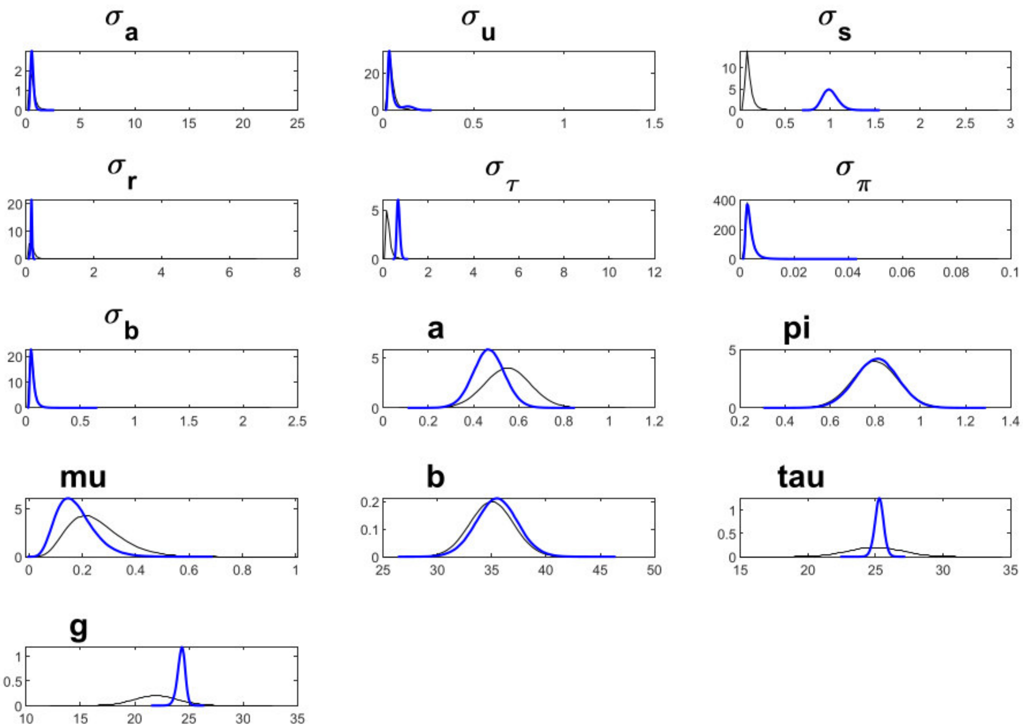


Figure 19: Prior and posterior densities of the estimated model parameters for regime F. The blue bold line depicts the posterior density, the black line the prior density. The densities of ϕ_π^* and ψ_b^* are specified as in Bhattarai et al. (2016), the remaining parameters as in Section 3.

Table 9: Posterior distributions for estimated parameters (Regime F)

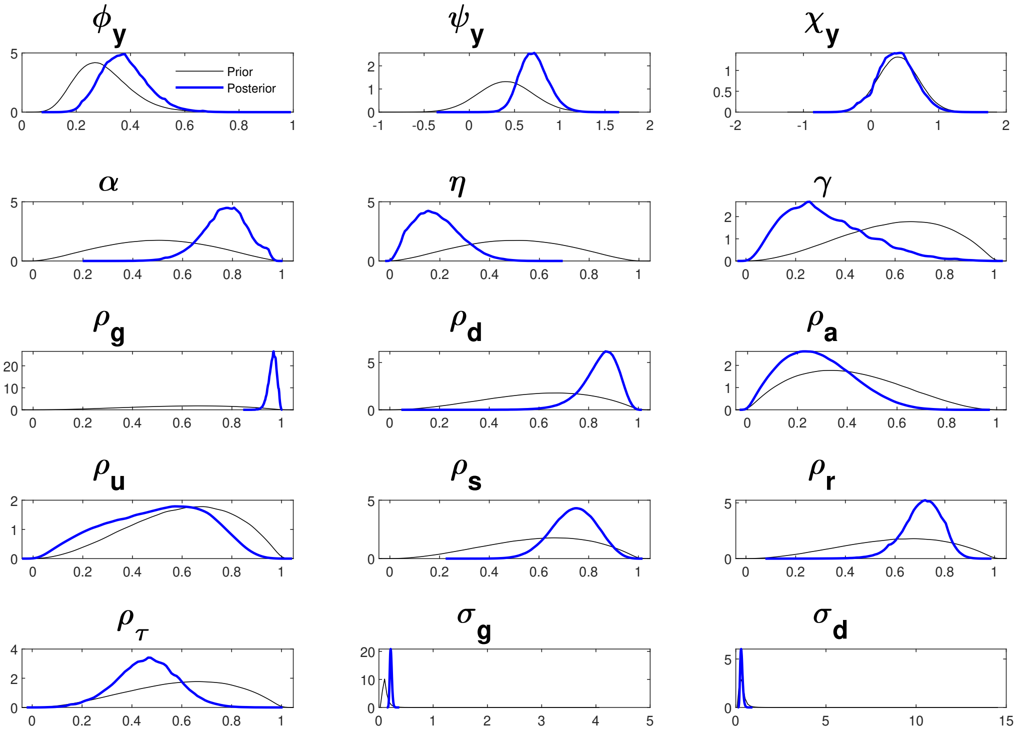
	Posterior		
Parameter	Mean	SD	90 percent credible set
Monetary policy			
ϕ_π, interest rate response to inflation	0.54	0.12	[0.33, 0.73]
ϕ_π^*, distance to monetary boundary	0.35	0.05	[0.31, 0.43]
ϕ_Y, interest rate response to output	0.44	0.06	[0.4, 0.54]
ρ_R, response to lagged interest rate	0.56	0.09	[0.38, 0.63]
Fiscal policy			
ψ_b, tax response to lagged debt	-0.02	0.01	[-0.04, -0.005]
ψ_b^*, distance to fiscal boundary	0.027	0.007	[0.02, 0.04]
ψ_Y, tax response to output	0.58	0.39	[-0.25, 0.86]
χ_Y, govt spending response to lagged output	0.38	0.36	[-0.38, 0.63]
ρ_g, response to lagged govt spending	0.93	0.02	[0.9, 0.95]
ρ_τ, response to lagged taxes	0.66	0.07	[0.61, 0.79]

Table 9: Posterior distributions for estimated parameters (Regime F) - continued

	Posterior		
Parameter	Mean	SD	90 percent credible set
Preference and HHs			
η, habit formation	0.69	0.1	[0.49, 0.78]
$\mu \coloneqq 100(\beta^{-1} - 1)$, discount factor	0.17	0.01	[0.16, 0.19]
Frictions			
α, price stickiness	0.85	0.02	[0.83, 0.86]
γ, price indexation	0.13	0.06	[0.09, 0.22]
Shocks			
ρ_d, preference	0.86	0.03	[0.82, 0.9]
ρ_a, technology	0.33	0.04	[0.26, 0.37]
ρ_u, cost-push	0.77	0.17	[0.45, 0.88]
ρ_s, transfers	0.72	0.03	[0.65, 0.74]
σ_g, govt spending	0.22	0.006	[0.21, 0.23]
σ_d, preference	0.87	0.14	[0.58, 1.03]
σ_a, technology	0.56	0.01	[0.55, 0.58]
σ_u, cost-push	0.06	0.03	[0.04, 0.12]
σ_s, transfers	1	0.003	[0.997, 1.01]
σ_R, monetary policy	0.15	0.01	[0.13, 0.16]
σ_τ, tax	0.68	0.03	[0.66, 0.72]
σ_π, inflation target	0.004	0	[0.0036, 0.0039]
σ_b, debt/output target	0.06	0.001	[0.059, 0.064]
Steady state			
$a \coloneqq 100(\bar{a} - 1)$, technology	0.47	0.007	[0.46, 0.48]
$\pi \coloneqq 100(\bar{\pi} - 1)$, inflation	0.81	0.02	[0.79, 0.83]
$b \coloneqq 100\bar{b}$, debt/output	35.5	0.16	[35.28, 35.62]
$\tau \coloneqq 100\bar{\tau}$, tax/output	25.26	0.12	[25.05, 25.36]
$g \coloneqq 100\bar{g}$, govt spending/output	24.31	0.09	[24.24, 24.45]

Note: Means and standard deviations are over 50 independent runs of the SMC algorithm with $N = 14,000$, $N_\delta = 500$, $\lambda = 2.5$, $N_{blocks} = 6$, and $M_{MH} = 1$. We compute 90 % highest posterior density intervals.

PMPF regime


ϕ_y
ψ_y
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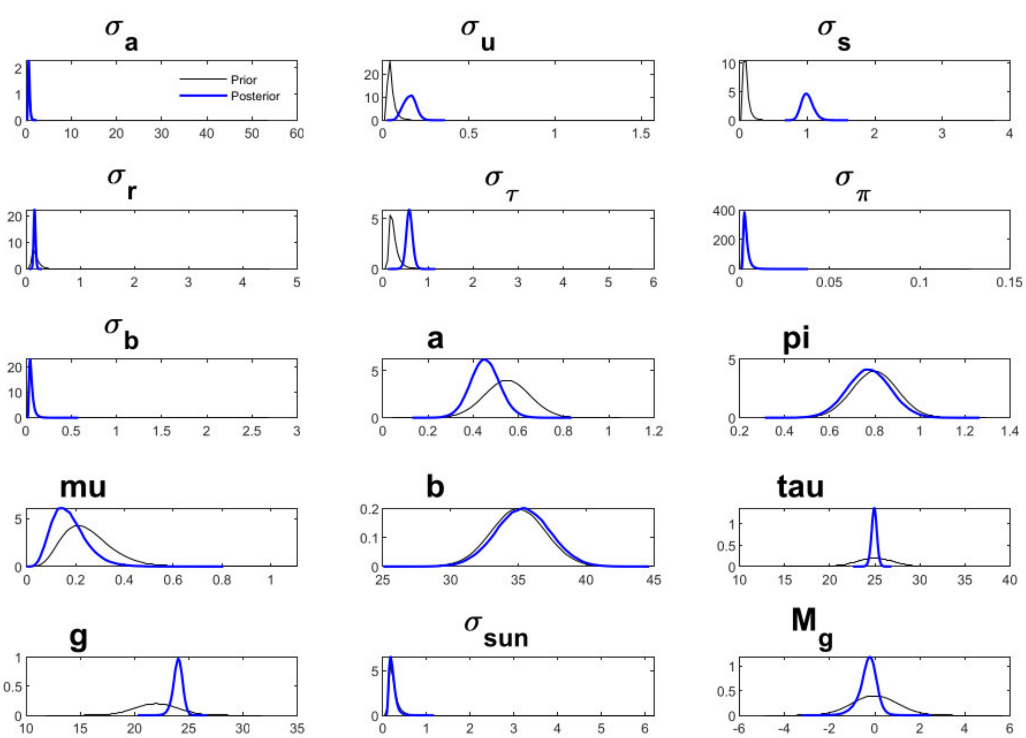
σ_a
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Prior
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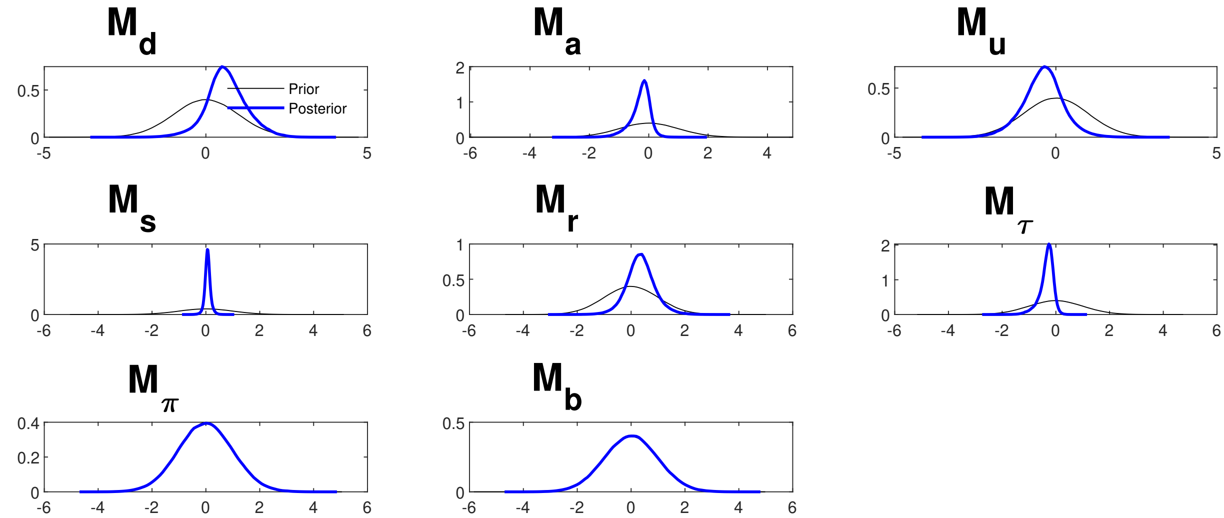


Figure 20: Prior and posterior densities of the estimated model parameters for the PMPF regime. The blue bold line depicts the posterior density, the black line the prior density. The densities of ϕ_π^* and ψ_b^* are specified as in Bhattarai et al. (2016), the remaining parameters as in Section 3.

Table 10: Posterior distributions for estimated parameters (PMPF regime)

	Posterior		
Parameter	Mean	SD	90 percent credible set
Monetary policy			
ϕ_π, interest rate response to inflation	0.11	0.19	[-0.18, 0.42]
ϕ_π^*, interest rate response to inflation	0.87	0.05	[0.83, 0.95]
ϕ_Y, interest rate response to output	0.39	0.02	[0.36, 0.41]
ρ_R, response to lagged interest rate	0.71	0.02	[0.69, 0.73]
Fiscal policy			
ψ_b, tax response to lagged debt	0.05	0.02	[0.02, 0.09]
ψ_b^*, distance to fiscal boundary	0.06	0.004	[0.05, 0.06]
ψ_Y, tax response to output	0.73	0.03	[0.7, 0.78]
χ_Y, govt spending response to lagged output	0.37	0.05	[0.29, 0.45]
ρ_g, response to lagged govt spending	0.97	0.002	[0.962, 0.969]
ρ_τ, response to lagged taxes	0.45	0.03	[0.4, 0.49]
Preference and HHs			
η, habit formation	0.19	0.02	[0.16, 0.21]
$\mu := 100(\beta^{-1} - 1)$, discount factor	0.17	0.01	[0.16, 0.19]

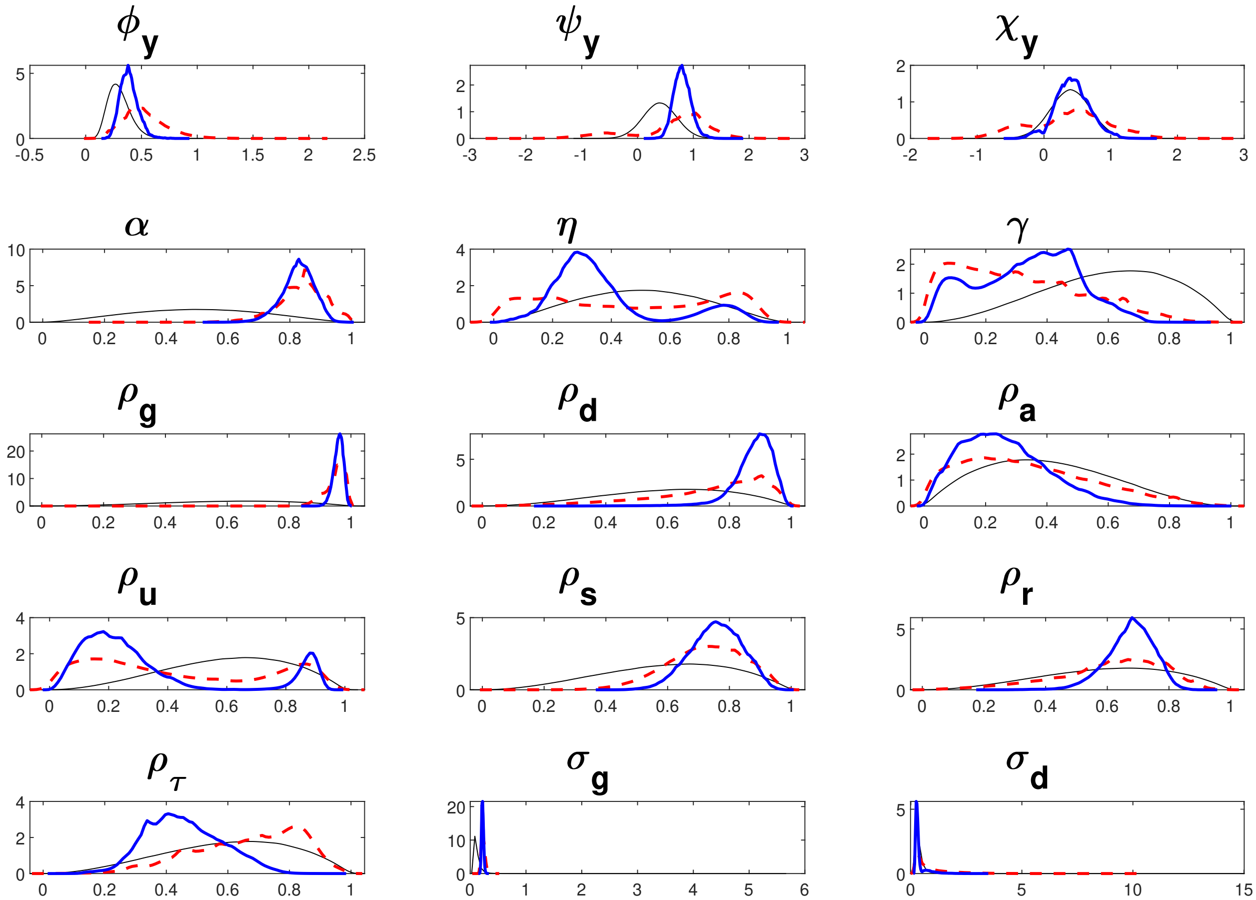
Table 10: Posterior distributions for estimated parameters (PMPF regime) - continued

	Posterior		
Parameter	Mean	SD	90 percent credible set
Frictions			
α, price stickiness	0.77	0.02	[0.74, 0.79]
γ, price indexation	0.31	0.04	[0.22, 0.35]
Shocks			
ρ_d, preference	0.85	0.01	[0.83, 0.87]
ρ_a, technology	0.26	0.02	[0.22, 0.29]
ρ_u, cost-push	0.48	0.07	[0.38, 0.59]
ρ_s, transfers	0.74	0.01	[0.73, 0.76]
σ_g, govt spending	0.22	0.001	[0.219, 0.222]
σ_d, preference	0.31	0.01	[0.29, 0.33]
σ_a, technology	0.69	0.05	[0.63, 0.73]
σ_u, cost-push	0.16	0.01	[0.15, 0.18]
σ_s, transfers	1.01	0.006	[0.99, 1.01]
σ_R, monetary policy	0.16	0.003	[0.155, 0.163]
σ_τ, tax	0.59	0.01	[0.57, 0.6]
σ_π, inflation target	0.004	0	[0.003, 0.004]
σ_b, debt/output target	0.06	0.004	[0.056, 0.068]
Steady state			
$a \coloneqq 100(\bar{a}-1)$, technology	0.45	0.008	[0.44, 0.46]
$\pi \coloneqq 100(\bar{\pi}-1)$, inflation	0.77	0.01	[0.75, 0.79]
$b \coloneqq 100\bar{b}$, debt/output	35.4	0.26	[35.02, 35.75]
$\tau \coloneqq 100\bar{\tau}$, tax/output	24.01	0.06	[24.82, 24.99]
$g \coloneqq 100\bar{g}$, govt spending/output	23.99	0.05	[23.93, 24.08]
Indeterminacy			
σ_ζ, sunspot shock	0.22	0.01	[0.21, 0.23]
$M_{g\zeta}$	-0.28	0.06	[-0.37, -0.2]
$M_{d\zeta}$	0.67	0.13	[0.48, 0.85]
$M_{a\zeta}$	-0.26	0.07	[-0.35, -0.19]
$M_{u\zeta}$	-0.41	0.09	[-0.54, -0.4]
$M_{s\zeta}$	0.07	0.02	[0.04, 0.09]
$M_{R\zeta}$	0.34	0.08	[0.24, 0.47]
$M_{\tau\zeta}$	-0.35	0.08	[-0.46, -0.25]
$M_{\pi\zeta}$	-0.02	0.1	[-0.18, 0.15]
$M_{b\zeta}$	0	0.03	[-0.11, 0.14]

Note: Means and standard deviations are over 50 independent runs of the SMC algorithm with $N = 14,000$, $N_\delta = 500$, $\lambda = 2.5$, $N_{blocks} = 6$, and $M_{MH} = 1$. We compute 90 % highest posterior density intervals.

Appendix E.2 Unrestricted estimation

Here we show plots of the prior and posterior densities for the remaining parameters from the unrestricted estimation with the SMC and RWMH sampler and tables that summarize the estimation results. Here, the prior specification and the estimation approach corresponds to the description in Section 3.



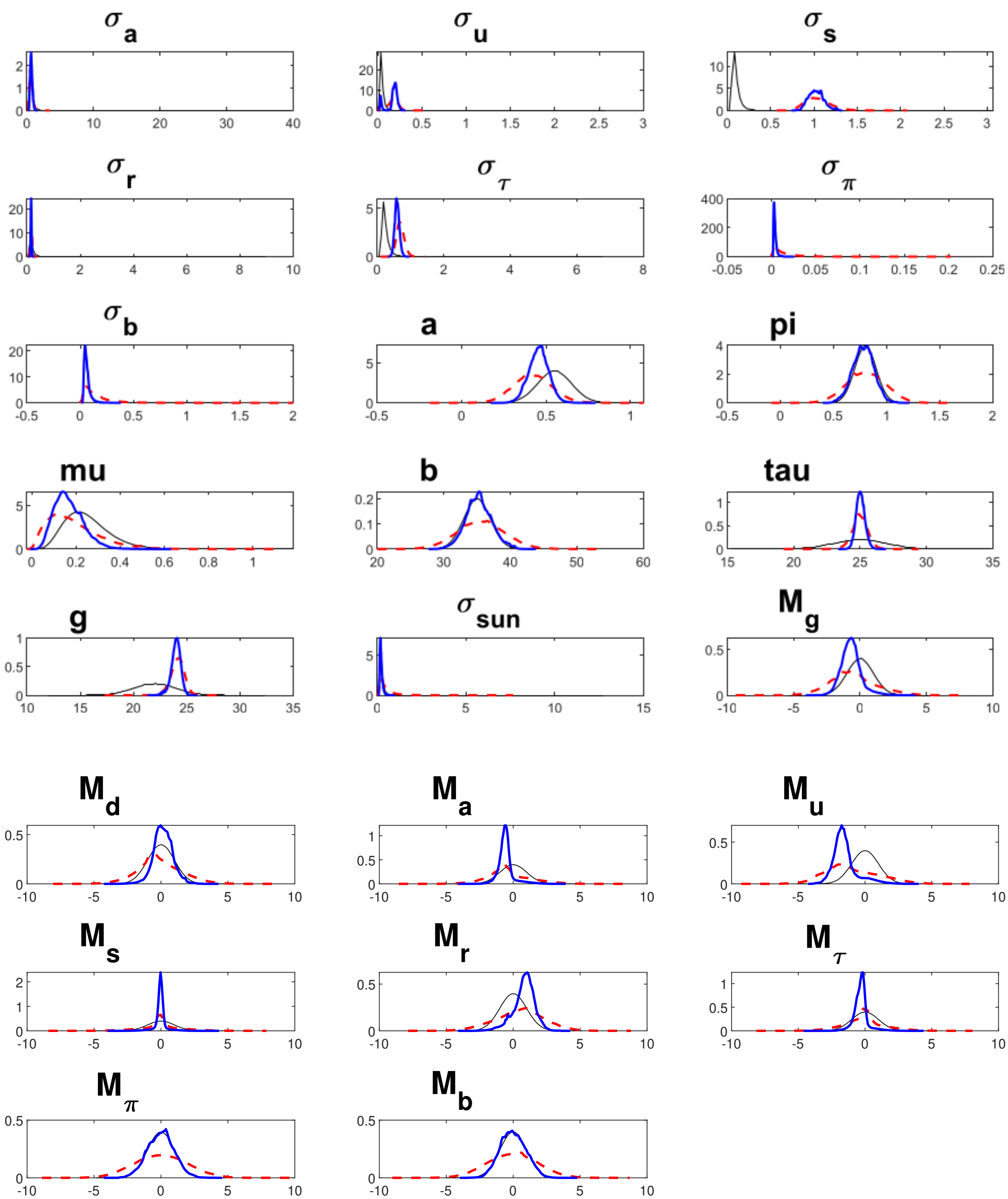


Figure 21: Prior and posterior densities of the estimated model parameters from the unrestricted estimation with SMC and RWMH. The red dashed line depicts the SMC posterior density, the blue solid line depicts the posterior density from RWMH sampling, and the black line the prior density.

Table 11: Posterior distributions, SMC estimation (Unrestricted)

	Posterior		
Parameter	Mean	SD	90 percent credible set
Monetary policy			
ϕ_π, interest rate response to inflation	0.4	0.22	[0.13, 0.73]
ϕ_Y, interest rate response to output	0.53	0.1	[0.4, 0.67]
ρ_R, response to lagged interest rate	0.61	0.11	[0.38, 0.74]
Fiscal policy			
ψ_b, tax response to lagged debt	0.026	0.04	[-0.05, 0.08]
ψ_Y, tax response to output	0.62	0.5	[-0.51, 1.05]
χ_Y, govt spending response to lagged output	0.38	0.35	[-0.25, 0.86]
ρ_g, response to lagged govt spending	0.95	0.02	[0.91, 0.97]
ρ_τ, response to lagged taxes	0.66	0.11	[0.5, 0.81]
Preference and HHs			
η, habit formation	0.45	0.23	[0.20, 0.81]
$\mu := 100(\beta^{-1} - 1)$, discount factor	0.19	0.04	[0.14, 0.22]
Frictions			
α, price stickiness	0.84	0.04	[0.8, 0.92]
γ, price indexation	0.31	0.12	[0.12, 0.44]
Shocks			
ρ_d, preference	0.73	0.11	[0.52, 0.87]
ρ_a, technology	0.33	0.08	[0.22, 0.41]
ρ_u, cost-push	0.41	0.2	[0.15, 0.71]
ρ_s, transfers	0.72	0.04	[0.64, 0.77]
σ_g, govt spending	0.23	0.01	[0.22, 0.24]
σ_d, preference	0.88	0.61	[0.31, 1.78]
σ_a, technology	0.62	0.09	[0.52, 0.72]
σ_u, cost-push	0.15	0.05	[0.09, 0.22]
σ_s, transfers	1.04	0.02	[1, 1.06]
σ_R, monetary policy	0.16	0.02	[0.13, 0.18]
σ_τ, tax	0.7	0.05	[0.64, 0.77]
σ_π, inflation target	0.006	0.006	[0.008, 0.02]
σ_b, debt/output target	0.15	0.05	[0.11, 0.2]
Steady state			
$a := 100(\bar{a} - 1)$, technology	0.42	0.03	[0.39, 0.45]
$\pi := 100(\bar{\pi} - 1)$, inflation	0.8	0.05	[0.74, 0.87]
$b := 100\bar{b}$, debt/output	35.62	0.79	[34.74, 36.44]
$\tau := 100\bar{\tau}$, tax/output	24.97	0.18	[24.68, 25.2]

Table 11: Posterior distributions, SMC estimation (Unrestricted) - continued

Parameter	Posterior Mean	SD	90 percent credible set
$g \coloneqq 100\bar{g}$, govt spending/output	24.12	0.21	[23.82, 24.48]
Indeterminacy			
σ_ζ, sunspot shock	0.49	0.14	[0.27, 0.68]
$M_{g\zeta}$	-0.58	0.58	[-1.43, 0.03]
$M_{d\zeta}$	-0.11	0.35	[-0.69, 0.33]
$M_{a\zeta}$	-0.41	0.43	[-0.94, 0.17]
$M_{u\zeta}$	-1.09	0.98	[-2.37, 0.03]
$M_{s\zeta}$	-0.04	0.14	[-0.28, 0.16]
$M_{R\zeta}$	0.5	0.64	[-0.21, 1.22]
$M_{\tau\zeta}$	-0.13	0.38	[-0.7, 0.22]
$M_{\pi\zeta}$	0	0.45	[-0.54, 0.46]
$M_{b\zeta}$	-0.07	0.29	[-0.34, 0.45]

Note: Means, standard deviations, and 90 % highest posterior density intervals are over 50 independent runs of the SMC algorithm with $N = 20,000$, $N_\delta = 600$, $\lambda = 2.4$, $N_{blocks} = 10$, and $M_{MH} = 2$.

Table 12: Posterior distributions, RWMH estimation (Unrestricted)

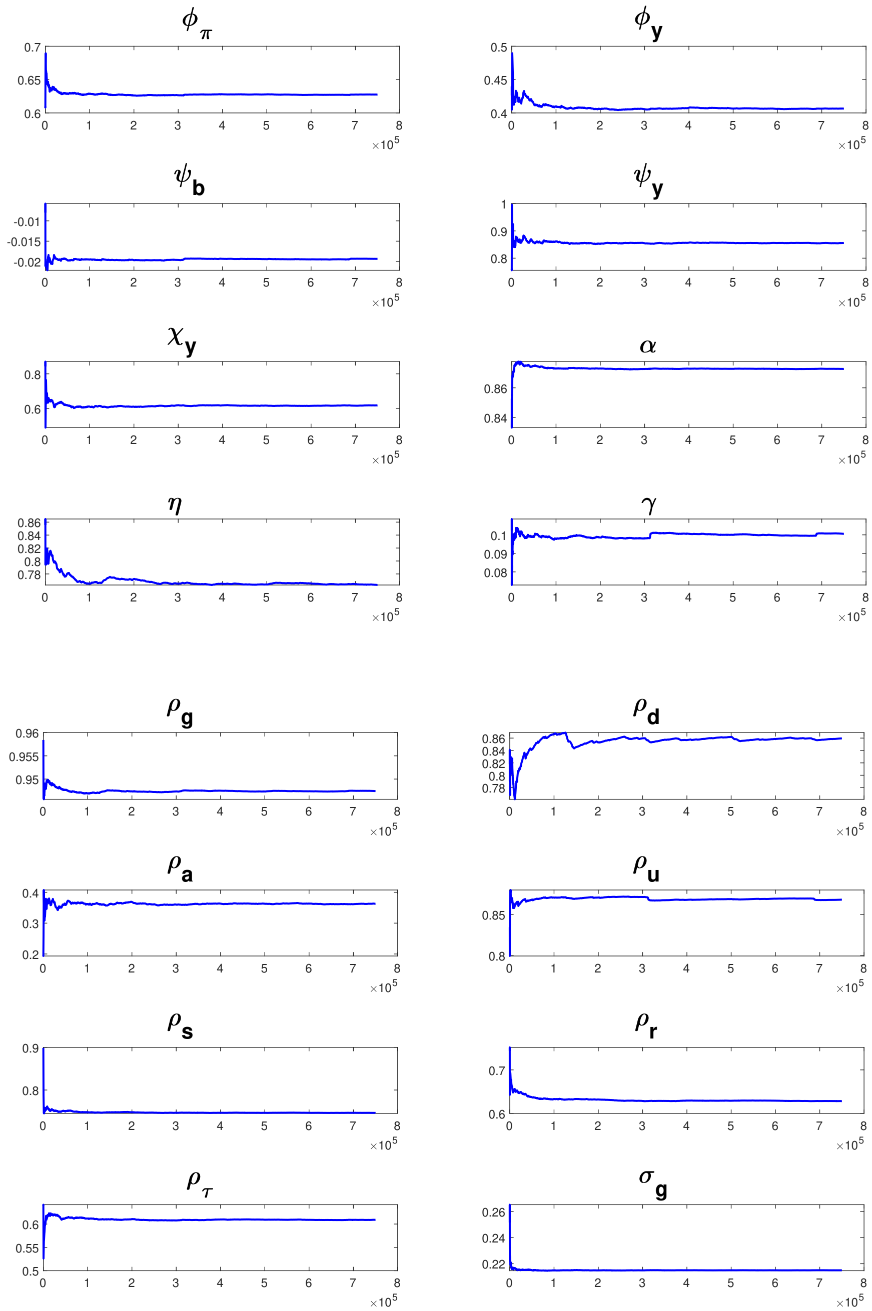
Parameter	Posterior Mean	SD	90 percent credible set
Monetary policy			
ϕ_π, interest rate response to inflation	0.22	0.21	[0.00, 0.61]
ϕ_Y, interest rate response to output	0.39	0.08	[0.26, 0.52]
ρ_R, response to lagged interest rate	0.67	0.076	[0.56, 0.8]
Fiscal policy			
ψ_b, tax response to lagged debt	0.051	0.037	[-0.026, 0.096]
ψ_Y, tax response to output	0.8	0.15	[0.55, 1.051]
χ_Y, govt spending response to lagged output	0.43	0.26	[0.036, 0.88]
ρ_g, response to lagged govt spending	0.96	0.016	[0.93, 0.99]
ρ_τ, response to lagged taxes	0.46	0.12	[0.26, 0.66]
Preference and HHs			
η, habit formation	0.38	0.19	[0.16, 0.8]
$\mu \coloneqq 100(\beta^{-1} - 1)$, discount factor	0.17	0.065	[0.062, 0.26]

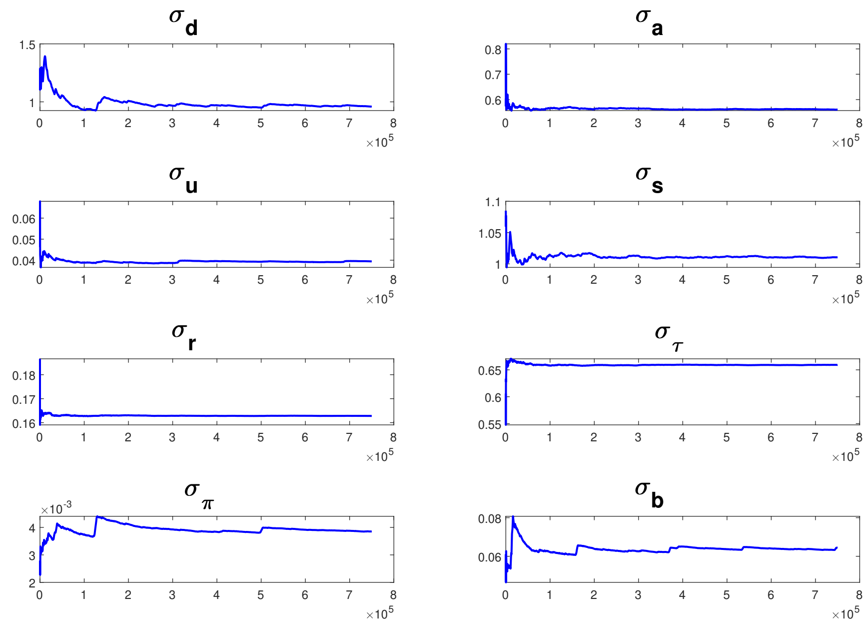
Table 12: Posterior distributions, RWMH estimation (Unrestricted) - continued

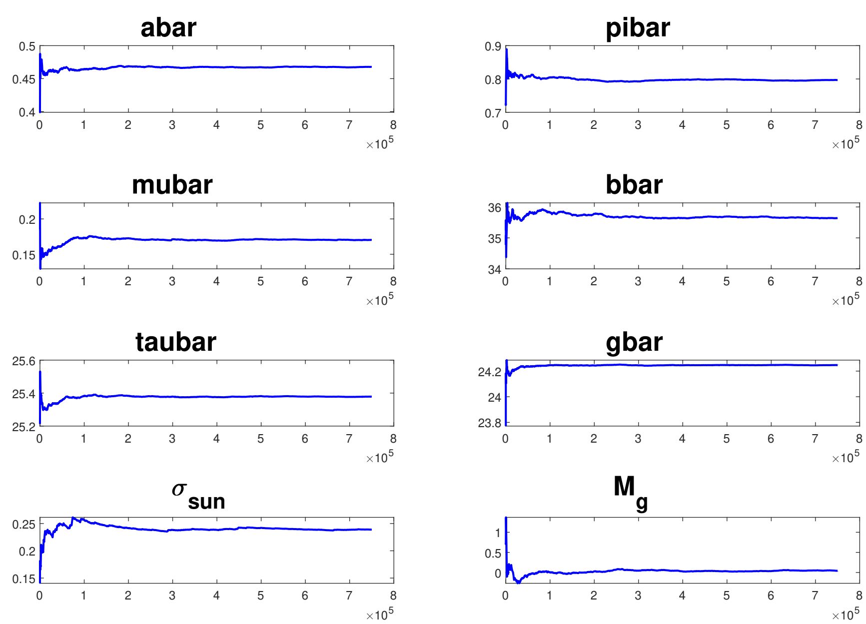
	Posterior		
Parameter	Mean	SD	90 percent credible set
Frictions			
α, price stickiness	0.83	0.052	[0.74, 0.91]
γ, price indexation	0.34	0.16	[0.034, 0.55]
Shocks			
ρ_d, preference	0.88	0.067	[0.79, 0.97]
ρ_a, technology	0.26	0.14	[0.031, 0.47]
ρ_u, cost-push	0.32	0.26	[0.077, 0.9]
ρ_s, transfers	0.76	0.083	[0.62, 0.9]
σ_g, govt spending	0.22	0.019	[0.19, 0.25]
σ_d, preference	0.39	0.31	[0.16, 0.78]
σ_a, technology	0.65	0.17	[0.39, 0.92]
σ_u, cost-push	0.17	0.063	[0.027, 0.23]
σ_s, transfers	1.03	0.087	[0.87, 1.15]
σ_R, monetary policy	0.16	0.02	[0.13, 0.19]
σ_τ, tax	0.6	0.07	[0.48, 0.71]
σ_π, inflation target	0.0037	0.0019	[0.0016, 0.0058]
σ_b, debt/output target	0.064	0.033	[0.027, 0.1]
Steady state			
$a \coloneqq 100(\bar{a}-1)$, technology	0.46	0.059	[0.36, 0.55]
$\pi \coloneqq 100(\bar{\pi}-1)$, inflation	0.78	0.1	[0.62, 0.95]
$b \coloneqq 100\bar{b}$, debt/output	35.27	1.96	[31.98, 38.46]
$\tau \coloneqq 100\bar{\tau}$, tax/output	25.03	0.33	[24.49, 25.58]
$g \coloneqq 100\bar{g}$, govt spending/output	23.99	0.44	[23.3, 24.7]
Indeterminacy			
σ_ζ, sunspot shock	0.22	0.08	[0.11, 0.32]
$M_{g\zeta}$	-0.69	0.74	[-1.95, 0.37]
$M_{d\zeta}$	0.16	0.71	[-0.96, 1.33]
$M_{a\zeta}$	-0.57	0.57	[-1.56, 0.14]
$M_{u\zeta}$	-1.53	0.91	[-2.96, 0.0072]
$M_{s\zeta}$	-0.034	0.42	[-0.59, 0.52]
$M_{R\zeta}$	0.8	0.79	[-0.57, 2]
$M_{\tau\zeta}$	-0.32	0.53	[-1.23, 0.34]
$M_{\pi\zeta}$	-0.0095	0.99	[-1.62, 1.63]
$M_{b\zeta}$	-0.0053	0.95	[-1.51, 1.6]

Note: Means, standard deviations, and 90 % highest posterior density intervals are over 12 independent RWMH runs à ten million draws from which we discard seven million respectively as burn-in.

RWMH convergence diagnostics - mode initialization in regime F




σ d
σ a
σ u
σ s
σ r
σ τ
σ π
σ b
×10^5
×10^-3


abar
pibar
mubar
bbar
taubar
gbar
σ sun
M g
×10^5

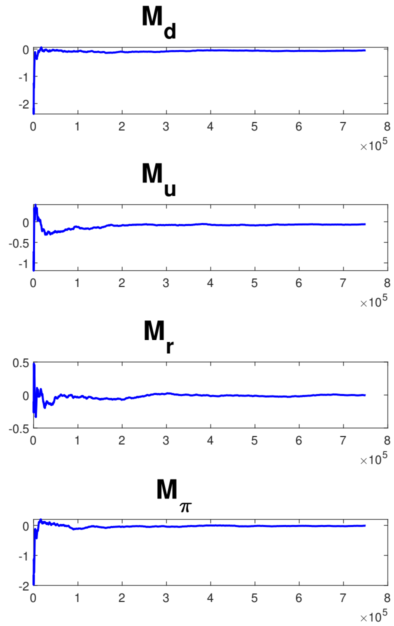
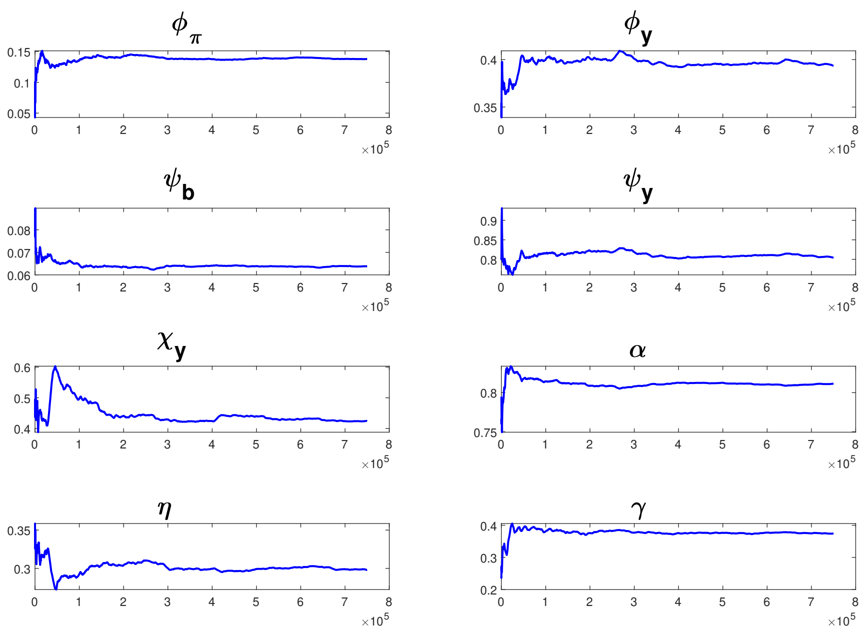
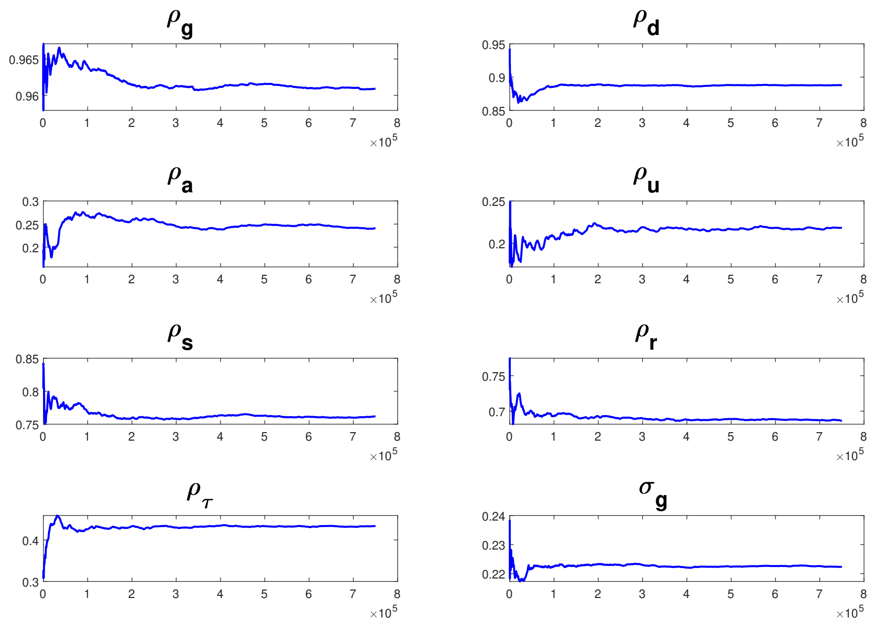
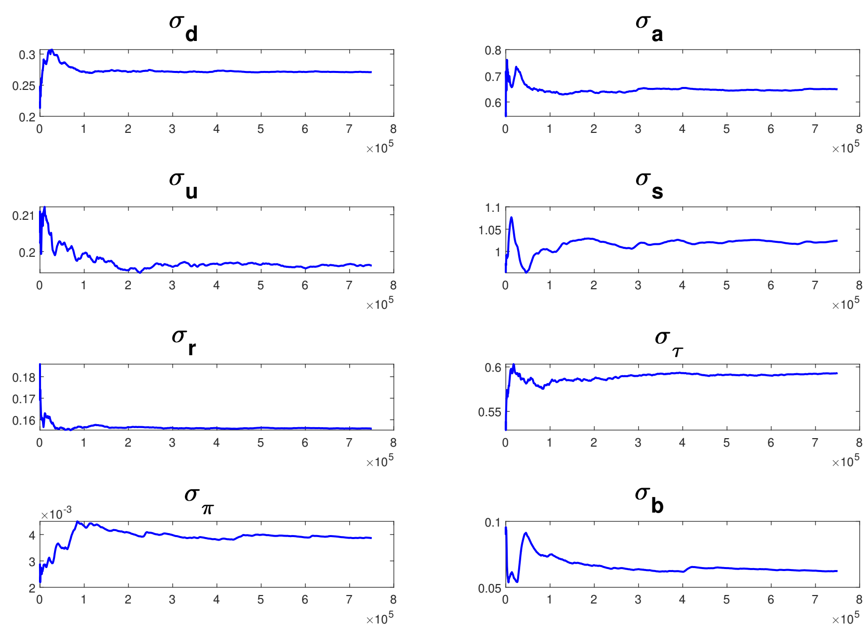


Figure 22: Recursive means - for RWMH runs initialized at the mode of regime F

RWMH convergence diagnostics - mode initialization in the indeterminacy regime




ρ_g
ρ_d
ρ_a
ρ_u
ρ_s
ρ_r
ρ_τ
σ_g


σ_d
σ_a
σ_u
σ_s
σ_r
σ_τ
σ_π
σ_b

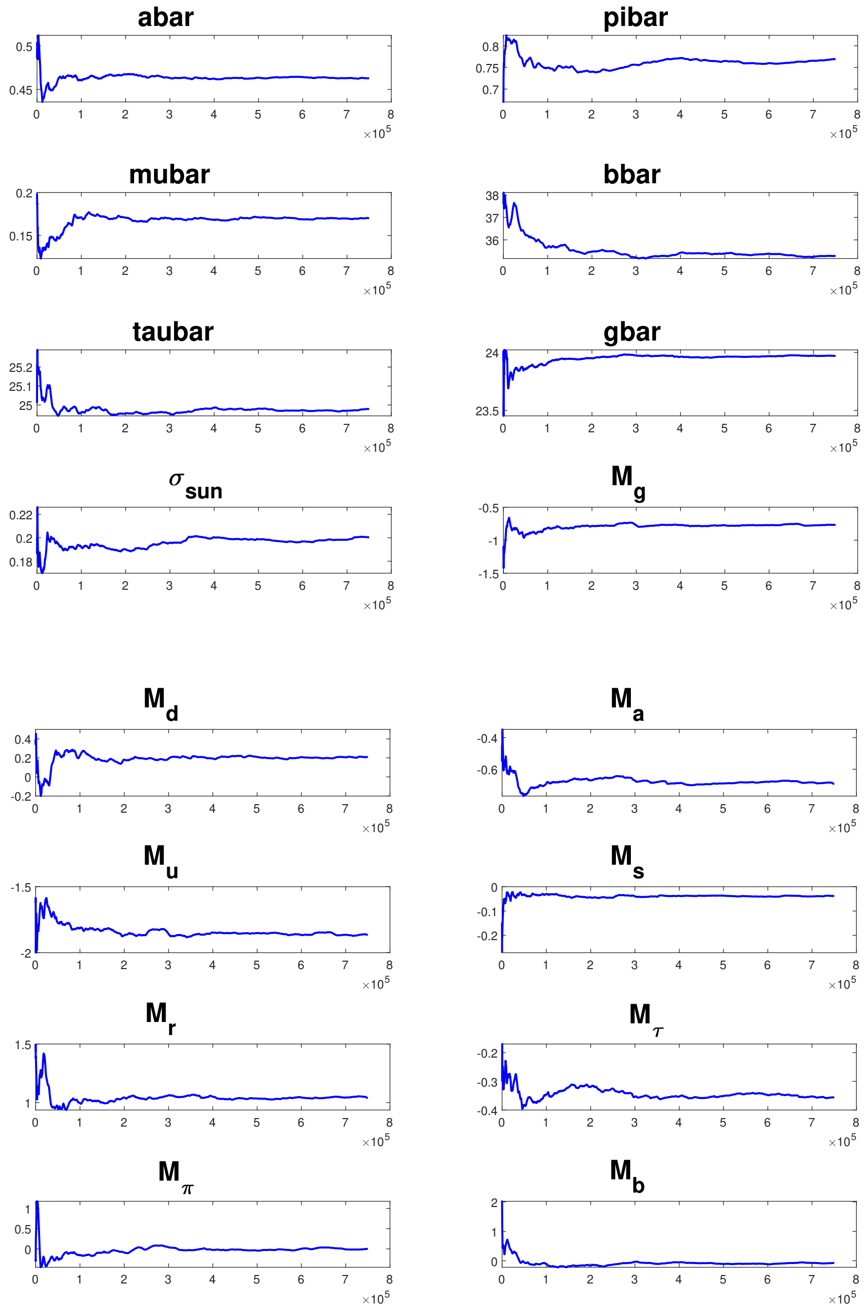
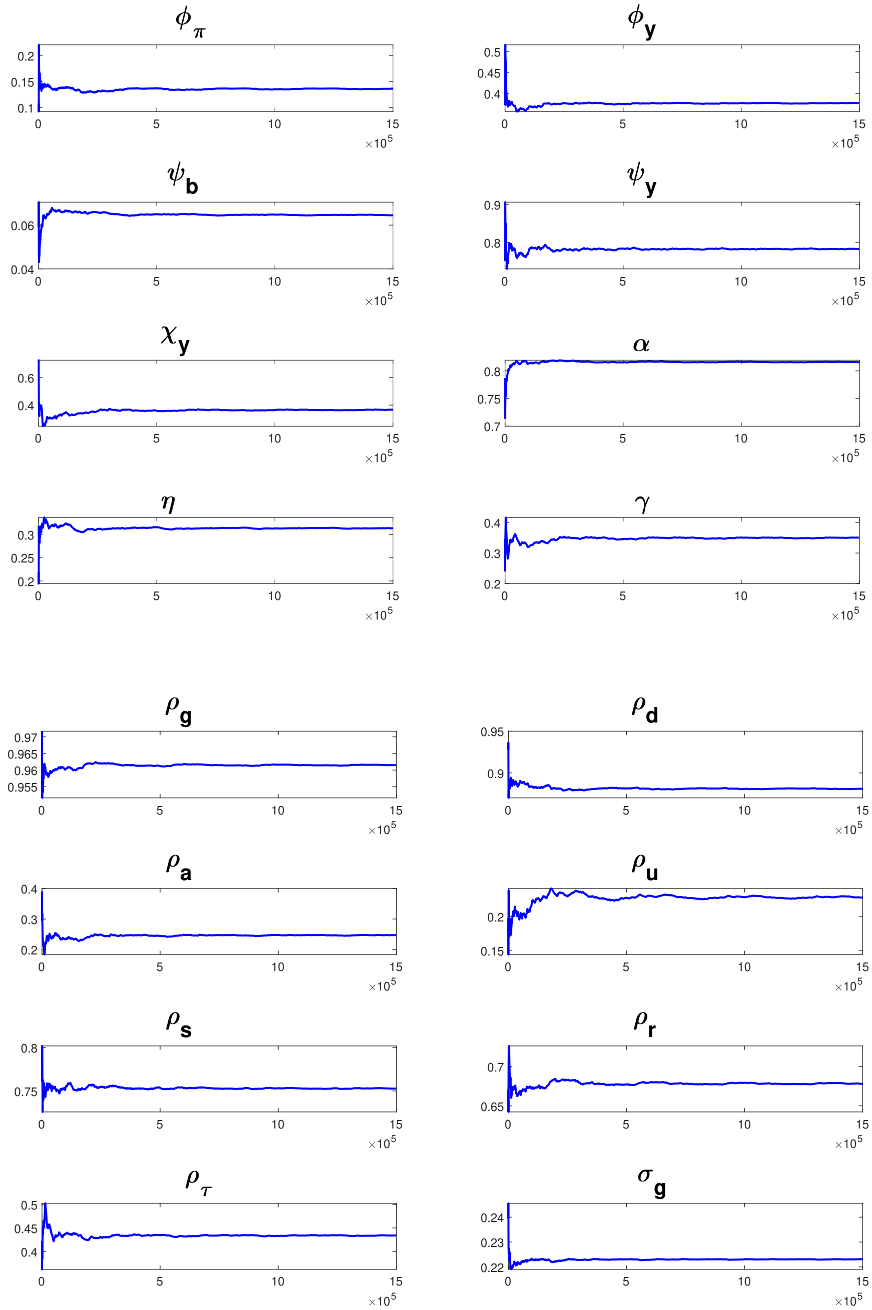
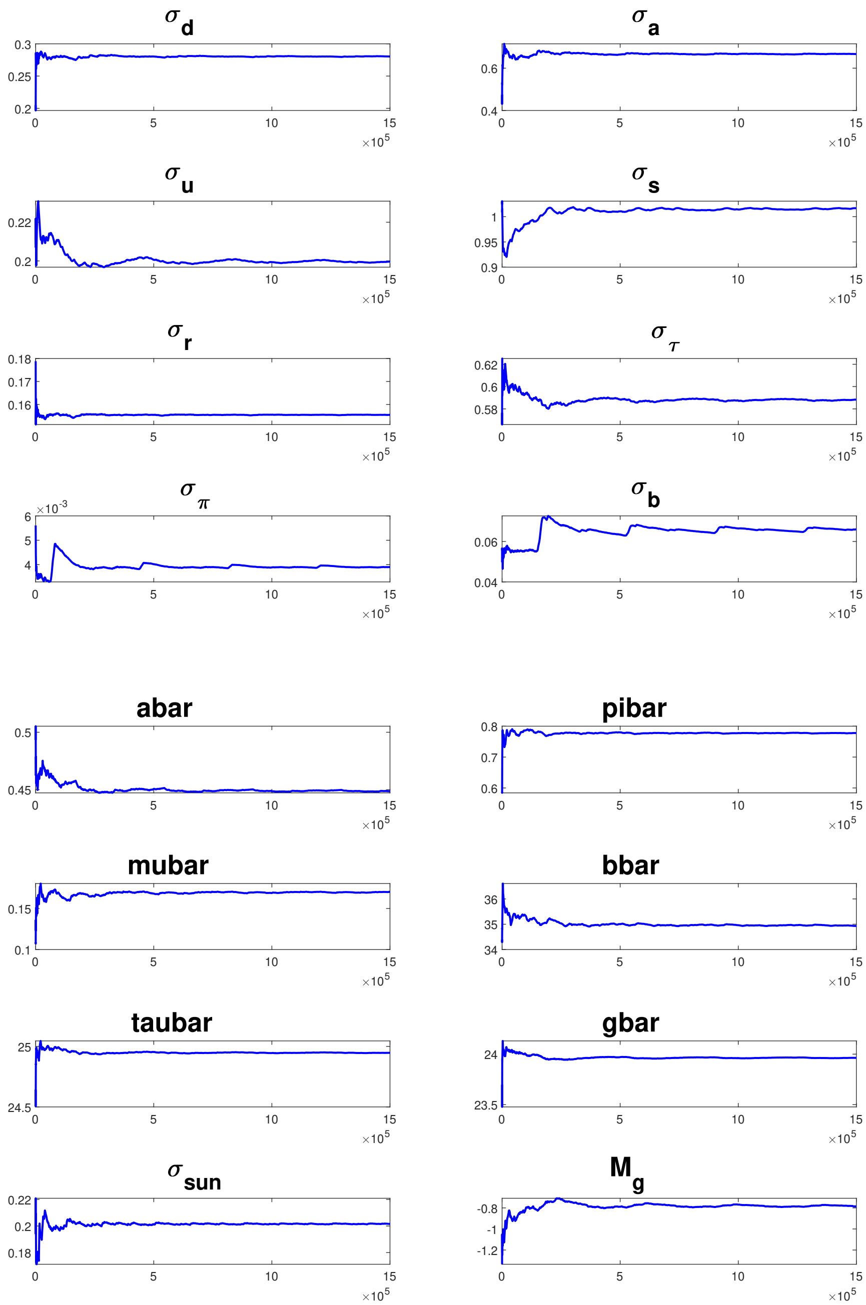


Figure 23: Recursive means - for RWMH runs initialized at the mode of regime PMPF

RWMH convergence diagnostics - random initialization in regime F




σ d
σ a
σ u
σ s
σ r
σ τ
σ π
σ b
abar
pibar
mubar
bbar
taubar
gbar
σ sun
M g
×10^5
×10^-3

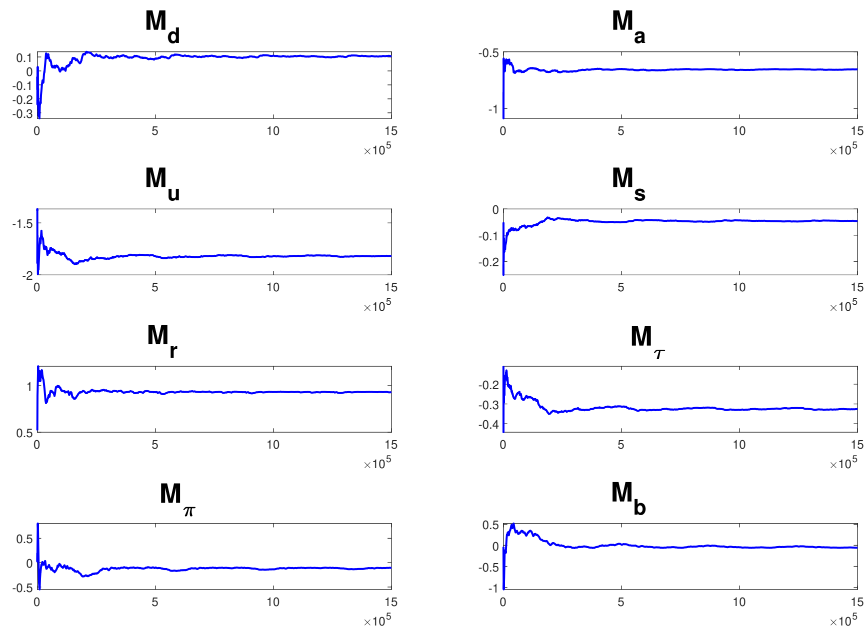
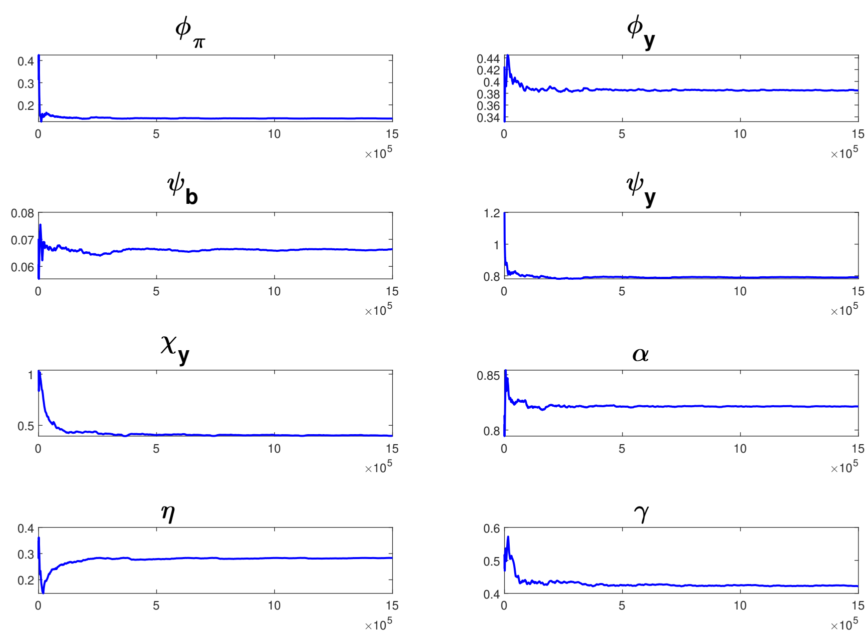
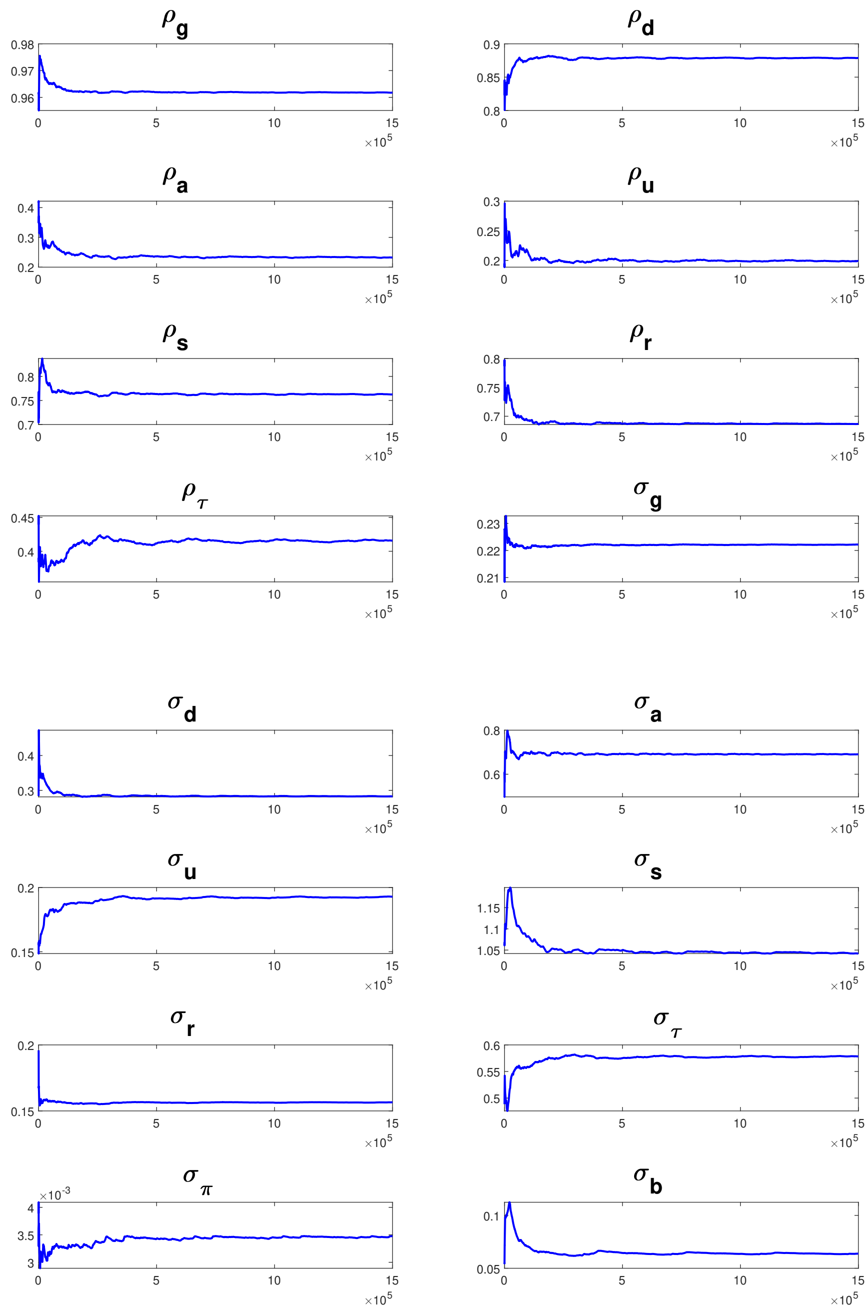


Figure 24: Recursive means - for RWMH runs initialized at a random value in regime F

RWMH convergence diagnostics - random initialization in the indeterminacy regime




ρg
ρd
ρa
ρu
ρs
ρr
ρτ
σg
σd
σa
σu
σs
σr
στ
σπ
σb

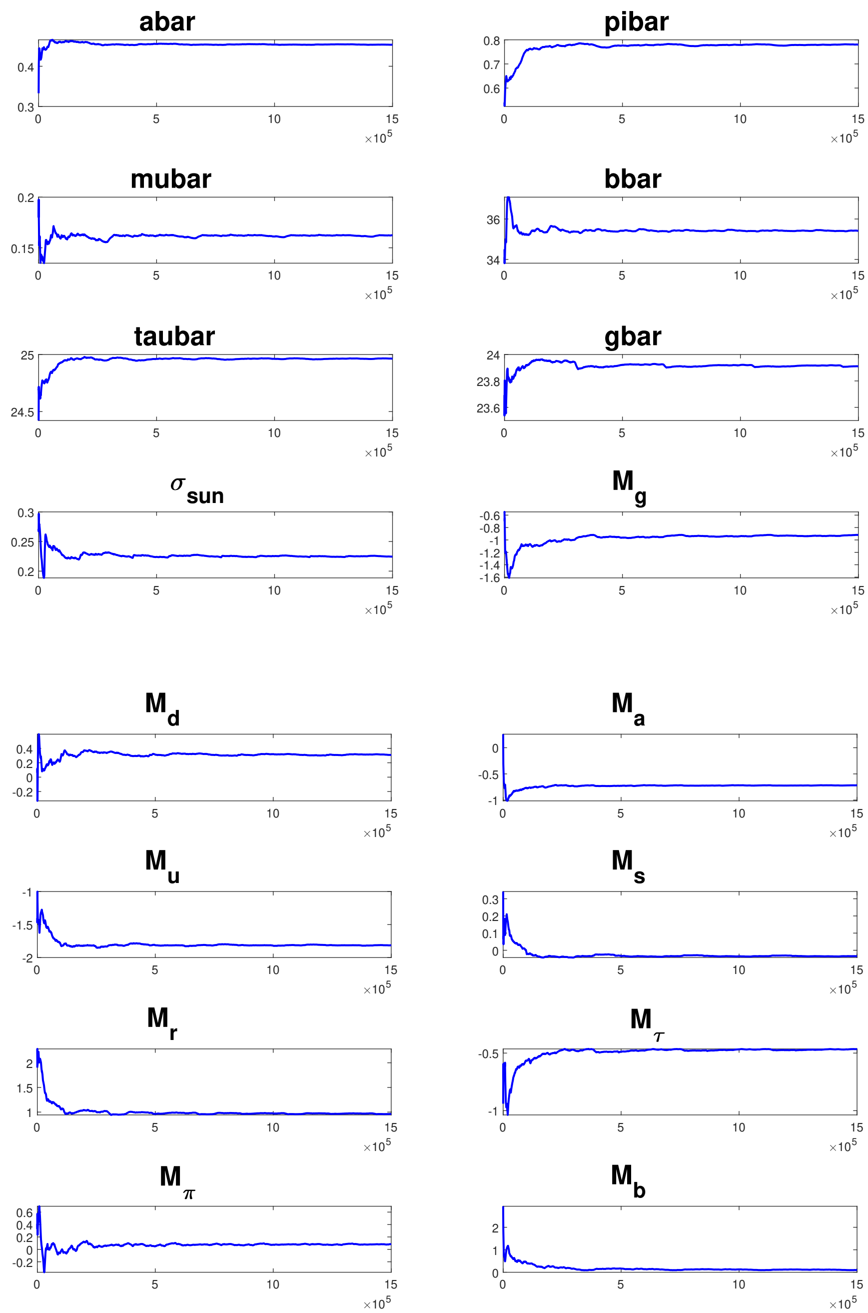
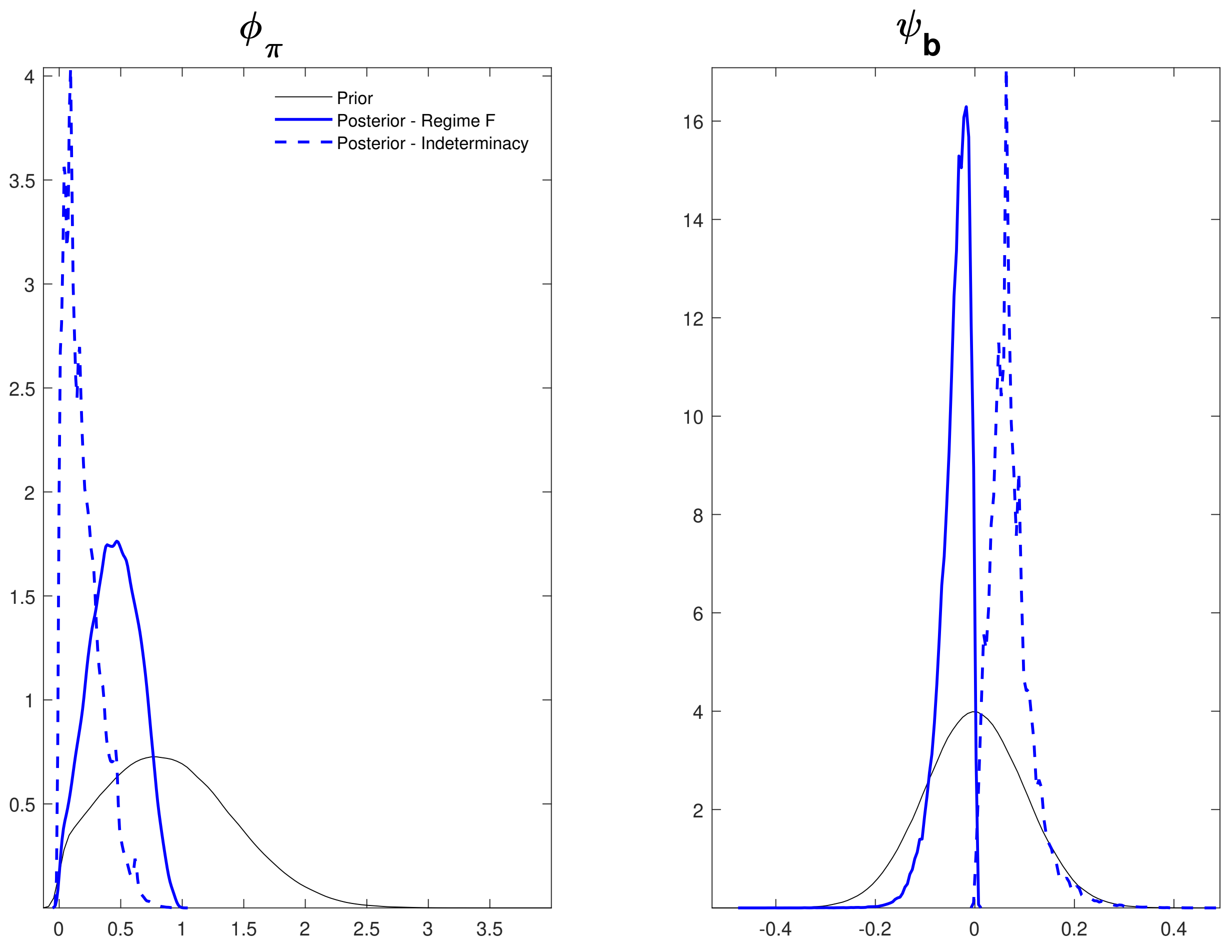
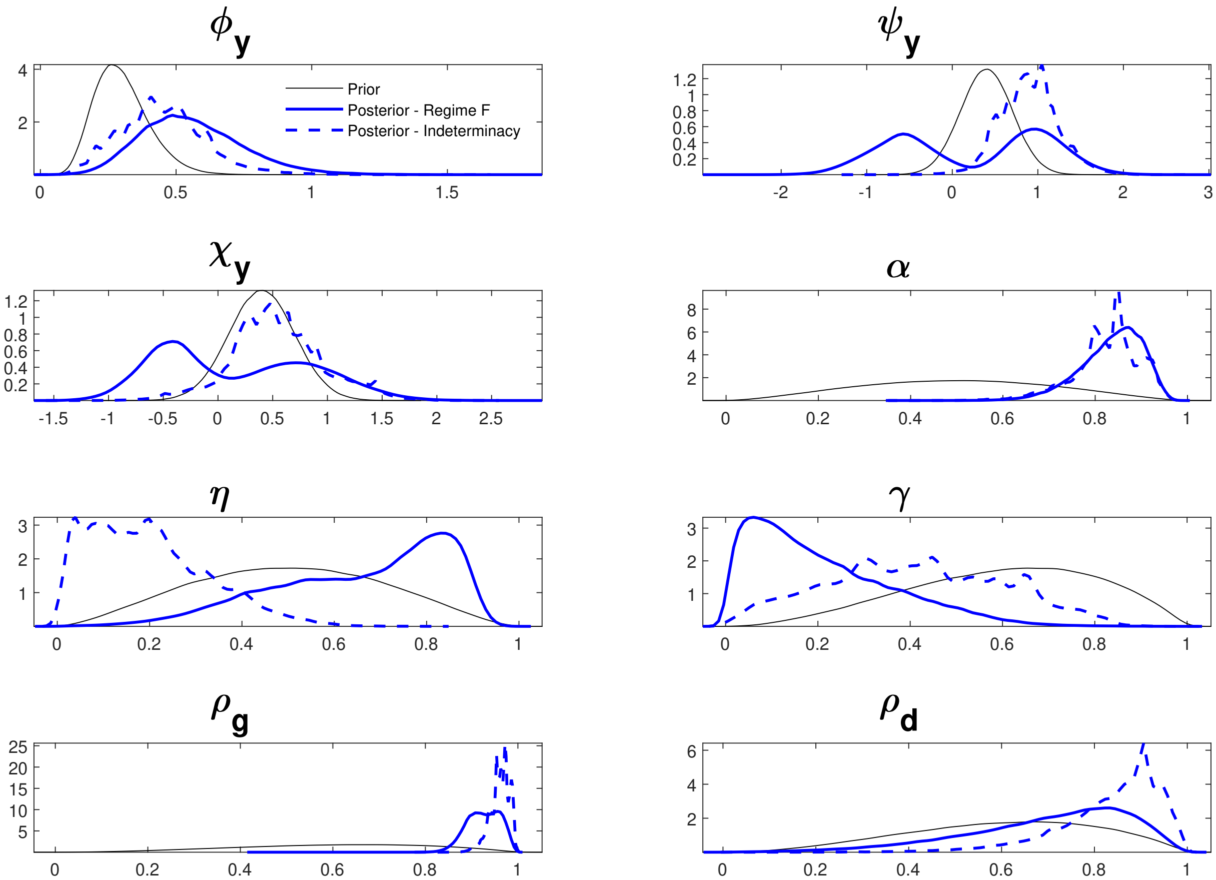


Figure 25: Recursive means - for RWMH runs initialized at a random value in regime PMPF

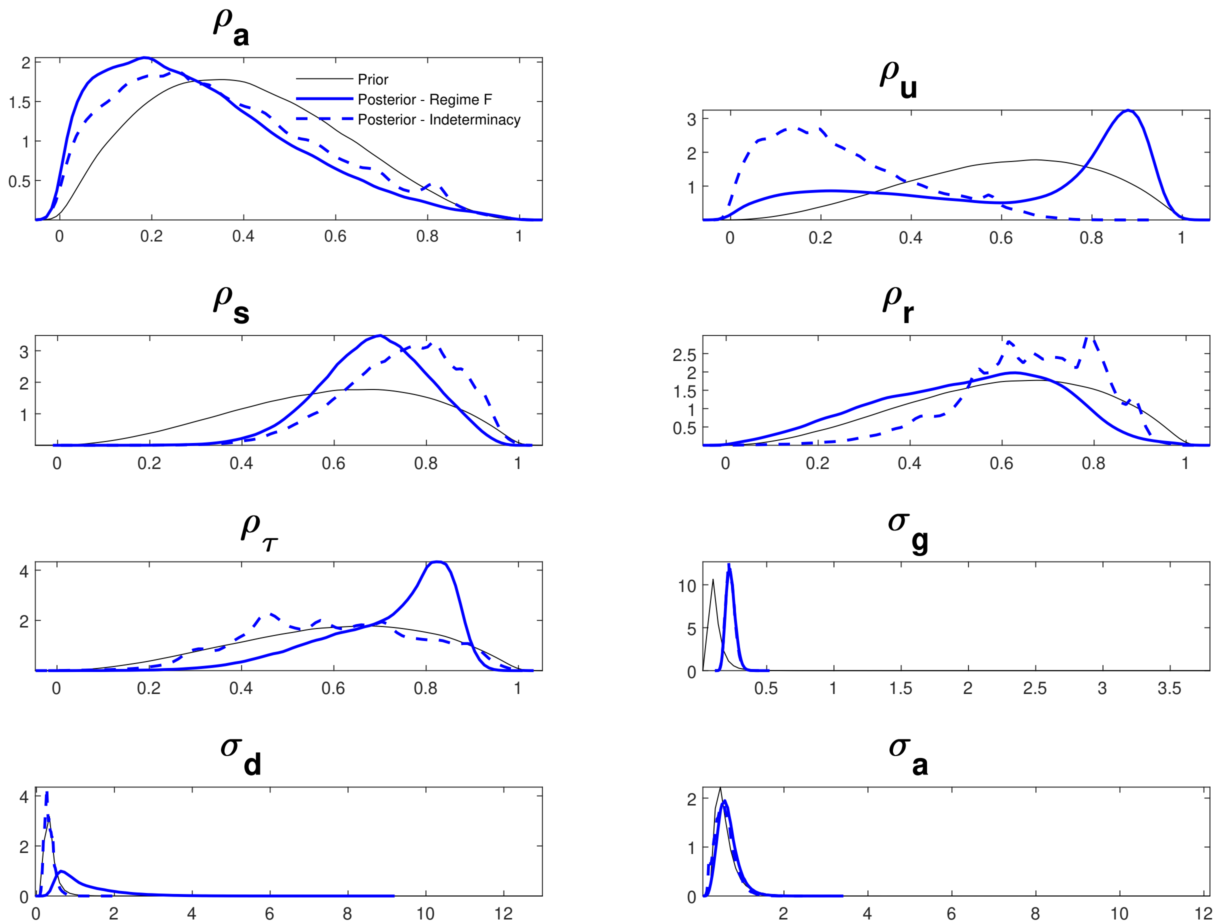
Appendix E.3 Unrestricted estimation - posterior densities conditional on regime F and the PMPF regime

Here we show plots of the prior and posterior densities conditional on regime F and indeterminacy from the unrestricted estimation with the SMC sampler for the policy parameters ϕ_π and ψ_b, and the remaining parameters.





ϕ_y
Prior
Posterior - Regime F
Posterior - Indeterminacy
ψ_y
χ_y
α
η
γ
ρ_g
ρ_d



ρ_a
Prior
Posterior - Regime F
Posterior - Indeterminacy
ρ_u
ρ_s
ρ_r
ρ_τ
σ_g
σ_d
σ_a

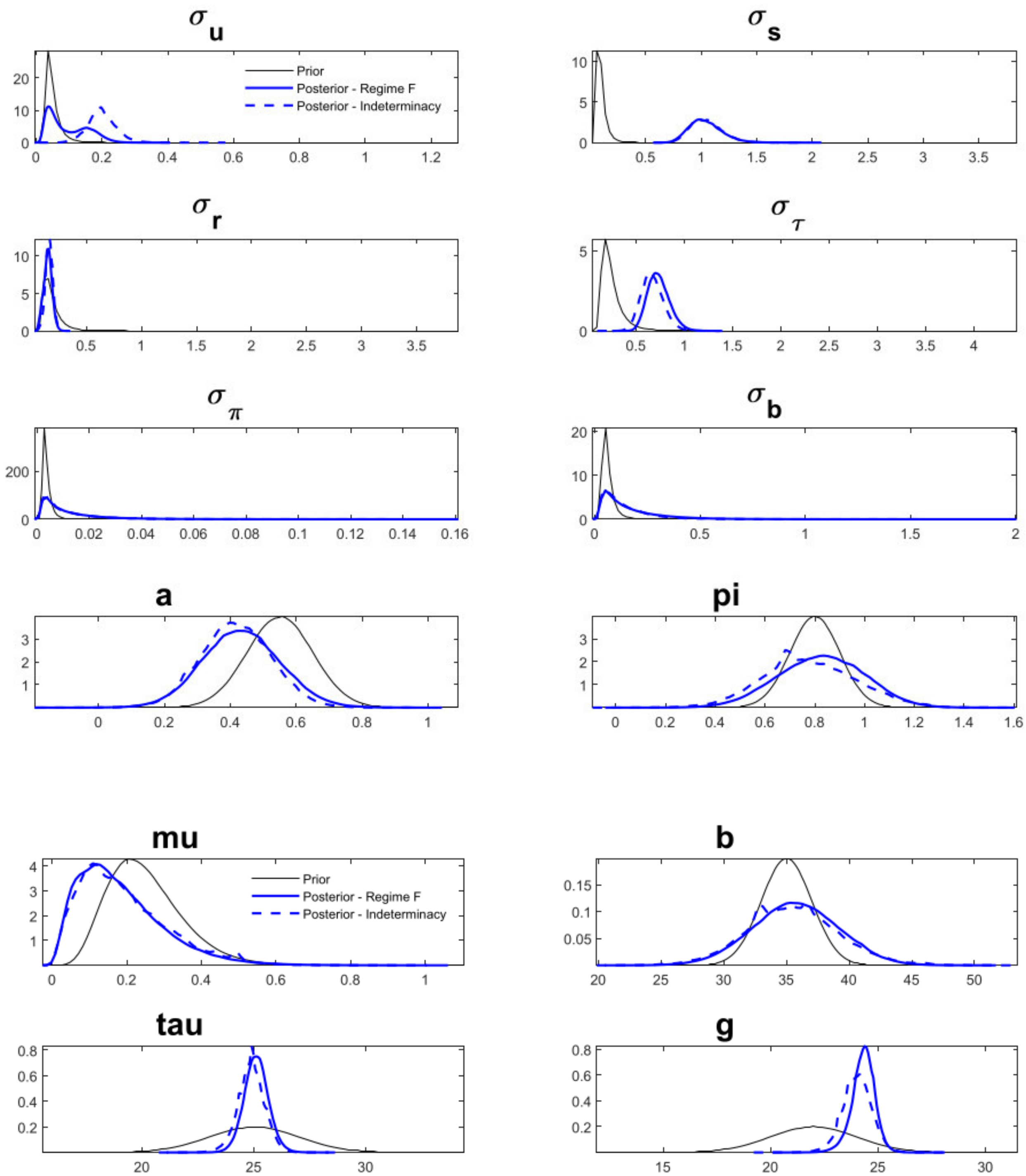


Figure 26: Prior and conditional posterior densities of the estimated model parameters from the unrestricted estimation. The blue bold line depicts the posterior density conditional on regime F, the dashed blue line the posterior density conditional on the PMPF regime, and the black line the prior density.

Appendix E.4 Historical decomposition conditional on regime M from unrestricted SMC estimation

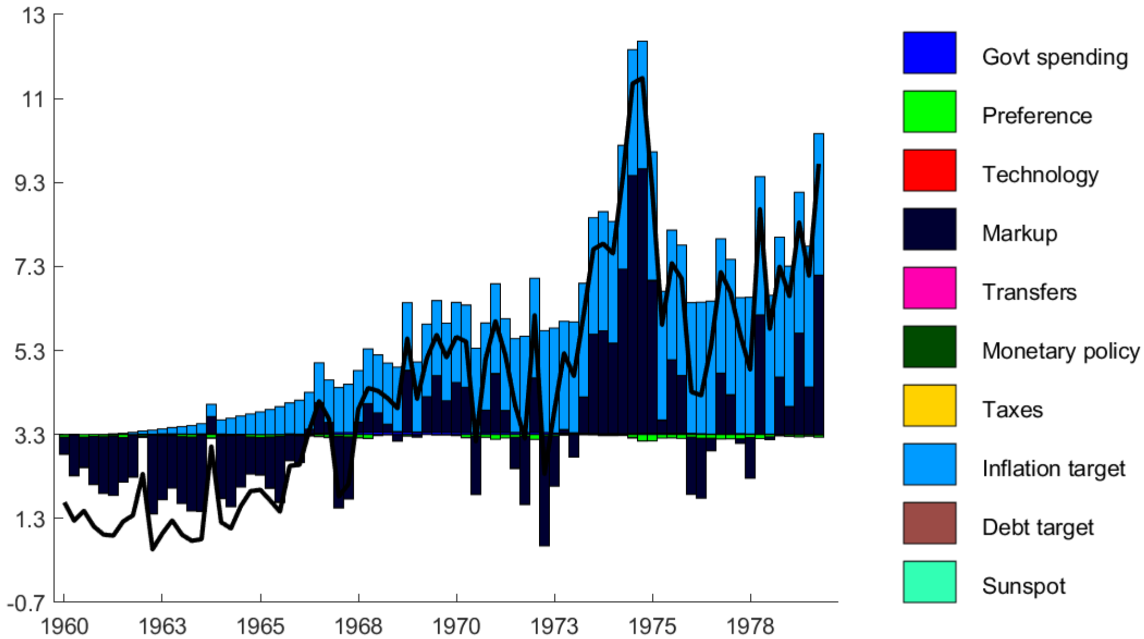


Figure 27: Contribution of each shock to inflation (annualized, in percentage points) in regime M. The bold black line shows observed inflation. The historical decomposition is conducted at the posterior mean of the AMPF regime.

Appendix F Smoothed shocks

Here we show plots of the remaining smoothed shocks for regime F and the PMPF regime, respectively.

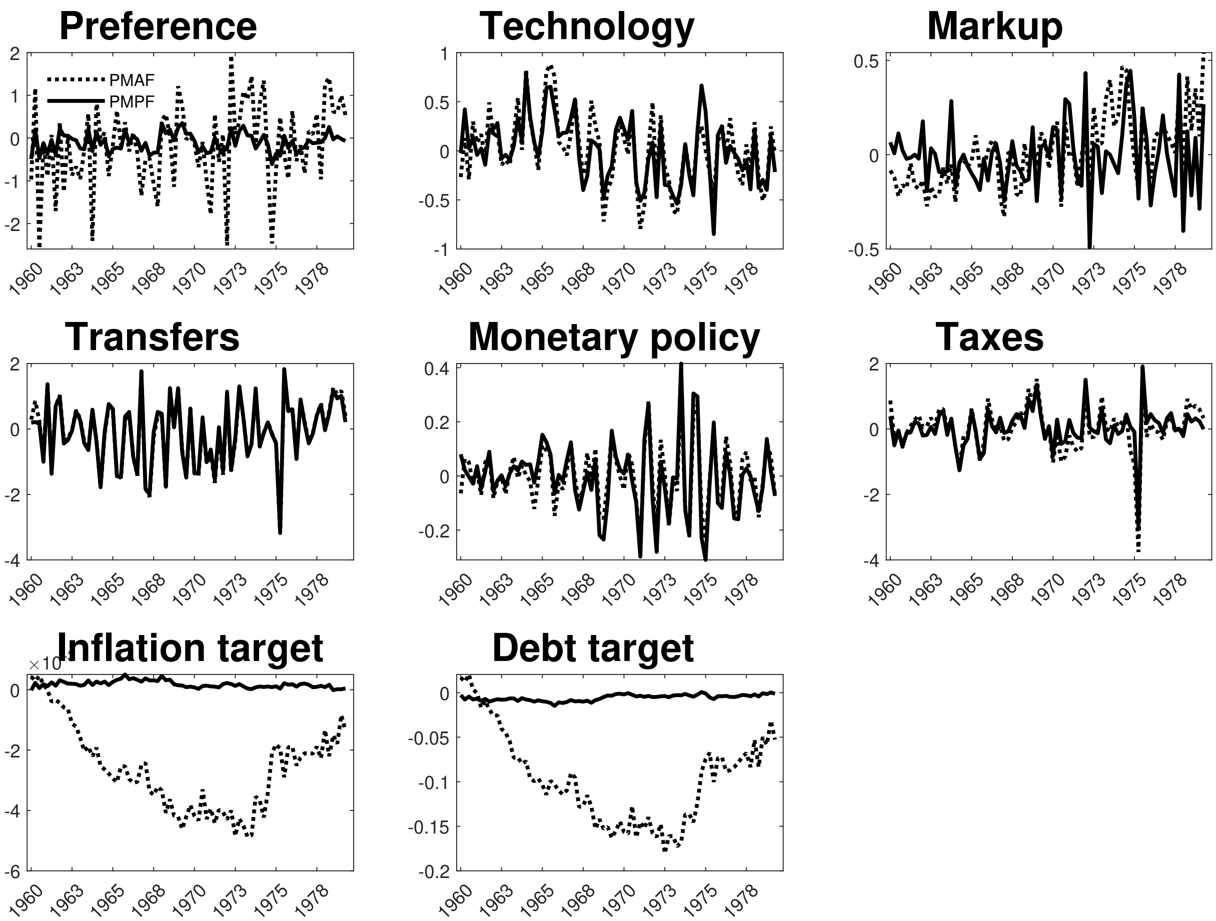


Figure 28: Smoothed shocks for 1960:Q1 to 1979:Q2 for regime F and the PMPF regime. The dashed line shows shocks computed at the mean of the posterior density from the unrestricted estimation conditional on regime F. The solid line shows shocks computed at the mean of the posterior density from the unrestricted estimation conditional on the PMPF regime.