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Fiscal stimuli: Monetary versus Fiscal Financing

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Abstract

In this paper, we investigate the use of money supply issued by the central bank to support expansionary fiscal interventions. We develop and estimate a New Keynesian model using US data for the sample 1960Q1 - 2019Q4. We conduct a quantitative counterfactual analysis to assess the effects of a fiscal stimulus that does not result in an increase in public debt, as it is financed by money supply. Our impulse response analysis indicates that both increases in government spending and transfers that are monetary financed have positive effects on private consumption, investment and output. However, the expansionary impact of monetary-financed fiscal shocks comes at a cost: an increase in inflation. Our sub-sample analysis indicates that monetary-financed fiscal stimuli would have had a greater positive impact on the economy during the Great Moderation. Lastly, we find that as the debt burden increases, the positive effects of a monetary-financed fiscal stimulus diminish.

Keywords: Fiscal Policy, Monetary Policy, Bayesian Estimation

JEL Codes: C11, E32, E52, E62

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1 Introduction

Following the Global Financial Crisis (GFC), central banks worldwide have undertaken various measures to boost economic activity. This has included reducing interest rates to historically low levels and implementing policies aimed at facilitating lending procedures, both to businesses and financial institutions. One of these monetary policy tools is Quantitative Easing (QE), which involves substantial investment through asset-purchasing programs to inject liquidity into the financial system and support the economy. Concurrently, governments have implemented significant fiscal stimulus packages with increases in government spending, tax cuts and an increase in lump-sum transfers to boost aggregate demand. However, these fiscal measures have left major economies, particularly the United States, with record-high levels of public debt. High levels of public debt and public debt-to-GDP have raised growing concern among scholars and policymakers about the negative effects on the economy.[1] Furthermore, while QE helps mitigate the adverse effects of a crisis, it does not prevent a further increase in public debt. An alternative way to enhance liquidity and support economies, while also maintaining control over the level of public debt, is through the financing of fiscal programs via the issuance of money supply. This paper contributes to the growing interest in fiscal sustainability and, specifically, to the financing of fiscal stimuli, in that it provides additional quantitative evidence on the economic impact of monetary-financed fiscal stimuli (Reichlin et al., 2013; Giavazzi and Tabellini, 2014; English et al., 2017; Di Giorgio and Traficante, 2018; Galí, 2020b; Punzo and Rossi, 2023).

Figures 1, 2a and 2b show the evolution of percent changes in US government spending and government transfers from the previous year during the NBER recessions from 1960Q1 to 2019Q4.[2] In particular, the graphs on the left-hand side of Figure 1 report the evolution of government spending in relation to the evolution of public debt measured two quarters later.

[1]For example, Checherita-Westphal and Rother (2012) find a non-linear relationship between public debt-to-GDP and economic growth in the Euro Area. The authors discovered a turning point, after which the level of public debt has a negative impact on economic growth at 90-100% of GDP. Cecchetti et al. (2011) conducted an analysis on the effects of public debt on economic growth in 18 OECD countries. They found that the threshold beyond which the level of public debt has negative implications on the economy is equal to 85% of GDP.

[2]The recession dates can be found at: https://www.nber.org/research/data/us-business-cycle-expansions-and-contractions.

The graphs on the right-hand side of the figure show the relationship between government spending and money supply. Figures 2a and 2b show the same comparison for the evolution of transfers. We only choose periods of fiscal stimuli (increases in government spending and/or government transfers) during the recessionary time.[3] The graphs show that when there was an increase in government spending or transfers during all recessions, fiscal stimulus coincided with an upward trend in public debt. A notable exception is the 1960 recession, a period previously described in the literature as a regime of passive monetary and active fiscal policy (Leeper, 1991; Davig et al., 2006; Davig and Leeper, 2011; Bianchi and Ilut, 2017; Bassetto and Cui, 2018; Bianchi and Melosi, 2019; Bassetto and Miller, 2022; Ascari et al., 2023). Therefore, these graphs seem to indicate that during recessionary periods, US fiscal stimuli may have been financed through an increase in public debt. On the other hand, in all cases, except for the 1960 recession, the fiscal stimulus and the money supply do not exhibit any evident co-movement, suggesting no relationship between them. In response to these episodes, several works (Reichlin et al., 2013; Turner, 2013, 2015, 2017; Giavazzi and Tabellini, 2014; Galí, 2020b) have asked whether the US central bank could have expanded its monetary policy toolkit to include monetary finance (i.e., the financing of government spending and transfers via money creation) rather than increasing public debt.

In this paper, we aim to answer this question by proposing and estimating a medium-scale New Keynesian model in the spirit of Del Negro et al. (2007), Smets and Wouters (2007) and Christiano et al. (2011). Our model includes nominal and real rigidities, as well as several demand and supply disturbances to the economy. Among the exogenous shocks, we consider a government spending shock and a government transfers shock. We estimate our model with Bayesian techniques for the sample period 1960Q1 - 2019Q4 using US macroeconomic aggregate data. Then, we proceed with a counterfactual analysis that employs the estimated parameters obtained with our model. To conduct this analysis, we extend the same model to incorporate a "monetary-financing" component. Within this framework, the central bank accommodates fiscal policy and shifts its emphasis from setting the interest rate to controlling

[3] During the 1970, 1981 and 1990 recessions only, changes in transfers exhibited an upward trend, while the same was true for government spending during the 2001 recession. During all other periods, both fiscal stimuli experienced an increase. Finally, we exclude the 1980 recession, spanning from 1980Q1 until 1980Q3, as neither fiscal stimulus was implemented during this period.

the money supply. This mechanism is similar to the one proposed by Galí (2020b), in which the money supply is determined endogenously and used to finance fiscal stimuli.

We contribute to the previous economic literature in different ways. Firstly, we compare the effects of debt-financed fiscal stimuli with monetary-financed fiscal stimuli by performing a counterfactual analysis based on an estimated model over the sample period 1960Q1 - 2019Q4. Secondly, we provide a similar analysis for two sub-samples, namely, from 1960Q1 to 1979Q2 and from 1984Q1 to 2007Q2. We select these time samples following Ascari et al. (2023) to distinguish between periods characterized as fiscally-led and monetary-led. Finally, we assess whether the effects of monetary-financed fiscal stimuli are different according to low or high degrees of public indebtedness.

Through our impulse response analysis, we find that this alternative way of financing fiscal policy has expansionary effects on the economy. In particular, monetary-financed fiscal stimuli induce an increase in both consumption and investment, while the level of public debt is maintained unchanged. Moreover, the estimations for the two sub-periods reveal that during the period from 1984Q1 to 2007Q2, a monetary-financed fiscal stimulus would have had a greater positive impact on the economy compared to the sub-period from 1960Q1 to 1979Q2. As an additional analysis, we focus on the magnitude of the public debt-to-GDP ratio and its implications for the macroeconomic impact of fiscal stimuli. Our results indicate that, while the effect of monetary-financed fiscal stimuli on the economy remains positive, the magnitude of the impact diminishes as the ratio of public debt-to-GDP increases.

Our findings show that the expansionary impact of a monetary-financed fiscal stimulus comes at a cost, which is a larger increase in inflation compared to the scenario in which the fiscal stimulus is debt-financed. Monetary-financing has raised concerns regarding the potential consequences of hyperinflation (Sargent and Wallace, 1973). However, given the increased credibility and independence of central banks in developed countries, Cukierman (2020) argues that the risk of hyperinflation may be of lesser concern nowadays. Indeed, past instances of hyperinflation resulting from the monetization of public spending occurred during periods when central banks and governments were not separate entities. English et al. (2017) explain that in the case of a monetary-financed program, the central bank can still maintain its independence. An example is given by the "dual key" approach suggested by

Bernanke (2016). In this case, the Federal Reserve would authorize the placement of funds in an account that the Treasury could use to finance spending. However, Congress would have to authorize the use of those funds. This dual approach would ensure that the central bank maintains its independence.

The remainder of the paper is structured as follows. Section 2 presents a short review of the literature on public debt, monetary policy and fiscal policy interactions, as well as monetary-financing. Section 3 describes the theoretical model. Section 4 discusses the estimation results. In Section 5, we present the impulse response analysis that compares two scenarios: debt-financed vs. monetary-financed fiscal stimulus. Section 6 provides some robustness exercises. Section 7 concludes.

2 Literature review

Our paper contributes to various strands of literature. One is the literature concerning the adverse consequences of high levels of public debt. Within this body of literature, certain studies focus on the analysis of fiscal multipliers. For instance, Ilzetzki et al. (2013) find that in countries with levels of public debt-to-GDP higher than 60%, fiscal multipliers are smaller compared to countries with lower debt-to-GDP ratios and tend to become negative in the long-run. Huidrom et al. (2020) show that the magnitude of the fiscal multiplier is influenced by the level of public debt. The authors explore two channels through which this occurs: the Ricardian equivalence channel and the interest rate channel. Other papers analyse the negative implications of high levels of public debt on GDP growth and identify thresholds of debt-to-GDP ratios beyond which public debt affects the economy negatively (Checherita-Westphal and Rother, 2012; Cecchetti et al., 2011).

Our paper also contributes to the literature that focuses on the financing components of public debt. Hall and Sargent (2011) show that the decrease in debt-to-GDP from 1945 until 2009 was mainly driven by economic growth, followed by primary surpluses and inflation. Das (2021) disentangles fiscal financing components distinguishing between fiscally-led and monetary-led policy regimes. The author identifies inflation, the growth rate and the primary surplus/deficit as significant factors affecting debt-to-GDP ratios during the fiscally-led regime.

Our paper contributes to the literature on the interactions between monetary policy and fiscal policy. Notably, seminal studies by Sargent et al. (1981), Leeper (1991), Sims (1994), Schmitt-Grohé and Uribe (2000) and Davig and Leeper (2011), among others, investigate the implications of the fiscal-monetary policy mix on various macroeconomic aggregates. Furthermore, Mertens and Ravn (2014) and Bianchi et al. (2020) examine the collaborative nature of monetary and fiscal policies as an effective tool for mitigating the adverse effects of both economic and non-economic shocks.

Given the relevance of high levels of public debt, another strand of literature explores the use of money supply as a fiscal financing alternative and analyses its impact on the economy. The concept of a "monetary-financed fiscal stimulus" has gained growing consensus among scholars, particularly due to its positive impact on the economy.[4] Benigno and Nisticò (2022) highlight the ongoing debate among academics and policymakers, suggesting that cooperation between governments and central banks could lead to effective measures to mitigate the adverse consequences of unexpected crises. In a VoxEU article, Giavazzi and Tabellini (2014) propose a cooperative policy measure to address the lack of aggregate demand in the EU. The policy measure involves implementing a tax cut financed by the issuance of long-term government debt, which would be purchased by the central bank. The central bank would refrain from neutralizing the increased liquidity injected into the market and the interest on debt would be paid to the central bank's shareholders as seigniorage. Galí (2020a) proposes focusing on the account the government holds at the central bank. Under this proposal, the central bank would transfer funds to the government's account to finance an emergency fiscal program. However, the use of monetary-financing should typically be reserved for extreme circumstances when public debt levels are already high. Bernanke (2016) suggests the establishment of a new government account at the central bank, exclusively for emergency situations.

In all cases, when the central bank engages in monetary financing of the public debt, the

[4] Bernanke (2003) and Buiter (2014) refer to the monetary-financed lump-sum transfers to households financed by newly printed money using Milton Friedman's terminology "Helicopter money".

money supply increases permanently.[5] Bernanke (2003) emphasizes the importance of making sure that "much or all of the increase in the money stock is viewed as permanent" (Bernanke, 2003, p.7). The use of money supply to finance a fiscal stimulus through a permanent increase in the monetary base makes it possible to address the issue of Ricardian equivalence, which undermines the efficiency of fiscal stimuli. Woodford (2012) and Turner (2015) demonstrate that during times of aggregate demand disruptions, monetary financing would stimulate aggregate demand to a greater extent than debt financing. Punzo and Rossi (2023) analyse the redistribution channel of a monetary-financed fiscal stimulus in a two-agent framework and find positive effects on the economy, but an increase in the consumption gap between the two types of agents. Finally, Okano and Eguchi (2023) find even more positive effects of a monetary-financed fiscal stimulus in a small open economy framework experiencing a liquidity trap, compared to a closed economy.

Giavazzi and Tabellini (2014) and Turner (2015) explain that monetary financing can be criticized from a political point of view. They argue that the use of this policy may be misleading and lead to its excessive and unwarranted utilization. Turner (2015) further argues that the monetary-financing policy is desirable under all circumstances and the only obstacle lies in addressing limitations from a policy perspective. Once these limitations have been overcome, the monetary-financing policy can become the optimal approach to stimulate aggregate demand when needed.

Our quantitative analysis contributes to the existing literature on monetary-financed fiscal stimuli, specifically in the context of US data. By conducting an analysis of the use of money supply to finance fiscal stimuli, we provide insights into the potential implications and outcomes of such a policy approach.

3 Theoretical model

In this section, we present the theoretical model. The structure of the model is in line with standard medium-scale new Keynesian models (see, for example, Smets and Wouters,

[5] It is worth noting that this distinguishes monetary financing from QE, which only has a temporary impact on the monetary base.

2007; Christiano et al., 2005; Del Negro and Schorfheide, 2008; Leeper et al., 2017).

The economy is populated by a continuum of households that provide labour and capital services to intermediate firms and obtain dividends from them. The representative household makes consumption decisions as well as capital accumulation decisions. We assume that it trades a riskless one-period government bond. Labour is differentiated across households, so that there is some monopoly power over wages that results in an explicit wage equation and allows for the introduction of Calvo (Calvo, 1983) sticky nominal wages. The representative household receives lump-sum transfers from the government.

Moreover, we include monopolistically competitive intermediate firms. These firms hire labour and rent capital from households, produce intermediate goods and set prices à la Calvo. The final good, which is then sold to households, is produced and packed by a final good firm. Additionally, we assume partial indexation of prices and wages to past inflation rates.

We consider a central bank that sets its policy rate following a Taylor-type interest-rate rule (Taylor, 1993). Moreover, the central bank supplies the money demanded by the household to support the desired nominal interest rate.

Since the focus of our work is on alternative ways of fiscal stimuli financing, we consider two scenarios. In the traditional debt-financed scenario, the expansionary fiscal policy is financed through the issuance of government bonds. In the monetary-financed scenario, an increase in government spending or transfers is financed through a rise in money supply. We estimate the model under the debt-financed scenario and, with the estimated parameter values, we run a simulation of the model under the monetary-financed scenario. This allows us to provide a counterfactual analysis of a monetary-financed fiscal stimulus and compare the impulse response functions derived from both scenarios.

3.1 Households

The utility of the representative household depends positively on consumption and real money balances, whereas it depends negatively on labour supply. The objective function for household $j \in [0,1]$ is given by:

$$\max_{C_t(j), \frac{M_t(j)}{P_t}, L_t(j)} \mathbb{E}_t \Bigg\{ \sum_{t=0}^{\infty} \beta^t b_t \Bigg[\Bigg(ln\left(C_t(j) - hC_{t-1}(j)\right) + \frac{\chi_t}{1-\nu_m} \left(\frac{M_t(j)}{P_t}\right)^{1-\nu_m} \Bigg) - \frac{L_t(j)^{1+\nu_l}}{1+\nu_l} \Bigg] \Bigg\} \tag{1}$$

where C_t, $\frac{M_t}{P_t}$, L_t represent consumption, real money balances and labour, respectively. β_t is the discount factor, b_t represents an intertemporal preference shock to the household's utility function and h is a parameter that measures the degree of external habit formation in consumption. Moreover, χ_t is a preference shifter that affects the marginal utility of money holdings. We assume that b_t and χ_t follow the exogenous processes:

$$ln\, b_t = \rho_b\, ln\, b_{t-1} + \sigma_b\, \epsilon_{b,t}, \text{with}\, \epsilon_{b,t} \sim N(0,1) \tag{2}$$

$$ln\, \chi_t = \rho_m\, ln\, \chi_{t-1} + \sigma_m\, \epsilon_{m,t}, \text{with}\, \epsilon_{m,t} \sim N(0,1) \tag{3}$$

Following Del Negro and Schorfheide (2008) and Punzo and Rossi (2023), we assume that consumption and real money balances enter the household's objective function in a separable way.

The nominal budget constraint faced by the representative household is given by:

$$\begin{aligned} & P_tC_t(j) + P_tI_t(j) + B_t(j) + M_t(j) \\ & \leq R_{t-1}B_{t-1}(j) + M_{t-1}(j) + R_t^k K_{t-1}(j) + W_tL_t(j) + P_tD_t + P_tT_t(j) \end{aligned} \tag{4}$$

where P_t indicates the price level, B_t denote government bonds, while R_t is the gross nominal return of government bonds. I_t represents the private investment and K_t are units of capital. W_t denotes the wage rate earned by the household, R_t^k is the rental rate and D_t are the firm's dividends that the households receive. We also assume that households receive transfers T_t from the government.

The equation for capital accumulation is given by:

$$K_t(j) = (1-\delta)\, K_{t-1}(j) + \mu_t \left(1 - S\left(\frac{I_t(j)}{I_{t-1}(j)}\right)\right) I_t(j) \tag{5}$$

where $S(\cdot)$ is a function that represents the investment adjustment costs, with $S''(\cdot) > 0$, while δ is the depreciation rate of capital. Finally, μ_t represents an exogenous process to investment, and evolves as:

$$ln\, \mu_t = \rho_\mu ln\, \mu_{t-1} + \sigma_\mu\, \epsilon_{\mu,t}, \text{with}\, \epsilon_{\mu,t} \sim N(0,1) \tag{6}$$

Additionally, each household supplies $L(j)$, a differentiated form of labour, to labour packers. Labour packers are perfectly competitive firms that hire labour from the households and combine it into labour services, L_t. These labour services are then offered to the intermediate firms.

3.2 Final good firms

Final good firms operate in a perfectly competitive market and produce a homogeneous good, Y_t. These firms buy $Y_t(i)$, that are goods produced by intermediate firms and pack and sell Y_t to households. The aggregation technology of the final good firm is given by:

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{1}{1+\lambda_t^p}}\, di\right]^{1+\lambda_t^p} \tag{7}$$

where λ_t^p is a markup shock following the process:

$$ln\, \lambda_t^p = \rho_\pi\, ln\, \lambda_{t-1}^p + \sigma_\pi\, \epsilon_{\lambda^p,t}, \text{with}\, \epsilon_{\lambda^p,t} \sim N(0,1) \tag{8}$$

The cost minimization problem yields the downward-sloping demand for each intermediate input:

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\frac{1+\lambda_t^p}{\lambda_t^p}} Y_t \tag{9}$$

where $P_t(i)$ is the price of the intermediate good, while P_t indicates the price of the final good. Perfect competition in the final good sector implies that P_t is given by:

$$P_t = \left[\int_0^1 P_t(i)^{-\frac{1}{\lambda_t^p}} \, di \right]^{-\lambda_t^p} \tag{10}$$

3.3 Intermediate good firms

Each intermediate good is produced by an intermediate good firm (i) that combines capital, K_t and labour, L_t through the following technology:

$$Y_t(i) = A_t^{1-\alpha} K_t(i)^{\alpha} L_t(i)^{1-\alpha} \tag{11}$$

where A_t indicates an exogenous component to total factor productivity following the process:

$$ln\, A_t = \rho_z \, ln\, A_{t-1} + \sigma_z \epsilon_{z,t}, \; \epsilon_{z,t} \sim N(0,1)$$

All firms face the same prices for their labour and capital inputs. Therefore, profit maximization implies that the capital-to-labour ratio is the same for all firms:

$$\frac{K_t(i)}{L_t(i)} = \frac{\alpha}{1-\alpha} \frac{W_t}{R_t^k} \tag{12}$$

We also assume that intermediate good firms adjust their prices in a sticky way, due to staggered prices à la Calvo. Finally, we allow for partial indexation to the past inflation rate.

3.4 Monetary policy

As mentioned above, the monetary authority sets the nominal interest rate R_t following a Taylor-type interest-rate rule (Taylor, 1993). As in Del Negro et al. (2007), this implies that the policy rate is adjusted according to changes in inflation and output.

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R} \right)^{\phi_r} \left[\left(\frac{\pi_t}{\pi} \right)^{\phi_\pi} \left(\frac{Y_t}{Y} \right)^{\phi_y} \right]^{1-\phi_r} e^{\lambda_t^r} \tag{13}$$

where R is the steady-state nominal interest rate, π is the steady-state inflation, and Y represents steady-state inflation. ϕ_π is the weight of inflation on the interest rate, ϕ_y is the weight of output on the interest rate, while ϕ_r captures the degree of interest rate smoothing. Finally, λ_t^r is a monetary policy shock and it is assumed to follow the exogenous process:

$$ln\,\lambda_t^r = \rho_r\, ln\,\lambda_{t-1}^r + \sigma_r \epsilon_{r,t},\ \epsilon_{r,t} \sim N(0,1)$$

3.5 Fiscal policy

The government budget constraint is given by:

$$P_t G_t + P_t T_t + R_{t-1} B_{t-1} = B_t + \Delta M_t \tag{14}$$

where G_t represents government spending and $\Delta M_t = M_t - M_{t-1}$.

Transfers follow a fiscal rule, which we build following Leeper et al. (2010). The fiscal rule is the following:

$$\frac{T_t}{T} = \left(\frac{B_{t-1}}{B}\right)^{-\psi_{bt}} \left(\frac{Y_t}{Y}\right)^{-\psi_{yt}} e^{t_t} \tag{15}$$

where T represents the steady-state level of transfers, B is the steady-state level of public debt, ψ_{bt} is the transfers' response to public debt in $t-1$, ψ_{yt} is the transfers response to the level of output, and t_t is a stochastic component to transfers and it is assumed to follow the process:

$$ln\,t_t = \rho_t\, ln\,t_{t-1} + \sigma_t \epsilon_{t^*,t},\ \epsilon_{t^*,t} \sim N(0,1) \tag{16}$$

The government spending shock follows the exogenous process:

$$ln\,g_t = \rho_g\, ln\,g_{t-1} + \sigma_g \epsilon_{g,t},\ \epsilon_{g,t} \sim N(0,1) \tag{17}$$

We estimate our model with the fiscal policy block as outlined above. In Section 5 we will use the obtained estimated parameters to calibrate a modified version of the model, in which the increase in transfers and government spending are monetary-financed. This will be the monetary-financed scenario.

3.6 Market equilibrium

The final goods market is in equilibrium if the firms' production equals the demand of the household for consumption, investment and government spending.

$$Y_t = C_t + I_t + G_t \tag{18}$$

4 Estimation results

In this section, we describe the data and the estimation technique used to estimate the theoretical model. We then discuss how we estimate the endogenous parameters and the exogenous processes related to the structural shocks. Finally, we present the main estimation results.

4.1 Data and estimation technique

We use quarterly data for nine time series publicly available on the Economic Data website of the Federal Reserve Bank of St. Louis over the sample period 1960Q1 - 2019Q4.

The nine observed variables are real output, real private consumption, real private investment, real wage, inflation, the shadow rate, real government spending, real government transfers and money supply. Accordingly, the model features nine shocks for the observed variables. Following Leeper et al. (2010) and Pfeifer (2014), we detrend the logarithm of each real variable separately,[6] while we demean the inflation rate and nominal interest rate.[7]

[6] In particular, we use the HP filter with a smoothing parameter equal to 1,600.

[7] Some studies (see, for example, Greenwood et al., 1997, Greenwood et al., 2000, Altig et al., 2011, Schmitt-Grohé and Uribe, 2012) have estimated DSGE models including one or two common stochastic trends. This strategy is feasible when the number of trends is limited to one or two, but it becomes non-trivial in the presence of a larger number of trends. In this regard, Leeper et al. (2010) argued that, in models analysing fiscal policy, the number of trends is often larger than two because several fiscal variables display their own trends. Moreover, some of these variables, such as transfers, show upward trends, and this requires specific modelling assumptions in order to guarantee fiscal sustainability. Indeed, online Appendix G shows that the fiscal series included in our analysis clearly displays different trends in the sample period considered. Accordingly, as an estimation strategy, we prefer to follow the treatment of observed variables used by Leeper et al. (2010).

The measurement equations for the observables matching the model variables is:

$$\text{Output} = 100 \times y_t$$
$$\text{Consumption} = 100 \times c_t$$
$$\text{Investment} = 100 \times i_t$$
$$\text{Real wage} = 100 \times w_t$$
$$\text{Inflation} = 100 \times \pi_t$$
$$\text{Shadow rate} = 100 \times r_t$$
$$\text{Government spending} = 100 \times g_t$$
$$\text{Transfers} = 100 \times t_t$$
$$\text{Money supply} = 100 \times m_t$$

where the left-hand side of the equation is the observable variable and the right-hand side represents the log-linearized model variable scaled by 100. For a detailed description of data construction, please see online Appendix C.

We employ Bayesian estimation techniques, which enable us to specify prior probability distributions for model parameters and subsequently combine these with likelihood functions derived from the data. This method is well-suited to our analysis, as we can draw upon extensive literature on DSGE modelling to inform our choice of priors. We employ Monte Carlo Markov Chain (MCMC) methods and the Metropolis Hastings (MH) algorithm. The model is estimated using 3,000,000 draws from posterior distributions. We run two parallel chains in the MCMC MH algorithm and the acceptance rate for each of the chains is approximately 24%.[8]

4.2 Fixed parameters and prior distributions

Table 1 describes calibrated values for the fixed parameters. We fix the household's discount factor to 0.99 to match a 4% annual real interest rate. We obtain an average annual inflation rate that closely matches the one in our sample, equal to approximately 4%. The

[8]All our estimations are done with Dynare (http://www.dynare.org/).

labour share in our production function is calibrated to be 0.33 and the capital depreciation rate is set at 0.025, as in Del Negro et al. (2007) and Bianchi et al. (2023). Finally, we follow Leeper et al. (2017) and Bianchi et al. (2023) and calibrate both steady-state markup values for wages and prices equal to 0.14. We follow Galí (2015) to calibrate the inverse elasticity of substitution between money and consumption and set this parameter equal to 1. The shares of government spending and transfers on output and the steady-state inverse velocity of money supply are set equal to our sample averages. Finally, we calibrate the share of public debt-to-GDP to 60%, as in Galí (2020a).

Table 2 shows priors and posteriors for the endogenous parameters. Consumption habits and investment adjustment costs are set as in Smets and Wouters (2007). Taylor rule parameters ϕ_r, ϕ_π and ϕ_y, as well as wage and price stickiness parameters ζ_w and ζ_p, wage and price indexation parameters, ι_w and ι_p, and the priors for fiscal policy parameters, ψ_{bt} and ψ_{yt}, are in line with Bianchi et al. (2023). Table 3 reports all priors for the exogenous processes. The prior values for persistence parameters align with Leeper et al. (2010), while those for the standard errors are set following Smets and Wouters (2007).

4.3 Posterior estimates

The last three columns of Tables 2 and 3 show the posterior mean estimates and their related 10 percent and 90 percent credible sets. Identification tests based on Qu and Tkachenko (2012) and Iskrev (2010) show that the Jacobian matrices of the first two moments and the spectral density have full rank. According to these tests, the parameters are all identified. Moreover, trace plots for each of the estimated parameters show that the Metropolis Hastings algorithm converges to a stable distribution.

Table 2 presents posterior estimates for the endogenous parameters, which align closely with values found in previous literature. The estimate for the inverse elasticity of labour supply is 1.65 and falls within the range of values estimated in Leeper et al. (2017) and Bianchi et al. (2023). Consumption habits indicate an 80% share of consumption in the previous period, consistent with findings in Del Negro et al. (2007). The posterior estimate for investment adjustment costs does not vary substantially from its previous mean and falls within the estimated value range in Smets and Wouters (2007).

Regarding the Taylor rule, the posterior mean of the interest rate smoothing parameter and the reaction of the policy rate to output are both estimated to be low values. Moreover, the mean of the weight of inflation on the interest rate is substantially high, indicating a strong reaction of the central bank in response to changes in the price level.

In terms of nominal rigidities, our estimated price stickiness parameter is relatively high, suggesting a flattened Phillips Curve, in line with estimates obtained in Leeper et al. (2017). The posterior mean of wage stickiness falls within the range of values estimated in Del Negro and Schorfheide (2008). Additionally, we observe a relatively low value for the price indexation posterior mean, as in Leeper et al. (2017), while the wage indexation parameter is in line with previous studies, such as Del Negro and Schorfheide (2008) and Drautzburg and Uhlig (2015).

Table 3 presents prior and posterior means for the exogenous parameters. Our results indicate that standard errors of the cost-push, investment and money supply exogenous processes are larger compared to the standard errors of the other exogenous processes. Moreover, the persistence parameters for monetary policy, money supply and government spending are greater than their prior means, with the highest values among all estimated persistence parameters. Graphs for prior and posterior distributions, together with other estimation output, can be found in online Appendix D.

5 Effects of monetary-financed fiscal stimuli

In this section, we analyse two scenarios in which the government and the central bank collaborate to implement expansionary fiscal policies through fiscal stimuli. Two types of fiscal stimuli are analysed: an increase in government transfers to households and an increase in government spending. We divide the analysis for each of the fiscal stimuli into two scenarios. The first scenario, called the debt-financed scenario, involves the central bank implementing a monetary policy strategy based on inflation targeting. In this scenario, the central bank controls the policy rate. In the second scenario, called the monetary-financed scenario, the central bank gives up control of the policy rate and focuses on the determination of money supply. The second scenario is obtained by modifying the theoretical model to include a "monetary-financing" specification, as described below. First, we estimate the model under the debt-financed scenario,[9] and then we simulate the model under the monetary-financed scenario. Finally, we compare the impact of the two fiscal stimuli under the two distinct scenarios. To calibrate both models, we use the estimated parameters derived from the estimation conducted under the debt-financed scenario.

In the debt-financed scenario, the model features a Taylor rule, as described by equation (13). In the alternative scenario, where the fiscal stimulus is financed by the money supply, the fiscal authority implements fiscal stimuli, while the central bank adjusts the money supply to maintain the level of the real public debt constant. As in Galí (2020b) and Punzo and Rossi (2023), having constant debt implies that the deviation of debt from its steady-state value must be equal to zero: $b_t = 0$. In this case, the linearized version of equation (14) reads as follows:

$$\Delta m_t = \frac{1}{\chi}\left[\frac{g}{y}g_t + \frac{t}{y}t_t + \frac{b}{y}\frac{r}{\pi}\left(i_{t-1} - \pi_t\right)\right] \tag{19}$$

Equation (19) evolves as a money growth rule, with money growth being endogenously determined as a result of the interactions between monetary policy and fiscal policy.

Graphs in Figure 3 show the effects of a rise in government spending on the main economic aggregates under the two scenarios: (i) when the increase in government spending is financed through debt; and (ii) when it is financed by money supply. We calibrate the magnitude of the shock to a one standard deviation.

In the debt-financing scenario the nominal interest rate exhibits a stronger increase relative to inflation. As a consequence, the higher real interest rate crowds-out consumption. The standard multiplier effect leads to an increase in output, though the increase is only half as large and persistent compared to the monetary-financed scenario.

A monetary-financed government spending shock leaves real public debt unchanged, while it contributes to a rise in inflation. The increase in inflation in this scenario is significantly greater compared to the debt-financed scenario. The central bank does not react to the increased inflation and adjusts the money supply to accommodate the fiscal stimulus implementation. Consequently, the nominal interest rate experiences a marginal increase,

[9]Estimation results have been described in Section 4.

driven by an adjustment inside the government constraint. However, this increase is minor on impact and it soon turns negative. This process leads to a decrease in the real rate and a resulting positive shift in the consumption response. This aspect is key for our analysis, as a monetary-financed government spending increase crowds-in consumption, while keeping the value of real public debt unchanged.

Graphs in Figure 4 show the impact of an increase in transfers on the main economic variables in the two scenarios: (i) when the increase in transfers is financed by public debt; and (ii) when it is financed through money supply. The magnitude of the shock is once again calibrated to its estimated value.

In the first scenario, due to the Ricardian equivalence, an increase in transfers does not affect economic aggregates. Consumers anticipate that an increase in transfers today will be offset by higher future taxes, leading them to maintain their consumption behaviour unchanged. This causes output and inflation to remain unaffected. Furthermore, neither money supply nor interest rates need to be adjusted by the central bank.

On the contrary, the increase in transfers financed by money supply has an expansionary impact on consumption, investment and output. This happens because the increase in transfers is perceived by households as a direct increase in their disposable income. Following the increase in money supply, the nominal interest rate adjusts downwards. As inflation increases, the real interest rate declines, affecting consumption and investment positively, and finally output. The increase in output together with a constant debt level reduces the debt-to-output ratio. Moreover, a higher inflation rate has an additional positive impact on levels of pre-existing debt, because it wipes-out part of its real value.

The reason why Ricardian equivalence holds only in the case of a debt-financed increase in government transfers, and not when transfers are monetary-financed, lies in the behaviour of households. In the first scenario, households anticipate that a future increase in lump-sum taxes or a decrease in transfers is needed to offset the current rise in transfers. In the second case, they anticipate that an increase in transfers needs not be paid back in the future through a tax rise, as it is financed by money supply. Therefore, an increase in money supply issued to fund the expansionary fiscal policy results in a corresponding direct increase in real balances. Since real balances contribute to consumers' wealth, the improvement in wealth translates into an increase in consumption and output.

Finally, Figure 5 shows the difference between the impulse response functions for the two fiscal stimuli when the financing occurs through money supply. The blue line shows the impact of a money-financed increase in government transfers, while the orange line represents the impact of a money-financed increase in government spending. As shown in the graphs of the previous figures, when the fiscal stimulus (either an increase in transfers or an increase in government spending) is financed through money supply, there is an expansionary impact on the main economic aggregates. The response of consumption to an increase in government spending peaks at over 0.4%, while its response to an increase in transfers peaks at approximately 0.15%. Similarly, our model predicts an increase in output of approximately 0.9% on impact after an increase in government spending, and approximatively 0.3% after an increase in transfers. The most positive effects of monetary-financed fiscal stimuli are represented by the peak in investment of 3%, after an increase in government spending, and 1% after an increase in transfers. Moreover, the rise in output contributes positively to a decrease in the debt-to-GDP ratio, with values of 0.2% for transfers and 0.9% for government spending. On the other hand, monetary-financed fiscal stimuli trigger an increase in inflation of 0.04% after an increase in government spending and roughly 0.015% after an increase in transfers.

Overall, our impulse response analysis on the impact of monetary-financed fiscal stimuli indicate that a government spending increase has a greater positive impact on macroeconomic aggregates compared to a transfers increase.

6 Robustness analysis

In this section, we provide several robustness exercises to confirm our analysis. Firstly, we split the entire data sample into two sub-periods, 1960Q1 - 1979Q2 (the so-called Great Inflation period) and 1984Q1 - 2007Q2 (the so-called Great Moderation period). Secondly, we focus on different hypothetical scenarios of debt-to-GDP ratios.

For the first robustness analysis, we select the two sub-periods following Ascari et al. (2023). The authors explain that this division is well matched to two periods, which are known as a fiscally-led regime and a monetary-led regime, respectively, in the literature. We estimate the model under the debt-financed scenario for each of the sub-samples and compare the estimated parameters across both sub-samples, as well as with those for the entire sample. We then compare the impulse response functions obtained under the debt-financed scenario and the monetary-financed scenario for each of the two sub-periods.

Previous literature has analysed the importance of different fiscal positions concerning the impact of fiscal shocks on macroeconomic aggregates and on the magnitude of fiscal multipliers (Ilzetzki et al., 2013; Huidrom et al., 2020). Therefore, as a second robustness check, we present responses to government spending and transfers shocks for different levels of debt-to-GDP ratios. Specifically, we compare the impulse response functions obtained for monetary-financed fiscal shocks in cases of public debt-to-GDP ratios set at 60% (used in the benchmark model), 30% and 120%.

6.1 Sub-samples

Tables 4 and 5 report the posterior means of the estimated parameters for the entire sample and the two sub-samples. The priors used for the two sub-periods are exactly the same as those employed for the entire sample (see Table 2).[10]

The estimated standard errors of exogenous processes are similar across the two sub-samples for a number of shocks. However, the standard error of the cost-push shock is significantly higher over the entire sample compared to the two sub-periods, and lower during the Great Inflation period compared to the Great Moderation period. Moreover, the money supply shock displays nearly double the value for the first sub-sample compared to the second sub-sample. Finally, the productivity shock standard error is higher over the entire sample compared to the sub-samples. Persistence parameters for the productivity and monetary policy shocks are lower during the Great Inflation period compared to the Great Moderation period. The exogenous processes for government spending and transfers show similar persistence across the two sub-periods. Lastly, the cost-push persistence parameter exhibits greater magnitude during the Great Inflation period.

[10] The only exception is ϕ_y, for which the prior used to estimate the model over the sub-sample 1960Q1 - 1979Q2 is set to 0.2.

Table 4 reports the values of the estimated endogenous parameters across the entire sample and the two sub-periods. While the posterior means of some parameters are quite similar, others differ between sub-samples. These differences in parameter estimates between S1 and S2 result in varying impacts of fiscal stimuli across the two sub-samples, as shown through the graphs in Figures 6 to 9. The graphs show the effects of debt-financed and monetary-financed fiscal stimuli on macroeconomic aggregates using the estimated model parameters for the two sub-periods. Qualitatively, the impulse responses confirm the results presented in Section 5. On the one hand, monetary-financed fiscal stimuli have positive effects on consumption, investment, hours worked and output. On the other hand, inflation increases to a greater extent in this scenario compared to the more traditional debt-financed scenario. Finally, the real debt remains unchanged, which results in a decline of the debt-to-GDP ratio.

The responses to an increase in government spending in both scenarios and over both sub-samples closely resemble those over the entire sample in the main analysis.[11] A comparison across the two sub-samples indicates that a rise in a debt-financed government spending impacts output similarly in S1 and S2. However, there is a different response of the central bank to the increase in inflation in S2 compared to S1. This is evident from the larger estimated value for ϕ_π in the first sub-sample with respect to the second sub-sample. Our result confirms the stronger reaction of monetary policy to changes in the price level during the post-Volcker period (Canova, 2009). Finally, the increase of the debt-to-GDP ratio in this sub-period is double as much compared to its evolution during the Great Inflation. This remarkable increase is driven by the larger rise in the nominal interest rate in S2, which contributes to a further increase in the level of public indebtedness. However, transfers respond more to public debt over the second sub-sample compared to the first sub-sample, as shown by the posterior mean of ψ_{bt}, the elasticity of transfers to public debt. This larger response to public debt accelerates the adjustment process of the debt-to-GDP ratio, which approaches equilibrium after 10 quarters. Conversely, in S1, the debt ratio remains in positive territory for at least 20 quarters.

On the other hand, a rise in monetary-financed government spending has a more expansionary impact on the economy in S2 (Figure 7) compared to S1 (Figure 6). Indeed,

[11] See Figure 3 for a comparison.

consumption, investment and output respond positively and to a larger extent to the fiscal stimulus in the second sub-sample, while the debt-to-GDP ratio experiences a larger decrease. Overall, the impulse response analysis shows that a hypothetical adoption of an increase in government spending that is monetary financed during the Great Moderation period would have had larger positive economic effects compared to its adoption during the Great Inflation period.

Graphs in Figure 8 show that the effects of a monetary-financed transfers shock over S1 are in line with results obtained over the entire sample (Figure 4), except that the nominal interest rate reacts positively. This effect is driven by a higher increase in the money demand compared to the money supply in our model. However, this response is only observed on impact, as the nominal interest rate quickly declines into negative territory thereafter. The lower reaction of the nominal interest rate compared to the reaction of inflation results in a decrease in the real rate, which stimulates consumption, investment and output. Conversely, in the debt-financed scenario, due to the Ricardian equivalence, an increase in transfers leaves all economic aggregates unchanged.

Finally, the graphs in Figure 9 again confirm the results obtained in the main analysis. Similar to results over the first sub-period, the nominal interest rate is in positive territory only on impact and falls below zero immediately thereafter. The higher response of inflation relative to the nominal interest rate results in a decline in the real interest rate, which, in turn, once again implies the crowding-in of consumption and investment. Comparing the effects across the two sub-periods, a monetary-financed increase in transfers would have had an amplified positive impact on the economy during the Great Moderation period compared to the Great Inflation period. Once more, consumption, hours worked, investment and output exhibit a higher response in magnitude to the fiscal stimulus shock in S2 compared to S1. However, inflation reacts more strongly as well. Lastly, there is a slightly higher increase in the debt-to-GDP in the second sub-sample compared to the first sub-sample. However, the increase in the public debt-to-GDP is less persistent in S2, which is once more driven by a higher estimated elasticity of transfers to public debt over the second sub-sample.

Overall, according to our counterfactual analysis, it appears evident that the hypothetical adoption of monetary-financed fiscal stimuli during the Great Moderation period would have had amplified positive effects on the economy compared to the Great Inflation period.

6.2 Debt-to-GDP ratios

Figures 10 and 11 show the simulated impulse response functions under the monetary-financed scenario with different values of public debt-to-GDP ratios. It appears evident from the graphs that fiscal shocks exert a more pronounced positive impact on the economy when the debt-to-GDP ratio is lower. This result holds true for both increases in monetary-financed government spending and transfers. Indeed, impulse responses show a reduced advantage of resorting to monetary-financing when the public debt-to-GDP ratio increases.

Our results align with findings in Checherita-Westphal and Rother (2012) and Cecchetti et al. (2011), among others. These papers have found that high ratios of public debt-to-GDP are detrimental for GDP growth. Moreover, a fiscal stimulus in economies with high government debt was found to be associated with lower private consumption compared to economies with lower government debt levels (Ilzetzki et al., 2013). With respect to these papers, we focus on the effects of fiscal stimuli that are monetary-financed across different public debt-to-GDP ratios.

Despite high values of public debt-to-GDP ratios, the impact of a monetary-financed fiscal stimulus remains positive. However, under higher values of public debt-to-GDP ratios, our impulse response functions reveal not only a lower positive impact on output, but also on consumption, investment and hours worked. In this case, the lower impact on output contributes to a less pronounced reduction in the debt-to-GDP ratio over time.

Moreover, we find that, under high values for public debt-to-GDP ratios, in response to fiscal stimuli, inflation increases to a lesser extent compared to settings with low public debt-to-GDP ratios. The lower increase in inflation is driven by a reduced positive impact on aggregate demand.

7 Conclusions

The collaboration between monetary policy and fiscal policy has proven to be an effective tool in mitigating the negative consequences of both economic and non-economic shocks.

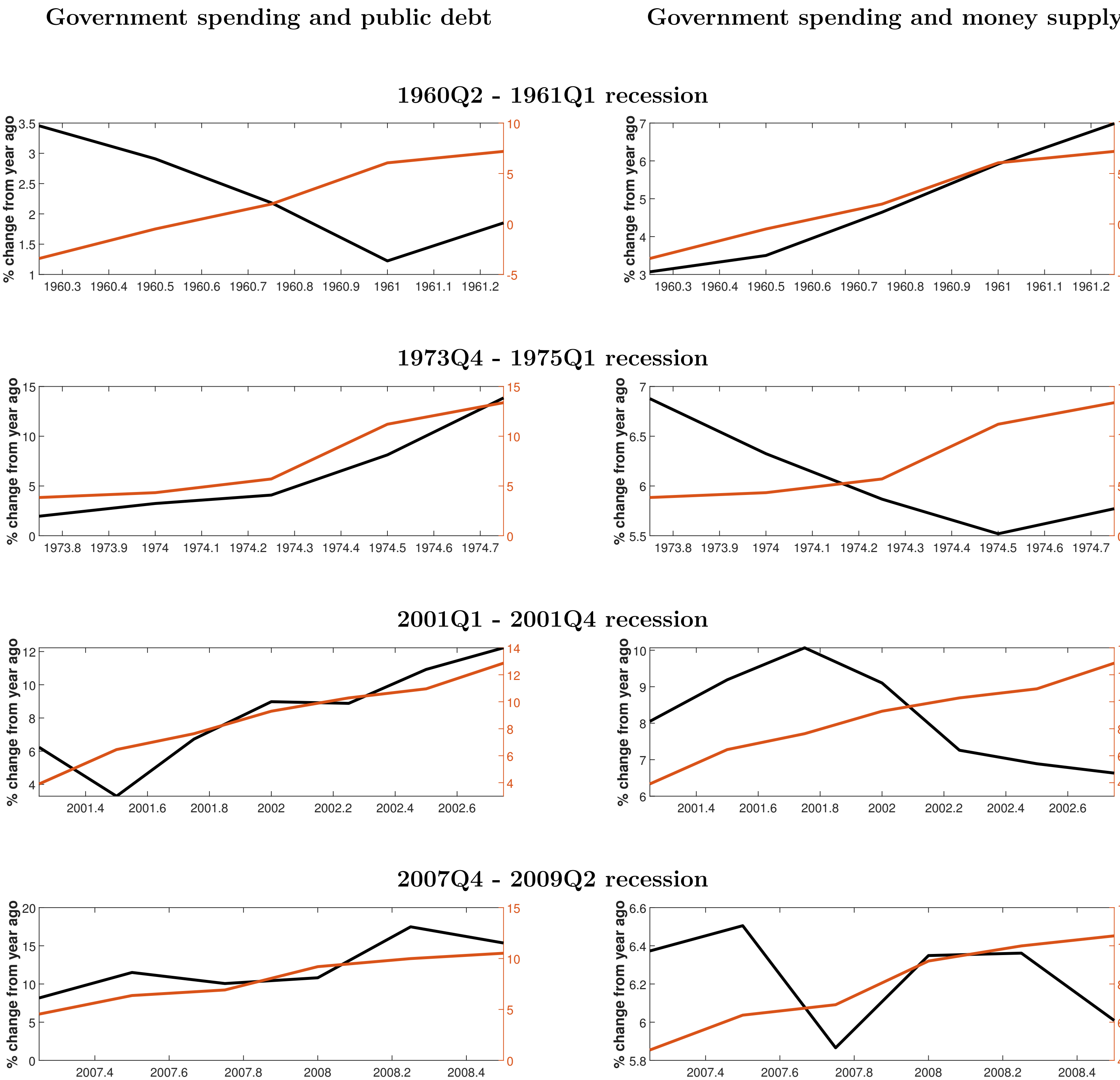
Given the rising levels of US government debt, the need for implementation of fiscal stimulus packages, and the prolonged period of low inflation observed in the US over the past few years, we consider it pertinent to conduct a counterfactual analysis of monetary-financed fiscal stimuli.

To carry out this analysis, we developed a New Keynesian model that incorporates fiscal policy. We employed Bayesian methods to estimate the model parameters using US data. Subsequently, we conducted a simulation analysis by augmenting the model with a feature representing a monetary-financed fiscal stimulus, using the previously estimated parameters. This allows us to quantitatively evaluate the expansionary impact of this alternative method to finance a fiscal stimulus. We show that a monetary financing scheme for fiscal stimuli has positive impacts on economic aggregates.

However, this comes at a cost: a higher increase in inflation compared to the alternative debt-financing method. Additional analysis shows that the impact of a monetary-financed fiscal stimulus remains positive, but varies slightly according to the estimation sub-period, when the sample is split into two. Lastly, we show that the higher the level of the public debt-to-GDP ratio, the lower the positive effects of a monetary-financed fiscal stimulus on the economy.

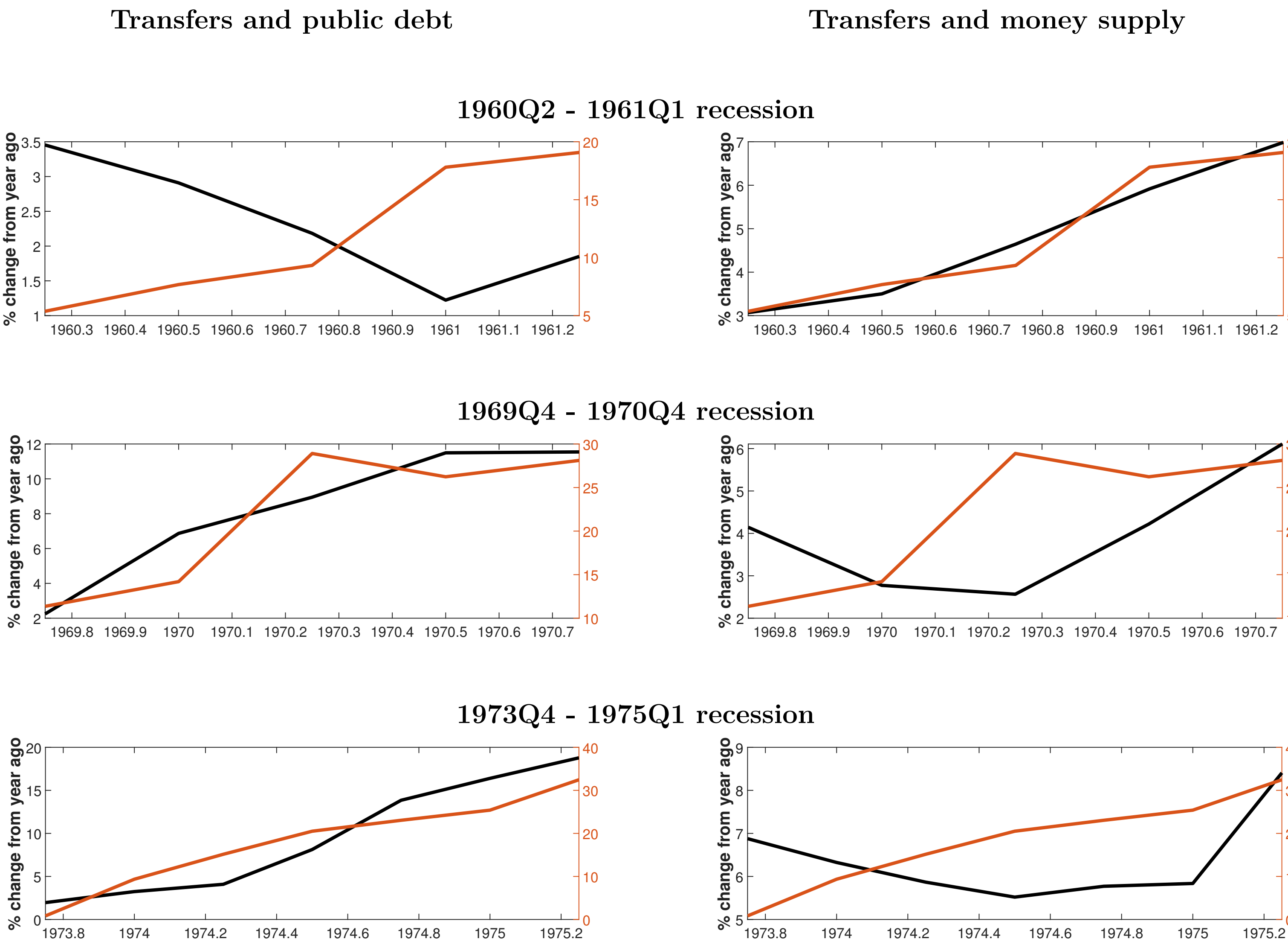
A caveat of our model is worth noting. Our model does not incorporate financial frictions and the implications for central bank balance sheets. If monetary financing is to be the focus of policy advice, it would be useful to include these features in the analysis.

Figure 1: Government spending, public debt and money supply



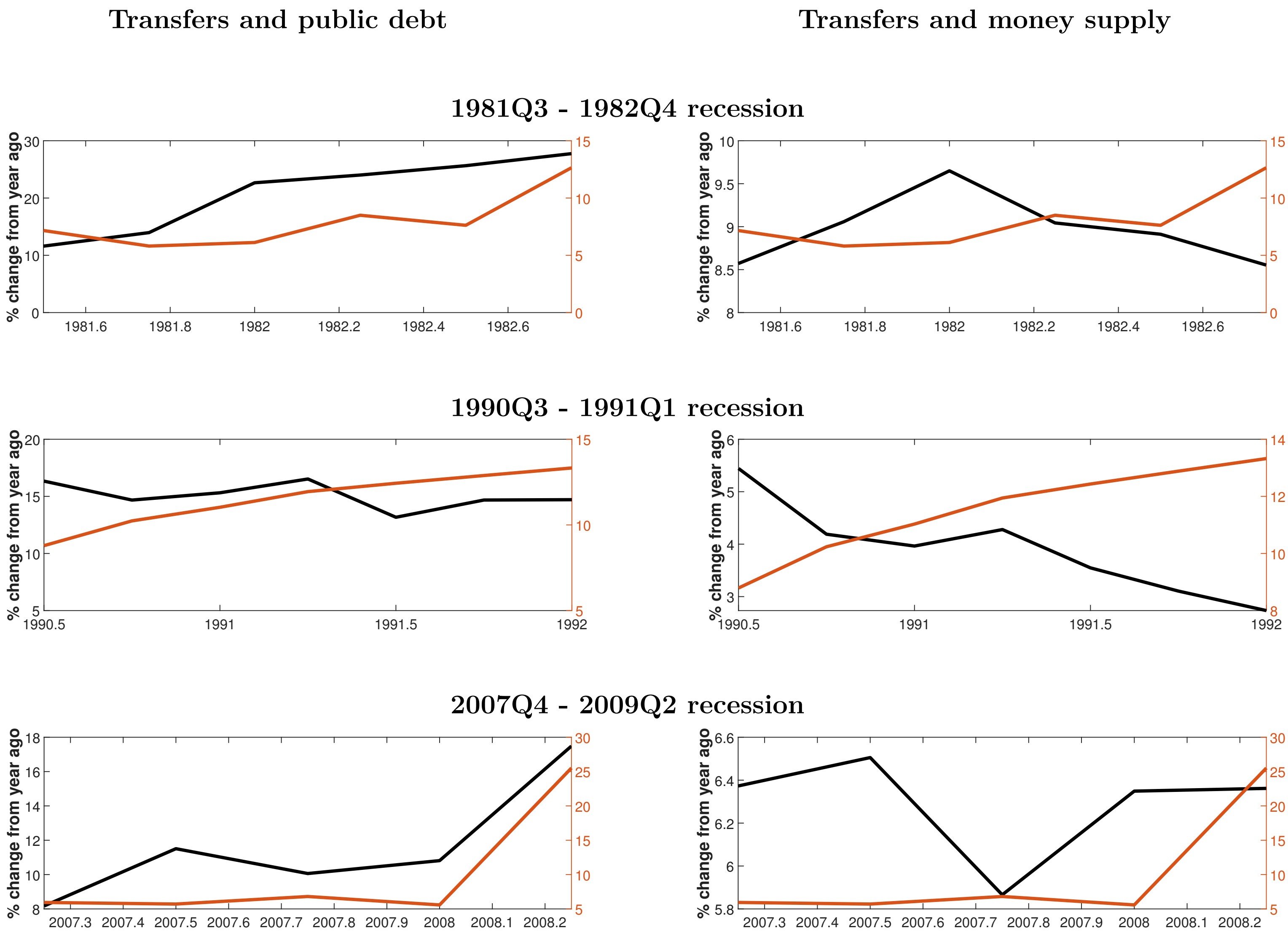
Notes: Source: FRED, Federal Reserve Bank of St. Louis. The two time series are in percentage changes from the previous year. The orange line represents government spending. The black line represents either public debt (left column) or money supply (right column). Public debt is measured two quarters ahead.

Figure 2a: Transfers, public debt and money supply



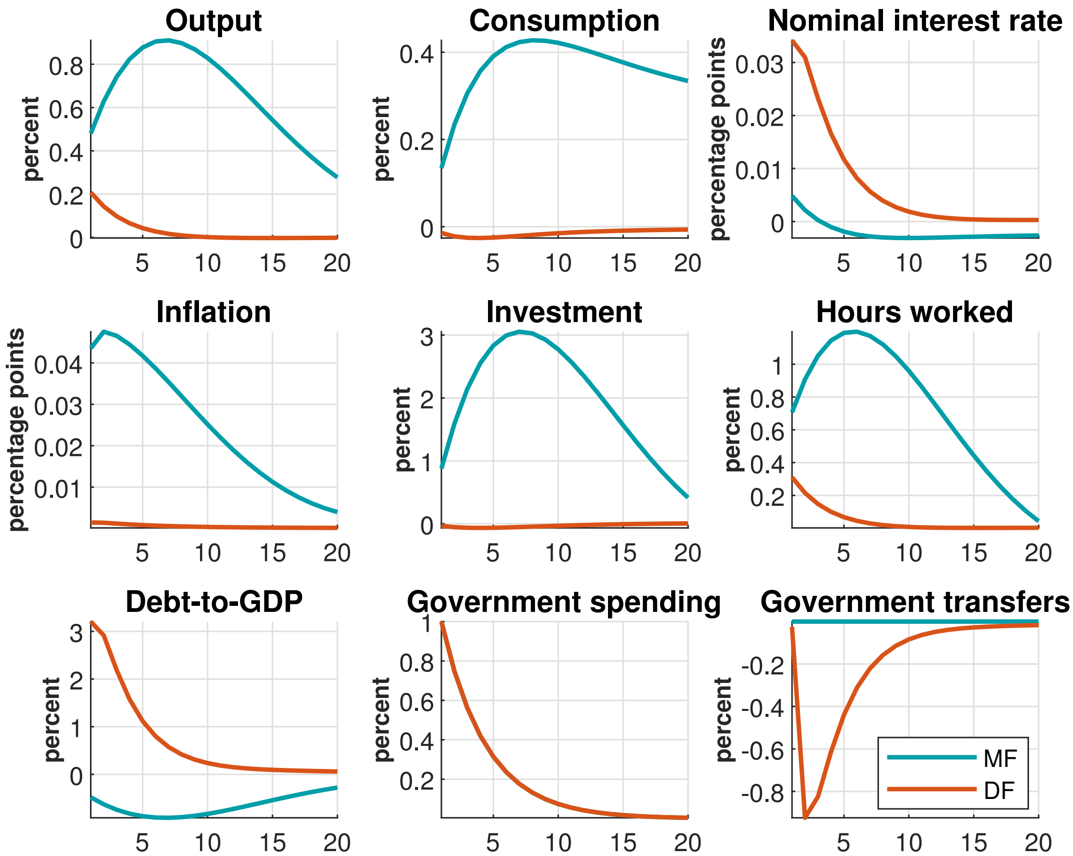
Notes: Source: FRED, Federal Reserve Bank of St.Louis. The two time series are in percentage changes from the previous year. The orange line represents government transfers. The black line represents either public debt (left column) or money supply (right column). Public debt is measured two quarters ahead.

Figure 2b: Transfers, public debt and money supply



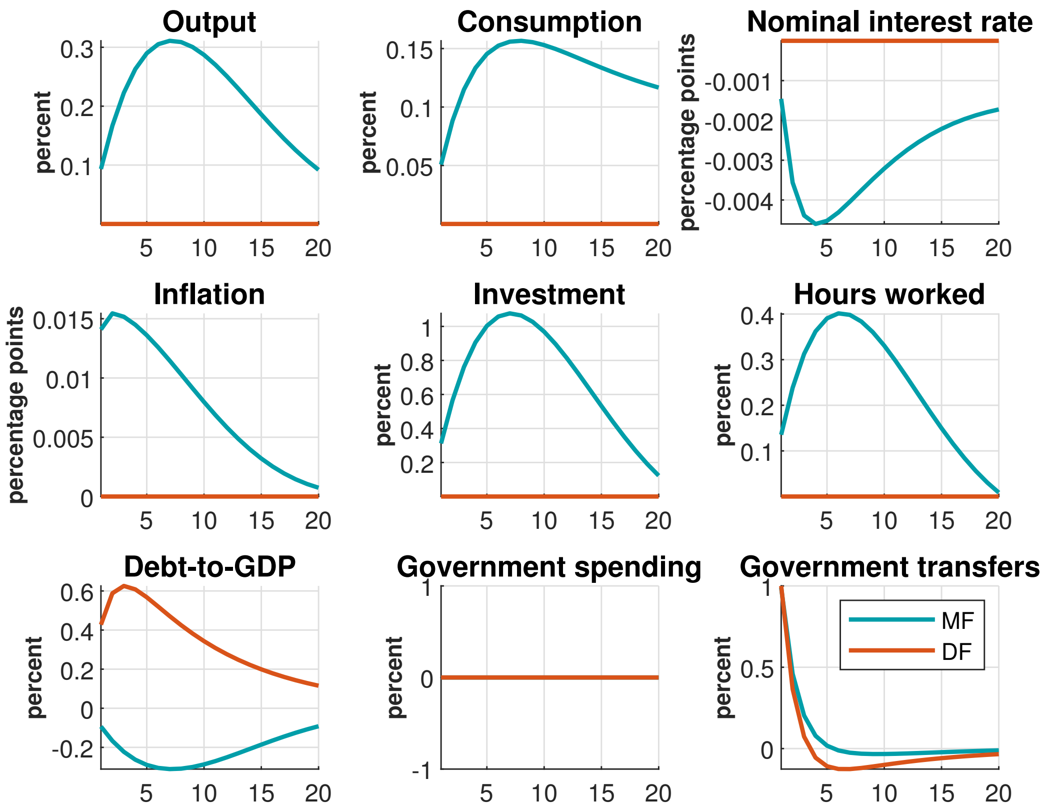
Notes: Source: FRED, Federal Reserve Bank of St.Louis. The two time series are in percentage changes from the previous year. The orange line represents government transfers. The black line represents either public debt (left column) or money supply (right column). Public debt is measured two quarters ahead.

Figure 3: Government spending increase: debt financing vs monetary financing



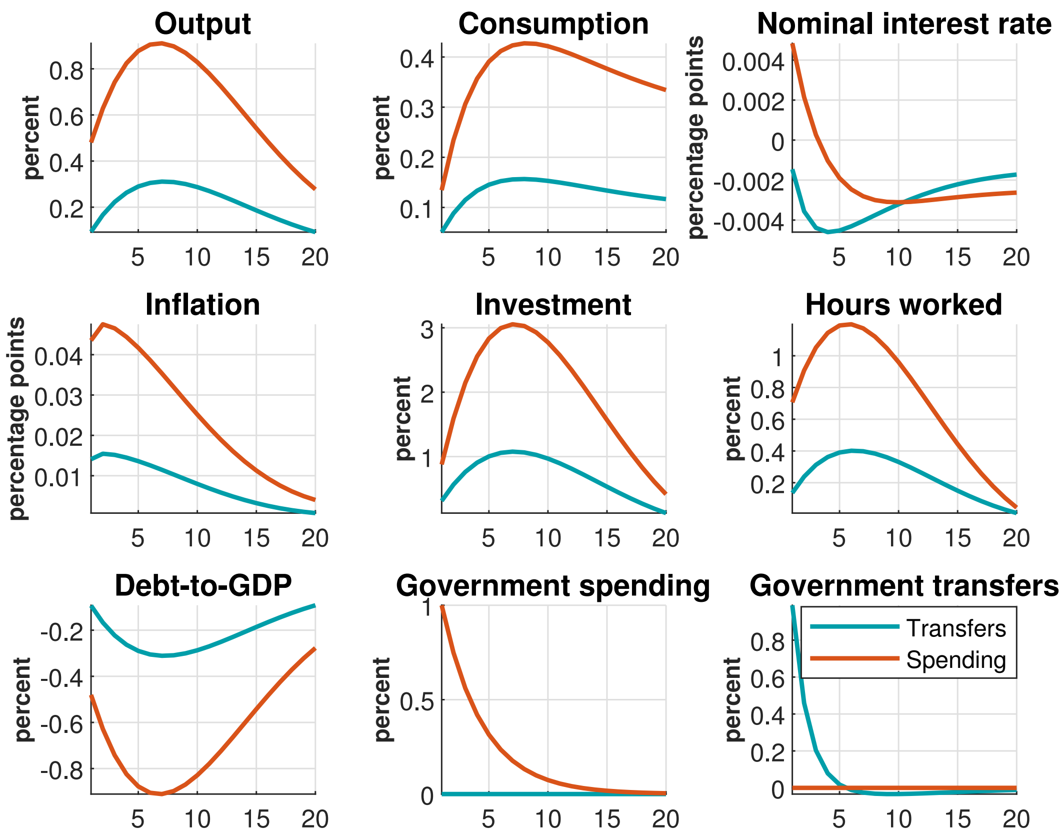
Notes: The impulse responses are obtained from a simulated one standard deviation shock to government spending. The values of the model parameters are set equal to their mean estimates of the posterior distribution. Horizontal axis: quarters after shock. The blue line represents responses to a monetary-financed government spending increase, while the orange line represents responses to a debt-financed government spending increase.

Figure 4: Transfers increase: debt financing vs monetary financing



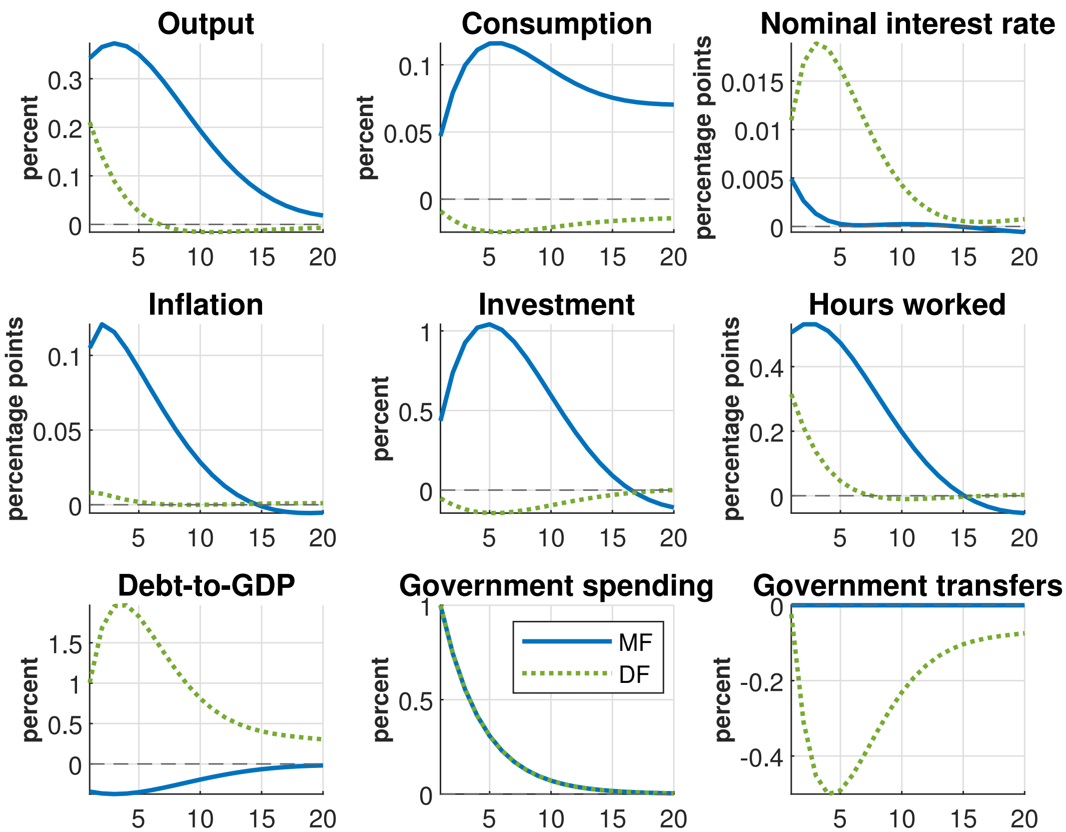
Notes: The impulse responses are obtained from a simulated one standard deviation shock to government transfers. The values of the model parameters are set equal to their mean estimates of the posterior distribution. Horizontal axis: quarters after shock. The blue line represents responses to the monetary-financed transfers increase, while the orange line represents responses to the debt-financed transfers increase.

Figure 5: Government spending and transfers increase: monetary financing



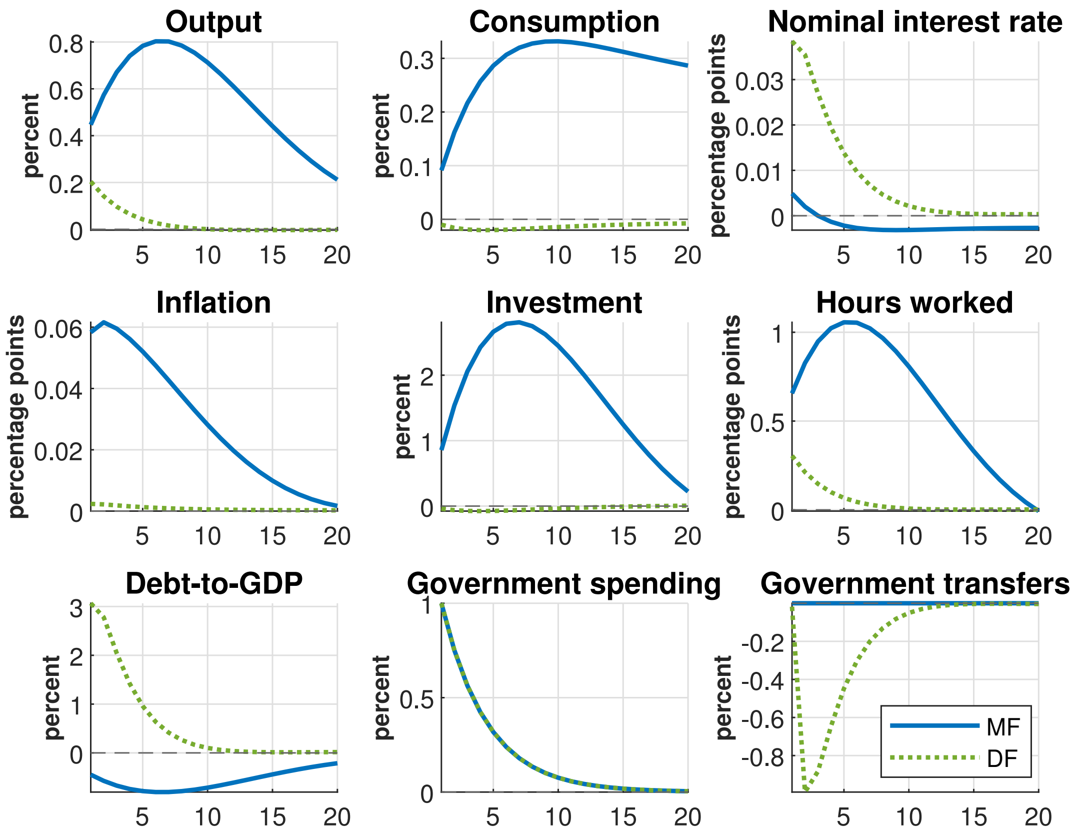
Notes: The impulse responses are obtained from a simulated one standard deviation shock to government spending and transfers. The values of the model parameters are set equal to their mean estimates of the posterior distribution. Horizontal axis: quarters after shock. The blue line shows responses to a monetary-financed transfers increase. The orange line shows responses to a monetary-financed government spending increase.

Figure 6: Government spending increase: 1960Q1 - 1979Q2 (S1)



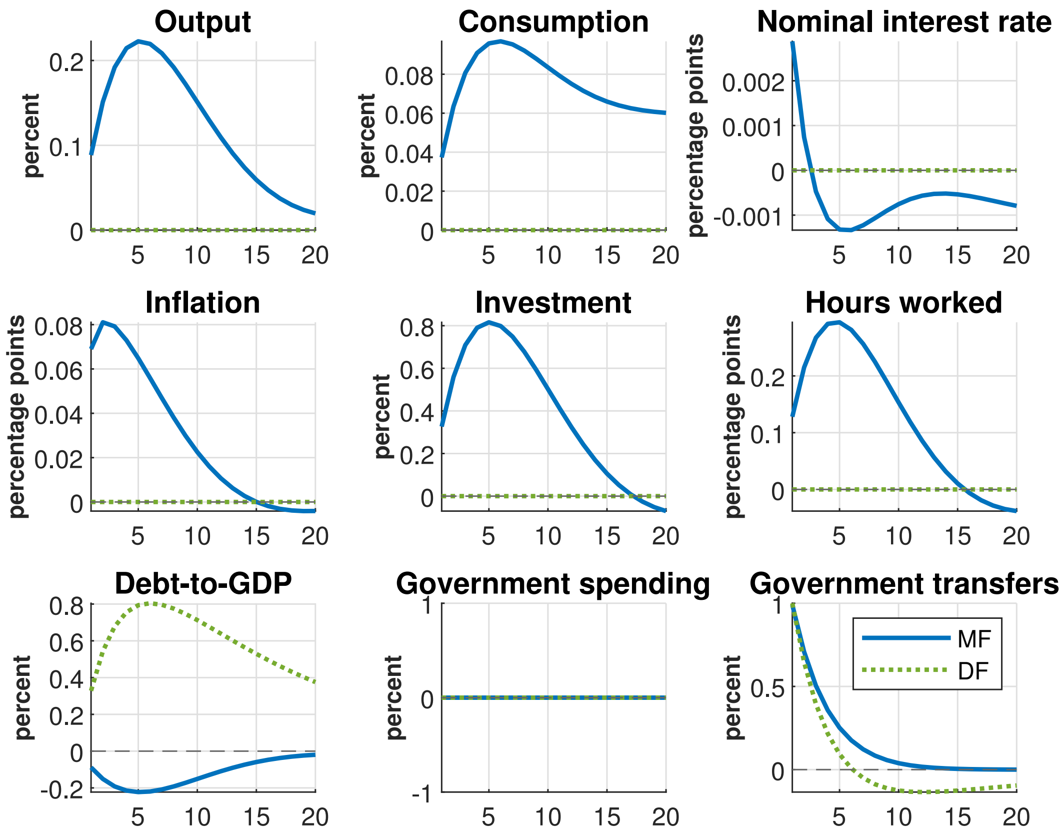
Notes: The impulse responses are obtained from a simulated one standard deviation shock to government spending. The values of the model parameters are set equal to their mean estimates of the posterior distribution. Horizontal axis: quarters after shock. The blue line represents responses to a monetary-financed government spending increase, while the green dashed line represents responses to a debt-financed government spending increase.

Figure 7: Government spending increase: 1984Q1 - 2007Q2 (S2)



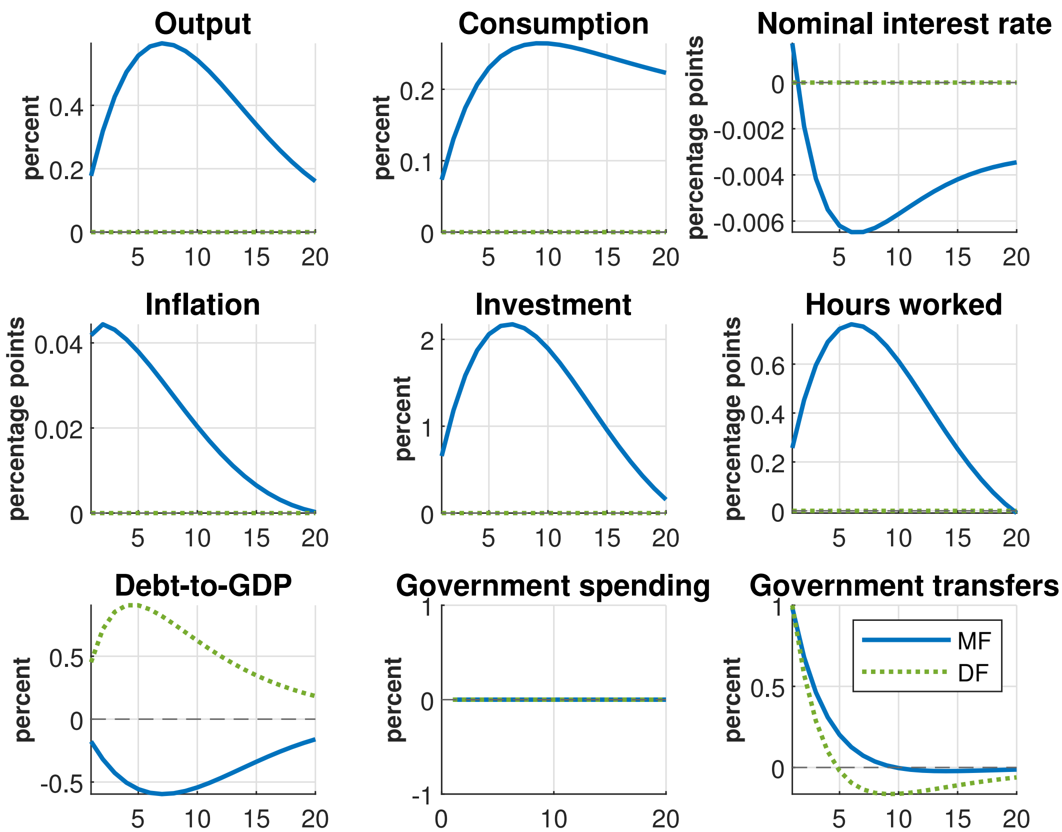
Notes: The impulse responses are obtained from a simulated one standard deviation shock to government spending. The values of the model parameters are set equal to their mean estimates of the posterior distribution. Horizontal axis: quarters after shock. The blue line represents responses to a monetary-financed government spending increase, while the green dashed line represents responses to a debt-financed government spending increase.

Figure 8: Transfers increase: 1960Q1 - 1979Q2 (S1)



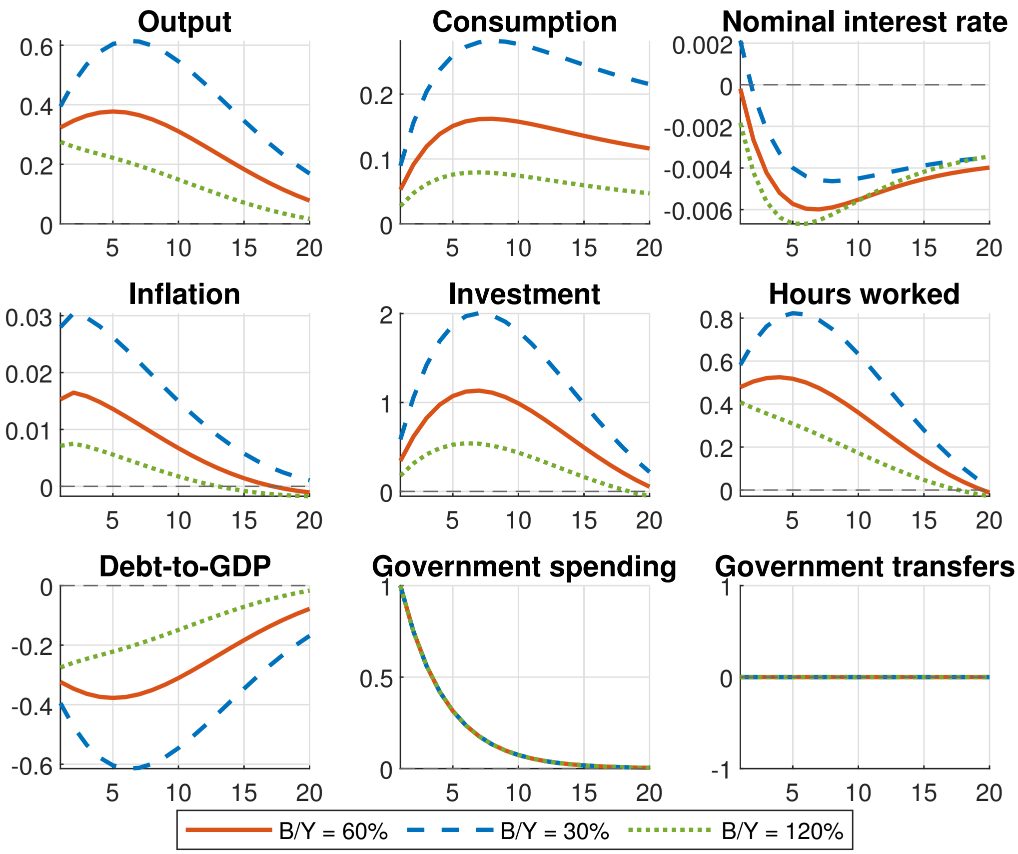
Notes: The impulse responses are obtained from a simulated one standard deviation shock to government transfers. The values of the model parameters are set equal to their mean estimates of the posterior distribution. Horizontal axis: quarters after shock. The blue line represents responses to a monetary-financed transfers increase, while the green dashed line represents responses to a debt-financed transfers increase.

Figure 9: Transfers increase: 1984Q1 - 2007Q2 (S2)



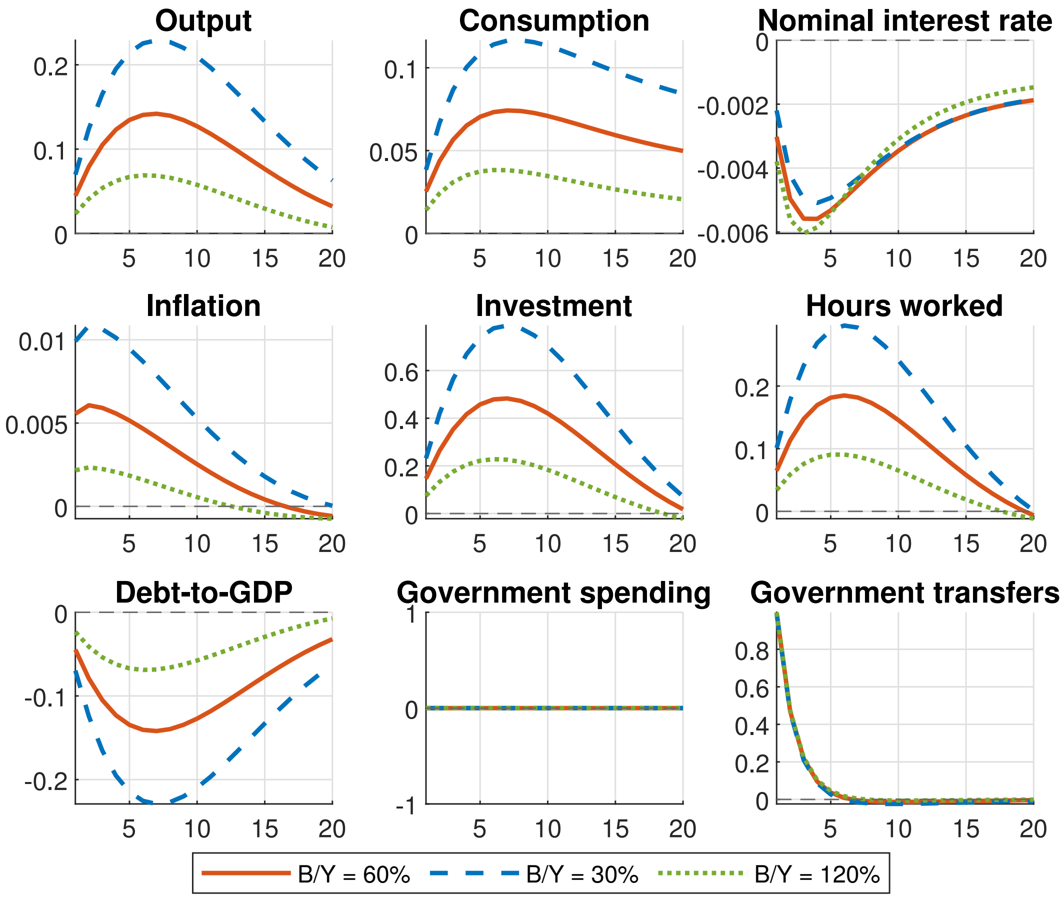
Notes: The impulse responses are obtained from a simulated one standard deviation shock to government transfers. The values of the model parameters are set equal to their mean estimates of the posterior distribution. Horizontal axis: quarters after shock. The blue line represents responses to a monetary-financed transfers increase, while the green dashed line represents responses to a debt-financed transfers increase.

Figure 10: Monetary-financed government spending increase under different levels of debt-to-GDP



Notes: The graphs show responses to a monetary-financed government spending increase. The orange line refers to a model with a steady-state debt-to-GDP ratio of 60%. The blue dashed line refers to a model with a steady-state debt-to-GDP ratio of 30%. The green line refers to a model with a steady-state debt-to-GDP ratio of 120%

Figure 11: Monetary-financed transfers increase under different levels of debt-to-GDP



Notes: The graphs show responses to a monetary-financed transfers increase. The orange line refers to a model with a steady-state debt-to-GDP ratio of 60%. The blue dashed line refers to a model with a steady-state debt-to-GDP ratio of 30%. The green line refers to a model with a steady-state debt-to-GDP ratio of 120%

Table 1: Fixed parameters according to quarterly data

Param.	**Description**	**Value**	**Source**
β	Households' discount factor	0.99	to match 4% real annual int. rate
α	Labour share in the Cobb Douglas function	0.33	Del Negro et al. (2007)
δ	Capital depreciation rate	0.02	Del Negro et al. (2007)
ν_m	Inv. elast. of substitution btw money&consumption	1.00	Galí (2015)
λ_w	Wage markup	0.14	Bianchi et al. (2023)
λ_p	Price markup	0.14	Bianchi et al. (2023)
$\frac{B}{Y}$	Share of public debt on GDP	2.40	Galí (2020b)
$\frac{G}{Y}$	Share of government spending on GDP	0.22	From our data sample
$\frac{T}{Y}$	Share of government transfers on GDP	0.26	From our data sample
χ	Steady-state inverse velocity of money supply	0.52	From our data sample

Notes: The table reports the name and the description of the fixed parameters, their calibrated values, and the target or the source.

Table 2: Priors and posteriors for the endogenous parameters

		Prior			**Posterior**		
Param.	**Description**	*Distribution*	*Mean*	*St. Dev.*	*Mean*	10%	90%
ν_l	Inverse Frisch elasticity	Gamma	2.000	0.250	1.654	1.329	1.966
h	Consumption habits	Beta	0.700	0.100	0.799	0.750	0.850
ϕ_r	Interest rate smoothing parameter	Beta	0.500	0.100	0.184	0.121	0.248
ϕ_π	Weight of inflation on the interest rate	Gamma	2.000	0.200	3.359	3.143	3.899
ϕ_y	Weight of output on the interest rate	Gamma	0.125	0.100	0.176	0.137	0.215
Γ	Investment adjustment costs	Normal	6.000	0.500	6.116	5.333	6.929
ψ_{bt}	Transfers parameter for debt	Gamma	0.250	0.100	0.266	0.144	0.383
ψ_{yt}	Transfers parameter for output	Gamma	0.100	0.050	0.121	0.030	0.206
ζ_w	Wage stickiness	Beta	0.500	0.100	0.473	0.414	0.531
ι_w	Wage indexation	Beta	0.500	0.200	0.464	0.166	0.753
ζ_p	Price stickiness	Beta	0.500	0.100	0.962	0.956	0.968
ι_p	Price indexation	Beta	0.500	0.200	0.108	0.056	0.160

Notes: The table reports the name and the description, the prior distributions, means and standard deviations, as well as the posterior means, the 10 percent and 90 percent credible sets of the endogenous parameters.

Table 3: Priors and posteriors for the exogenous processes parameters

		Prior			Posterior		
Param.	**Description**	*Distribution*	*Mean*	*St. Dev.*	*Mean*	10%	90%
ρ_z	Productivity persistence parameter	Beta	0.700	0.200	0.303	0.201	0.404
ρ_b	Preference persistence parameter	Beta	0.700	0.200	0.454	0.328	0.577
ρ_g	Government spending persistence parameter	Beta	0.700	0.200	0.749	0.689	0.810
ρ_μ	Investment persistence parameter	Beta	0.700	0.200	0.301	0.208	0.395
ρ_r	Monetary policy persistence parameter	Beta	0.700	0.200	0.995	0.991	0.999
ρ_π	Cost-push persistence parameter	Beta	0.700	0.200	0.653	0.565	0.742
ρ_t	Transfers persistence parameter	Beta	0.700	0.200	0.479	0.382	0.576
ρ_m	Money supply persistence parameter	Beta	0.700	0.200	0.815	0.754	0.875
σ_z	Productivity shock standard error	Inv. gamma	0.100	2.000	0.126	0.085	0.167
σ_b	Preference shock standard error	Inv. gamma	0.100	2.000	0.022	0.017	0.027
σ_g	Government spending shock standard error	Inv. gamma	0.100	2.000	0.025	0.023	0.027
σ_μ	Investment shock standard error	Inv. gamma	0.100	2.000	0.169	0.140	0.198
σ_r	Monetary policy shock standard error	Inv. gamma	0.100	2.000	0.008	0.007	0.009
σ_π	Cost-push shock standard error	Inv. gamma	0.100	2.000	1.259	0.785	1.716
σ_t	Transfers shock standard error	Inv. gamma	0.100	2.000	0.042	0.039	0.045
σ_m	Money supply shock standard error	Inv. gamma	0.100	2.000	0.218	0.201	0.234

Notes: The table shows the name and the description, the prior distributions, means and standard deviations, as well as the posterior means, 10 percent and 90 percent credible sets of the parameters for the exogenous processes.

Table 4: Priors and posteriors for the endogenous parameters - sub-samples

Param.	**Description**	**Posterior mean**		
		Full sample (1960Q1 - 2019Q4)	S1 (1960Q1 - 1979Q2)	S2 (1984Q1 - 2007Q2)
ν_l	Inverse Frisch elasticity	1.653	2.072	1.831
Γ	Investment adjustment costs	6.116	5.861	6.079
h	Consumption habits	0.799	0.868	0.850
ϕ_π	Weight of inflation on the interest rate	3.529	2.224	3.195
ψ_{yt}	Transfers parameter for output	0.121	0.109	0.088
ψ_{bt}	Transfers parameter for debt	0.265	0.242	0.299
ι_w	Wage indexation	0.464	0.354	0.468
ζ_p	Price stickiness	0.969	0.873	0.954
ι_p	Price indexation	0.108	0.205	0.076
ζ_w	Wage stickiness	0.471	0.440	0.388
ϕ_r	Interest rate smoothing parameter	0.185	0.793	0.192
ϕ_y	Weight of output on the interest rate	0.173	0.166	0.196

Notes: The table reports the name and the description of the structural parameters, as well as their posterior means. The first column shows the posterior means for the entire sample, while the second and the third columns show the posterior means for the first and the second sub-samples respectively.

Table 5: Priors and posteriors for the exogenous processes parameters - sub-samples

Param.	**Description**	**Posterior mean**		
		Full sample (1960Q1 - 2019Q4)	S1 (1960Q1 - 1979Q2)	S2 (1984Q1 - 2007Q2)
σ_z	Productivity shock standard error	0.126	0.068	0.074
σ_b	Preference shock standard error	0.022	0.038	0.024
σ_g	Government spending shock standard error	0.025	0.027	0.021
σ_μ	Investment shock standard error	0.168	0.194	0.130
σ_r	Monetary policy shock standard error	0.008	0.009	0.008
σ_π	Cost-push shock standard error	1.259	0.376	0.509
σ_t	Transfers shock standard error	0.042	0.031	0.022
σ_m	Money supply shock standard error	0.218	0.247	0.136
ρ_z	Productivity persistence parameter	0.302	0.194	0.269
ρ_b	Preference persistence parameter	0.452	0.381	0.281
ρ_π	Cost-push persistence parameter	0.653	0.820	0.745
ρ_m	Money supply persistence parameter	0.815	0.795	0.888
ρ_g	Government spending persistence parameter	0.749	0.745	0.751
ρ_μ	Investment persistence parameter	0.301	0.261	0.239
ρ_t	Transfers persistence parameter	0.479	0.724	0.707
ρ_r	Monetary policy persistence parameter	0.995	0.232	0.982

Notes: The table shows the name and the description of the parameters for the exogenous processes, as well as their posterior means. The first column shows the posterior means for the entire sample, while the second and the third columns show the posterior means for the first and the second sub-samples respectively.

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Appendices

Appendix A Maximisation problems and first order conditions

Household The household's problem is:

$$\max_{C_t(j),\frac{M_t(j)}{P_t},L_t(j)} \mathbb{E}_t\left\{\sum_{t=0}^{\infty}\beta^s b_t\left[\left(ln\left(C_t(j)-hC_{t-1}(j)\right)+\frac{\chi_t}{1-\nu_m}\left(\frac{M_t(j)}{P_t}\right)^{1-\nu_m}\right)-\frac{L_t(j)^{1+\nu_l}}{1+\nu_l}\right]\right\}$$
$$-\varrho_t\Big[P_tC_t(j)+P_tI_t(j)+B_t(j)+M_t(j)-R_{t-1}B_{t-1}(j)$$
$$-M_{t-1}(j)-R_t^k(j)K_{t-1}(j)-W_t(j)L_t(j)-P_tD_t-P_tT_t(j)\Big]$$
$$-\lambda_t^k\left[K_t(j)-(1-\delta)K_{t-1}(j)-\mu_t\left(1-S\left(\frac{I_t(j)}{I_{t-1}(j)}\right)\right)I_t(j)\right]$$

with ϱ_t being the Lagrange multiplier. The first order conditions for the representative household read as follows:

$$[\partial C_t]\quad \lambda_t=b_t\frac{1}{C_t-hC_{t-1}}-\beta h\mathbb{E}_t\left(b_{t+1}\frac{1}{C_{t+1}-hC_t}\right) \tag{A.20}$$

$$[\partial M_t]\quad \lambda_t-\beta\,\mathbb{E}_t[P_{t+1}\lambda_{t+1}]=\chi_t b_t\left(\frac{M_t}{P_t}\right)^{-\nu_m} \tag{A.21}$$

$$[\partial B_t]\quad \lambda_t=\beta R_t\,\mathbb{E}_t[P_{t+1}\lambda_{t+1}] \tag{A.22}$$

$$[\partial I_t]\quad \lambda_t=\lambda_t^k\mu_t\left[1-S\left(\frac{I_t}{I_{t-1}}\right)-S'\left(\frac{I_t}{I_{t-1}}\right)\frac{I_t}{I_{t-1}}\right]+\beta\mathbb{E}_t\left[\lambda_{t+1}^k\mu_{t+1}S'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right] \tag{A.23}$$

$$[\partial K_t]\quad \lambda_t^k=\beta\mathbb{E}_t\left[\lambda_{t+1}\frac{R_{t+1}^k}{P_{t+1}}+\lambda_{t+1}^k(1-\delta)\right] \tag{A.24}$$

Where $\lambda_t=P_t\varrho_t$.

Labour packers The aggregation of labour into labour services is given by:

$$L_t=\left[\int_0^1 L_t(j)^{\frac{1}{1+\lambda_w}}dj\right]^{1+\lambda_w} \tag{A.25}$$

where λ_w is a parameter and it represents the steady state value of the markup on wages. We obtain the labour demand function:

$$L_t(j) = \left(\frac{W_t(j)}{W_t}\right)^{-\frac{1+\lambda_w}{\lambda_w}} L_t \tag{A.26}$$

and the aggregate nominal wage:

$$W_t = \left[\int_0^1 W_t(j)^{-\frac{1}{\lambda_w}} di\right]^{-\lambda_w} \tag{A.27}$$

The wage setting is subject to nominal rigidities following Calvo (1983). Each period the labour packers cannot optimize nor change the wage of a fraction ζ_w of households. For these households, the wage increases at the geometrically weighted average of the steady state rate of inflation $\pi^\star$ and of last period's inflation π_{t-1} with weights $1-\iota_w$ and ι_w. The problem for the households that can adjust their wages is:

$$\begin{aligned}
&\max_{\widetilde{W}_t(j)} \mathbb{E}_t \sum_{s=0}^{\infty} \zeta_w^s \beta^s b_{t+s} \left[-\frac{L_{t+s}(j)^{1+\nu_l}}{1+\nu_l}\right] \\
&\text{s.t.} \quad L_t(j) = \left(\frac{\widetilde{W}_t(j)}{W_t}\right)^{-\frac{1+\lambda_w}{\lambda_w}} L_t \\
&\text{eq. (1) in the main text, for s} = 0, \dots, \infty, \text{and} && \text{(A.28)} \\
&W_{t+s}(j) = \left(\prod_{l=1}^{s} (\pi^*)^{1-\iota_w} (\pi_{t+l-1})^{\iota_w}\right) \widetilde{W}_t(j) \\
&\text{for s} = 1, \dots, \infty && \text{(A.29)}
\end{aligned}$$

where $\widetilde{W}_t(j)$ is the wage set by labour packers that can adjust it. The first order condition for the labour packers is:

$$\left[\partial \widetilde{W}_t\right] \quad \frac{\lambda_t L_t}{\lambda_w W_t} \mathbb{E}_t \sum_{s=0}^{\infty} \zeta^s \beta^s \lambda_{t+s} L(i)_{t+s} \left[-\frac{\mathcal{X}_{t,s} \widetilde{W}_t(j)}{P_{t+s}} + (1+\lambda_w) \frac{b_{t+s} L_{t+s}(j)^{\nu_l}}{\lambda_{t+s}}\right]$$

where

$$\mathcal{X}_{ts} = \begin{cases} 1 & \text{if } s = 0 \\ \prod_{l=1}^{s} \pi_*^{1-\iota_w} \pi_{t+l-1}^{\iota_w} & \text{otherwise} \end{cases} \tag{A.30}$$

Finally, we can derive the aggregate wage dynamics, which is defined by:

$$W_t = \left[(1 - \zeta_w) \widetilde{W}_t^{-1/\lambda_w} + \zeta_w \left(\pi_*^{1-\iota_w} \pi_{t-1}^{\iota_w} W_{t-1} \right)^{-1/\lambda_w} \right]^{-\lambda_w} \tag{A.31}$$

Intermediate goods firms The cost minimisation problem for the intermediate firms implies the maximisation of the following profits:

$$P_t Y_t - W_t L_t - R_t^k K_t \tag{A.32}$$

and the first order conditions are:

$$W_t = (1 - \alpha) A_t^{1-\alpha} K_t^{\alpha} L_t^{-\alpha}$$
$$R_t^k = \alpha A_t^{1-\alpha} K_t^{\alpha-1} L_t^{1-\alpha}$$

Intermediate goods firms set their prices à la Calvo. This price setting allows a number $1 - \zeta_p$ of firms to reset their prices in period t, while the remaining ζ_p fraction of firms keep their prices indexed to the inflation rate in period $t - 1$. Those firms that cannot adjust their prices will have a price increasing with the steady state inflation π_* and the inflation in period $t - 1$, π_{t-1}. Firms that may change their price, choose a price P_t^* today taking into consideration the impact of P_t^* on future profits. The price P_t^* is the same across all firms readjusting it, while prices for the non-adjusting firms follow:

$$P_t(i) = \pi_{t-1}^{\iota^p} (\pi^*)^{1-\iota^p} \tag{A.33}$$

The firms that can adjust their prices follow an optimal price equation:

$$\max_{\tilde{P^*}_t(i)} \sum_{s=0}^{\infty} \zeta_p^s \beta^s \Xi_{t+s}^p \left(\tilde{P}_t(i) \left(\prod_{l=1}^{s} \pi_{t+l-1}^{\iota^p} {\pi^*}^{1-\iota^p} \right) - MC_{t+s} \right) Y_{t+s}(i) \tag{A.34}$$

where $\tilde{P}_t(i)$ is the newly set price and MC_{t+s} is the marginal cost. ι^p represents the price indexation parameter and Ξ_{t+s}^p is the Lagrange multiplier for the firms.

The aggregate price dynamics is given by a weighted average of the price set by the firms that adjust it and the price of firms that keep it indexed to last period's inflation, with a weight given by ζ_p. Moreover, intermediate firms choose a price that maximises the expected present discounted value of profits. The price setting problem is:

$$\begin{aligned}
&\max_{\tilde{P}_t} \lambda_t^p \Big(\tilde{P}_t(i) - MC_t\Big) Y_t(i) \\
&+ \mathbb{E}_t \sum_{s=1}^{\infty} \zeta_p^s \beta^s \lambda_{t+s}^p \left[\tilde{P}_t(i) \left(\prod_{l=1}^{s} \pi_{t+l-1}^{\iota_p} \pi_*^{1-\iota_p}\right) - MC_{t+s}\right] Y_{t+s}(i) \\
&s.t.\, Y_{t+s}(i) = \left[\frac{\tilde{P}_t(i)\left(\prod_{l=1}^{s} \pi_{t+l-1}^{\iota_p} \pi_*^{1-\iota_p}\right)}{P_{t+s}}\right]^{-\frac{1+\lambda_{p,t+s}}{\lambda_{p,t+s}}} Y_{t+s}
\end{aligned}$$

and the first order conditions is:

$$\begin{aligned}
&\lambda_t^p \left(\frac{\tilde{P}_t(i)}{P_t}\right)^{-\frac{1+\lambda_{p,t}}{\lambda_{p,t}}-1} \frac{1}{\lambda_{p,t} P_t} \Big(\tilde{P}_t(i) - (1+\lambda_{p,t})\, MC_t\Big) Y_t(i) + \\
&\mathbb{E}_t \sum_{s=1}^{\infty} \zeta_p^s \beta^s \lambda_{t+s}^p \left(\frac{\tilde{P}_t(i)\left(\prod_{l=1}^{s} \pi_{t+l-1}^{\iota_p} \pi_*^{1-\iota_p}\right)}{P_{t+s}}\right)^{-\frac{1+\lambda_{p,t+s}}{\lambda_{p,t+s}}-1} \frac{\left(\prod_{l=1}^{s} \pi_{t+l-1}^{\iota_p} \pi_*^{1-\iota_p}\right)}{\lambda_{p,t+s} P_{t+s}} \\
&\left[\tilde{P}_t \left(\prod_{l=1}^{s} \pi_{t+l-1}^{\iota_p} \pi_*^{1-\iota_p}\right) - (1+\lambda_{p,t})\, MC_{t+s}\right] Y_{t+s} = 0
\end{aligned}$$

The derived aggregate price dynamics, considering the Calvo pricing parameter, writes:

$$P_t = \left[(1-\zeta_p)\, \tilde{P}_t(i)^{-\frac{1}{\lambda_{p,t}}} + \zeta_p \left(\pi_{t-1}^{\iota_p} \pi_\star^{1-\iota_p} P_{t-1}\right)^{-\frac{1}{\lambda_{p,t}}}\right]^{-\lambda_{p,t}}$$

Appendix B Log-linearized equations

Euler equation

$$
\begin{aligned}
&(1-h\beta)\,(1-h)\ \xi_t = \\
&(1-h)\ b_t - \left(\beta\, h^2\right) c_t + h\, c_{t-1} - \beta h\,(1-h)\,\mathbb{E}_t\left[b_{t+1}\right] + \beta h\,\mathbb{E}_t\left[c_{t+1}\right]
\end{aligned} \tag{B.35}
$$

where $\quad \xi_t = r_t - \mathbb{E}_t\left[\pi_{t+1}\right] + \mathbb{E}_t\left[\xi_{t+1}\right]$

Money demand

$$\nu_m m_t = \chi_t + b_t - \frac{1}{R-1} r_t - \xi_t \tag{B.36}$$

Investment FOC

$$i_t - \frac{\beta}{1+\beta}\,\mathbb{E}_t\left[i_{t+1}\right] = \frac{1}{1+\beta} i_{t-1} + \frac{1}{\Gamma\,(1+\beta)} q_t - \frac{1}{\Gamma\,(1+\beta)} \xi_t + \frac{1}{\Gamma\,(1+\beta)} \mu_t \tag{B.37}$$

Law of motion of capital

$$k_t = \left(1 - \frac{i}{k}\right) k_{t-1} + \frac{i}{k} i_t + \frac{i}{k} \mu_t \tag{B.38}$$

Production function

$$y_t = a_t + \alpha k_t + (1-\alpha)\, n_t \tag{B.39}$$

Capital-labour relation

$$r_t^k = w_t + n_t - k_t \tag{B.40}$$

Household's FOC for capital

$$q_t = \frac{r^k}{r^k + (1-\delta)}\,\mathbb{E}_t\left[r_{t+1}^k\right] + \frac{(1-\delta)}{r^k + (1-\delta)}\,\mathbb{E}_t\left[q_{t+1}\right] + \frac{r^k}{r^k + (1-\delta)}\,\mathbb{E}_t\left[\xi_{t+1}\right] \tag{B.41}$$

Marginal cost

$$\Lambda_t = \alpha r_t^k + (1-\alpha)\, w_t - a_t \tag{B.42}$$

Wages

$$w_t - w_{t-1} + \pi_t - \iota^w \pi_{t-1} =$$
$$\frac{1-\zeta_w}{\zeta^w} \frac{1-\beta\zeta^w}{1+\nu_l \frac{1+\lambda^w}{\lambda^w}} \left(b_t + \phi_l + \nu_l n_t - \xi_t - w_t\right) + \beta\, \mathbb{E}_t \left(w_{t+1} - w_t + \pi_{t+1} - \iota^w \pi_t\right) \tag{B.43}$$

New Keynesian Phillips curve

$$\pi_t = \frac{(1-\zeta_p\,\beta)\,(1-\zeta_p)}{(1+\beta\,\iota^p)\;\zeta_p} \left(\Lambda_t + \frac{\lambda_p}{1+\lambda_p} \lambda_t^p\right) + \frac{\iota^p}{1+\iota^p\beta}\,\pi_{t-1} + \frac{\beta}{1+\beta\,\iota^p}\; \mathbb{E}_t\left[\pi_{t+1}\right] \tag{B.44}$$

Aggregate economy

$$y_t = \frac{c}{y}\,c_t + \frac{i}{y}\,i_t + \frac{g}{y}\,g_t \tag{B.45}$$

Monetary policy

$$r_t = (1-\phi_r)\left(\phi_\pi \pi_t + \phi_y y_t\right) + \phi_r r_{t-1} + \lambda_t^r \tag{B.46}$$

Government budget constraint

$$\frac{b}{y}\frac{r}{\pi}\left(b_{t-1} + r_{t-1} - \pi_t\right) + \frac{g}{y} g_t + \frac{t}{y} t_t = \frac{b}{y} b_t + \chi \Delta m_t \tag{B.47}$$

Fiscal rule

$$t_t = -\psi_{yt} y_t - \psi_{bt} b_{t-1} + t_t$$

Law of motion of money

$$m_{t-1} = m_t + \pi_t - \Delta m_t \tag{B.48}$$

Exogenous processes

Cost-push:	$\lambda_t^p = \rho_\pi \, \lambda_{t-1}^p + \epsilon_t^{\lambda^p}$
Investment:	$\mu_t = \rho_\mu \, \mu_{t-1} + \epsilon_{\mu,t}$
Monetary policy:	$\lambda_t^r = \rho_r \, \lambda_{t-1}^r + \epsilon_{r,t}$
Preference shifter:	$b_t = \rho_b \, b_{t-1} + \epsilon_{b,t}$
Technology:	$a_t = \rho_z \, a_{t-1} + \epsilon_{z,t}$
Money demand:	$\chi_t = \rho_m \, \chi_{t-1} + \epsilon_{m,t}$
Transfers:	$t_t = \rho_t t_{t-1} + \epsilon_{t^*,t}$
Government spending:	$g_t = \rho_g g_{t-1} + \epsilon_{g,t}$

Appendix C Data construction

In this Section, we describe the data construction. In what follows, the following data series, retrieved from FRED, Federal Reserve Bank of St.Louis, are used: GDPDEF is the implicit price deflator, which is seasonally adjusted, with 2012=100. POPINDEX is a population index such that population in 1992Q3=1. CNP16OV is the civil non institutional population 16 year and older. The time series is non seasonally adjusted, and it is expressed in thousands. The variables are constructed as follows:

1. Output:

$$100 \times \text{LN}\left(\frac{\text{Real gross domestic product (GDPC1)}}{\text{POPINDEX}}\right) \tag{C.49}$$

2. Consumption:

$$100 \times \text{LN}\left(\frac{\text{Non durable goods and services/GDPDEF}}{\text{POPINDEX}}\right) \tag{C.50}$$

3. Investment:

$$100 \times \text{LN}\left(\frac{\text{Fixed Private Investment(FPI)}}{\text{POPINDEX}}\right) \tag{C.51}$$

4. Real wage:

$$100 \times \text{LN}\left(\frac{\text{Nonfarm Business Sector: Real Hourly Compensation (COMPRNFB)}}{\text{GDPDEF}}\right) \tag{C.52}$$

5. Inflation:

$$100 \times \text{LN}\left(\Delta\text{GDPDEF}\right) \tag{C.53}$$

Considering the prolonged time period with interest rates hitting their effective lower bound, we use the Shadow rate as in Wu and Xia (2016)[12]. However, we also estimated our model with the short term nominal interest rate. Estimation results are robust to both interest rate time series. Shadow rates and short term interest rates are constructed as:

6. Shadow rate and nominal interest rate:

$$\frac{\text{Shadow rate}}{4} \tag{C.54}$$

$$\frac{\text{Effective federal funds rate (FEDFUNDS)}}{4} \tag{C.55}$$

Fiscal variables are available on the Bureau of Economic Analysis website, and are retrieved from the NIPA tables available at https://www.bea.gov/data/government/receipts-and-expenditures.

7. Government spending:

$$100 \times \text{LN}\left(\frac{\text{GS/GDPDEF}}{\text{POPINDEX}}\right) \tag{C.56}$$

where GS = (Government consumption expenditure + government gross investment + government net purchases of non-produced assets) - consumption of fixed capital

8. Transfers:

$$100 \times \text{LN}\left(\frac{\text{T/GDPDEF}}{\text{POPINDEX}}\right) \tag{C.57}$$

where T = [(current transfer payments - current transfer receipts) + (capital transfer payments - capital transfer receipts) + subsidies] (table 3.2, lines 26, 19, 46, 42, 36) - [(current tax receipts + contributions for government social insurance + income receipts on assets + current surplus of government enterprises) (table 3.2, lines 2, 10, 13, 23) - *total tax*

[12]The time series is available here: https://www.atlantafed.org/cqer/research/wu-xia-shadow-federal-funds-rate.

revenues]

and:

total tax revenues = consumption tax revenues + labour tax revenues + capital tax revenues

with:

consumption tax revenues = excise taxes + custom duties

labour tax revenues = average labour income tax rate * tax base

capital tax revenues = average capital income tax rate * tax base

9. Money supply:

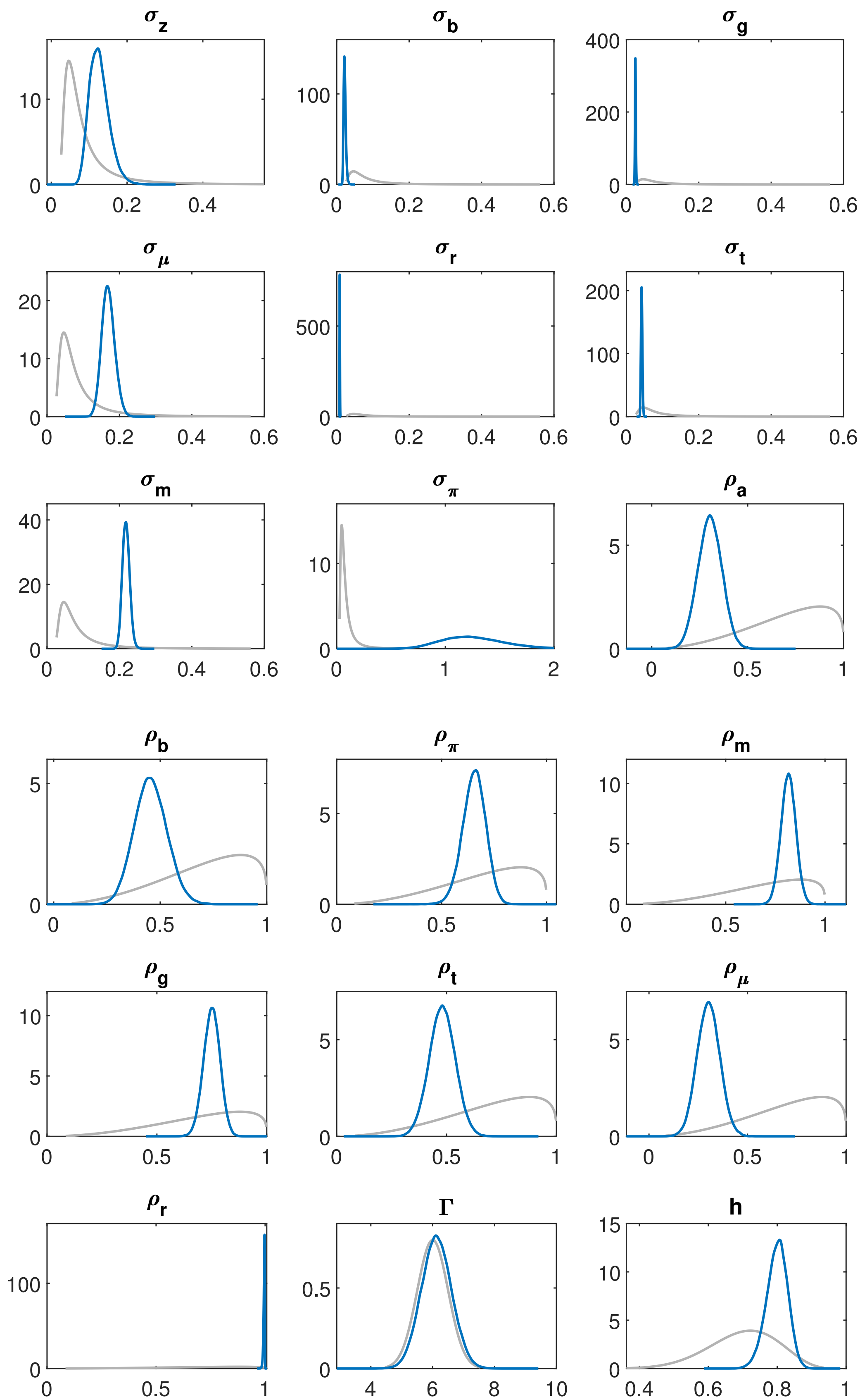
$$100 \times \text{LN}\left(\frac{\text{M2(M2SL)/GDPDEF}}{\text{POPINDEX}}\right) \tag{C.58}$$

Appendix D Diagnostic tests 1960Q1-2019Q4

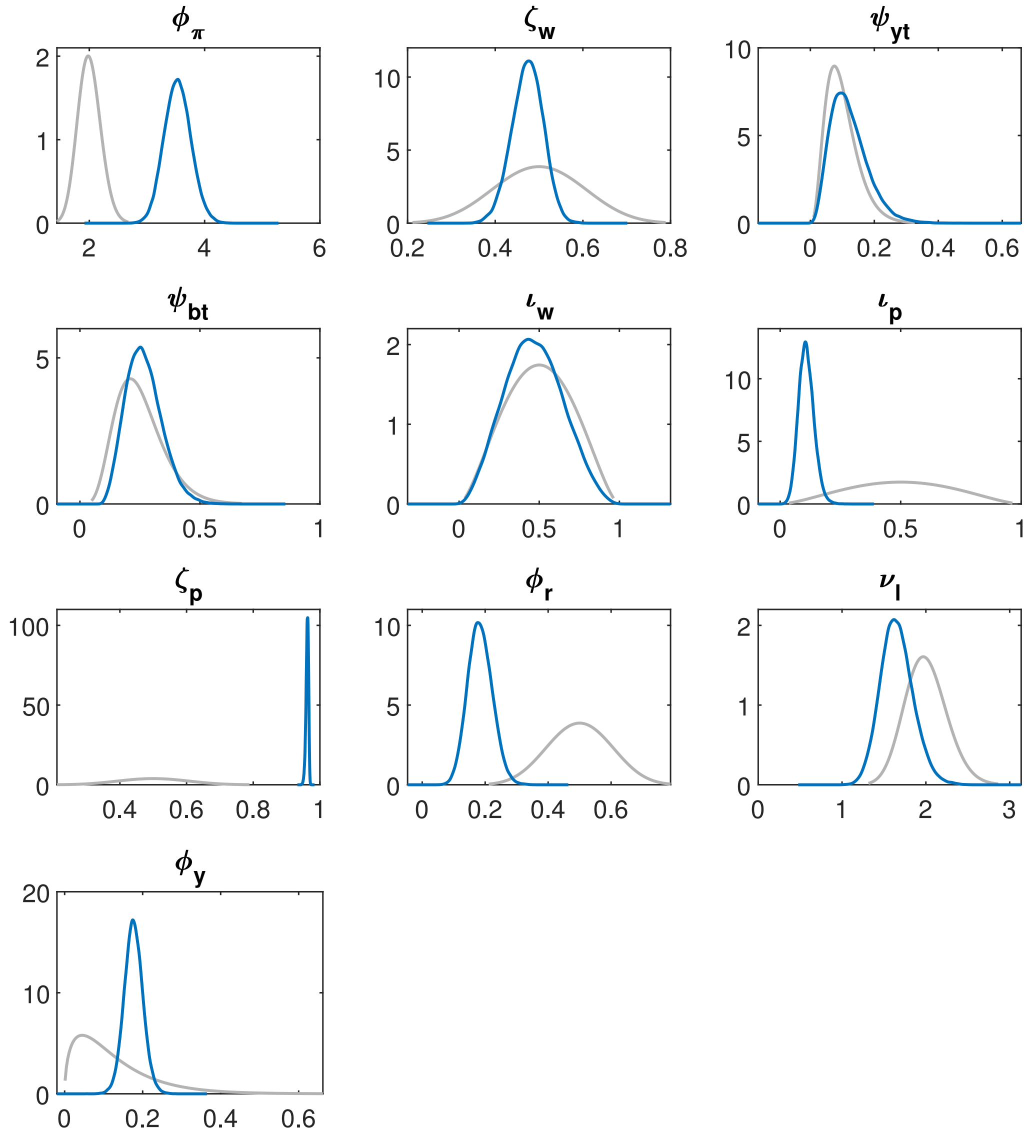
This Section presents diagnostic tests for the entire sample, spanning from 1960Q1 to 2019Q4.

D.1 Prior and posterior distributions

In the graphs below, the grey lines represent the prior distributions while the blue lines correspond to the posterior distributions of the estimate parameters.



σ z
σ b
σ g
σ μ
σ r
σ t
σ m
σ π
ρ a
ρ b
ρ π
ρ m
ρ g
ρ t
ρ μ
ρ r
Γ
h



ϕ_π
ζ_w
ψ_{yt}
ψ_{bt}
ι_w
ι_p
ζ_p
ϕ_r
ν_l
ϕ_y

D.2 Monte Carlo Markov Chain univariate diagnostics

In the graphs below, the first column (Interval) shows the Brooks and Gelman (1998) convergence diagnostics for the 80% interval. The blue line represents the 80% interval range based on the pooled draws from all sequences, whereas the red line indicates the mean interval based on the draws of the individual sequences. The second and the third column with labels (m2 and m3, respectively) denote an estimate of the same statistics for the second and third central moments.

Figure 12: Univariate convergence diagnostics, 1960Q1-2019Q4

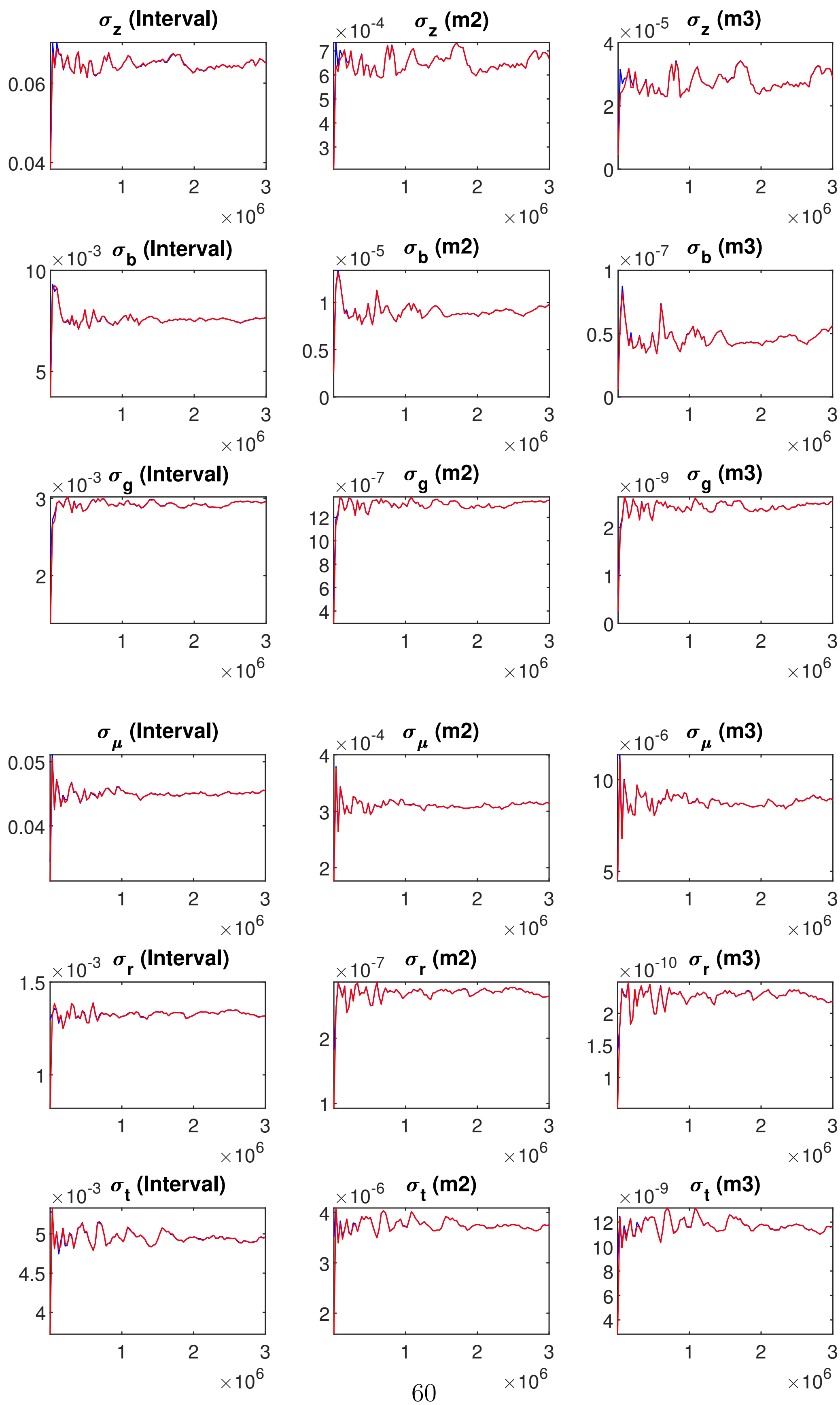


Figure 13: Univariate convergence diagnostics, 1960Q1-2019Q4

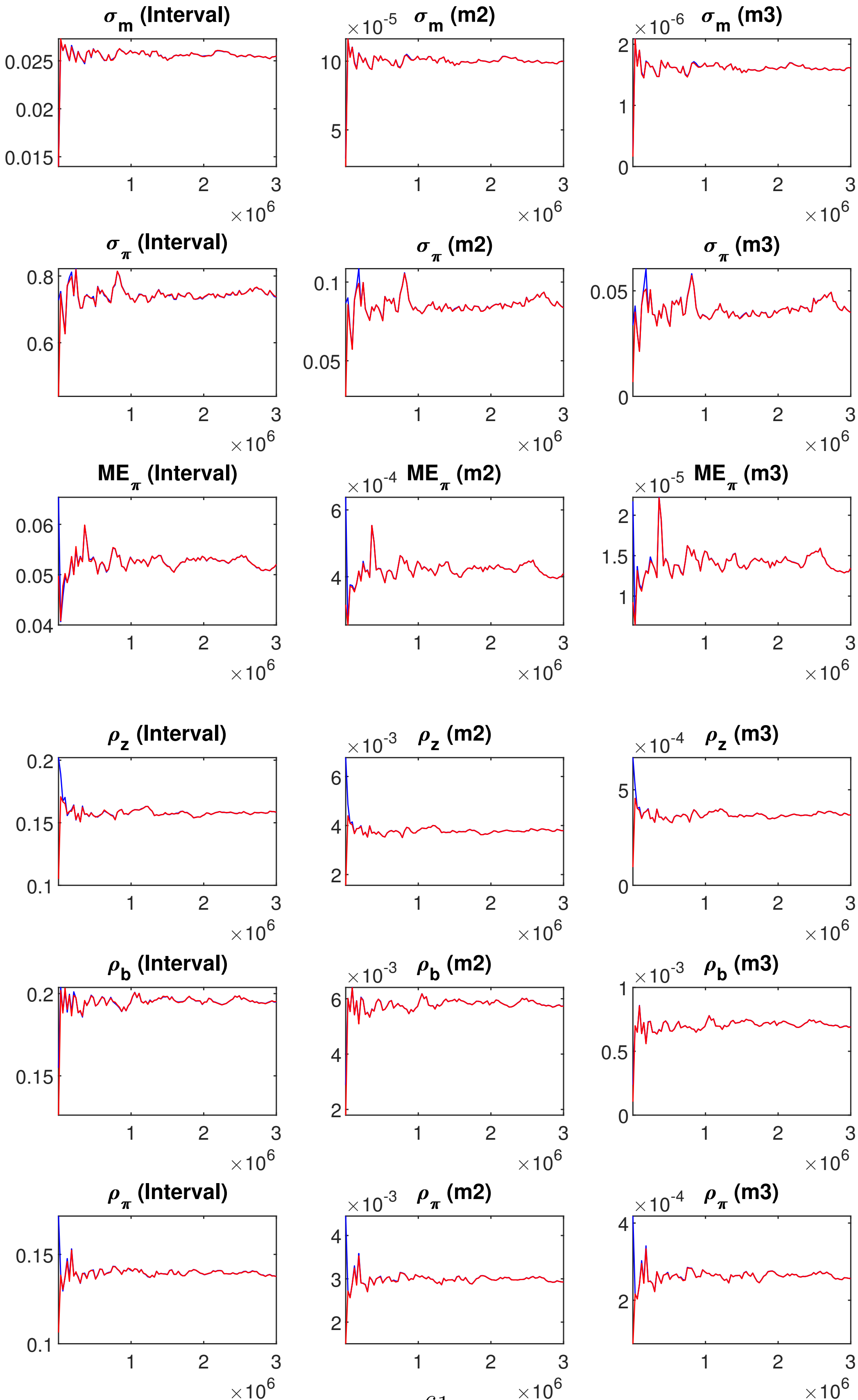


Figure 14: Univariate convergence diagnostics, 1960Q1-2019Q4

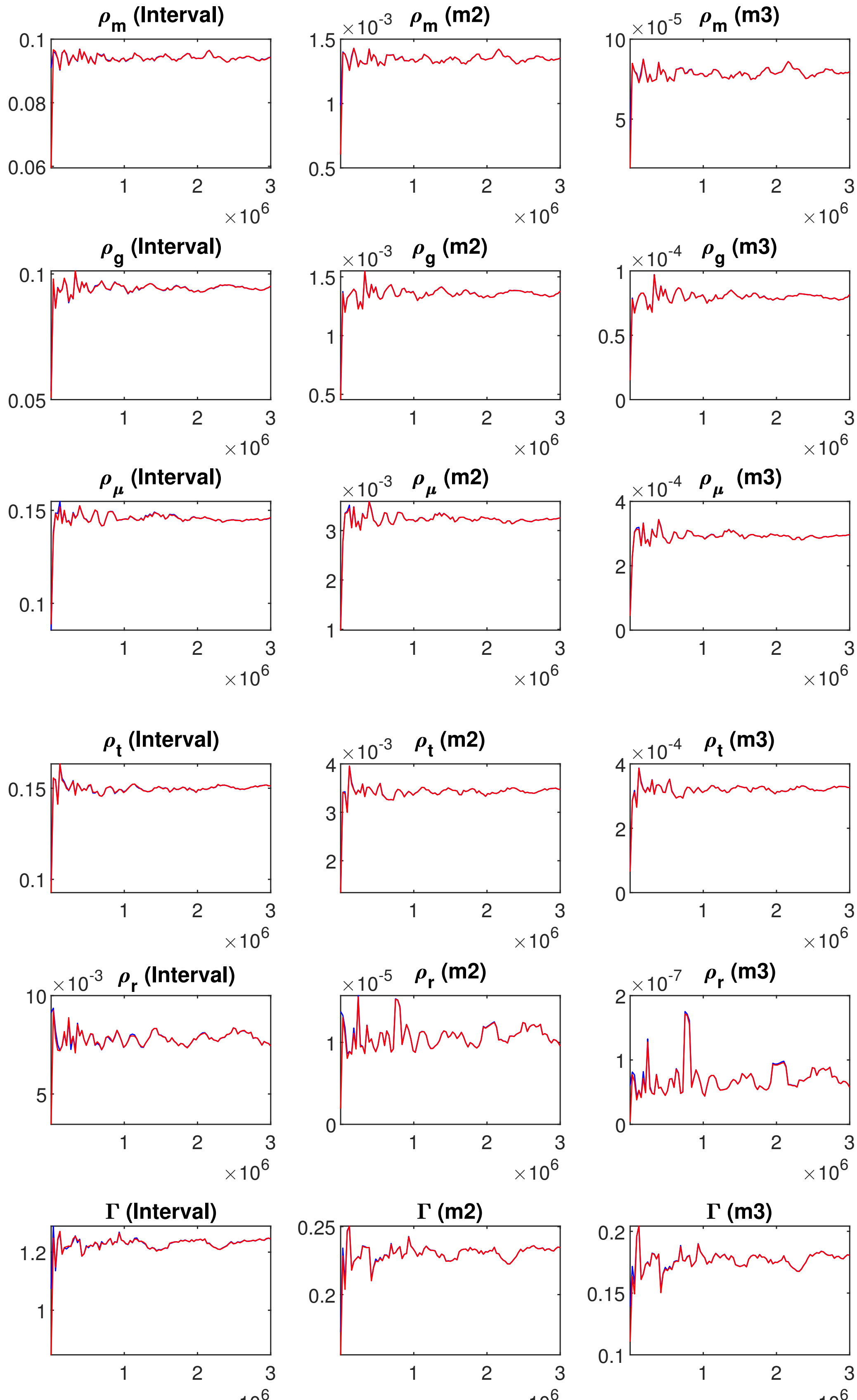


Figure 15: Univariate convergence diagnostics, 1960Q1-2019Q4

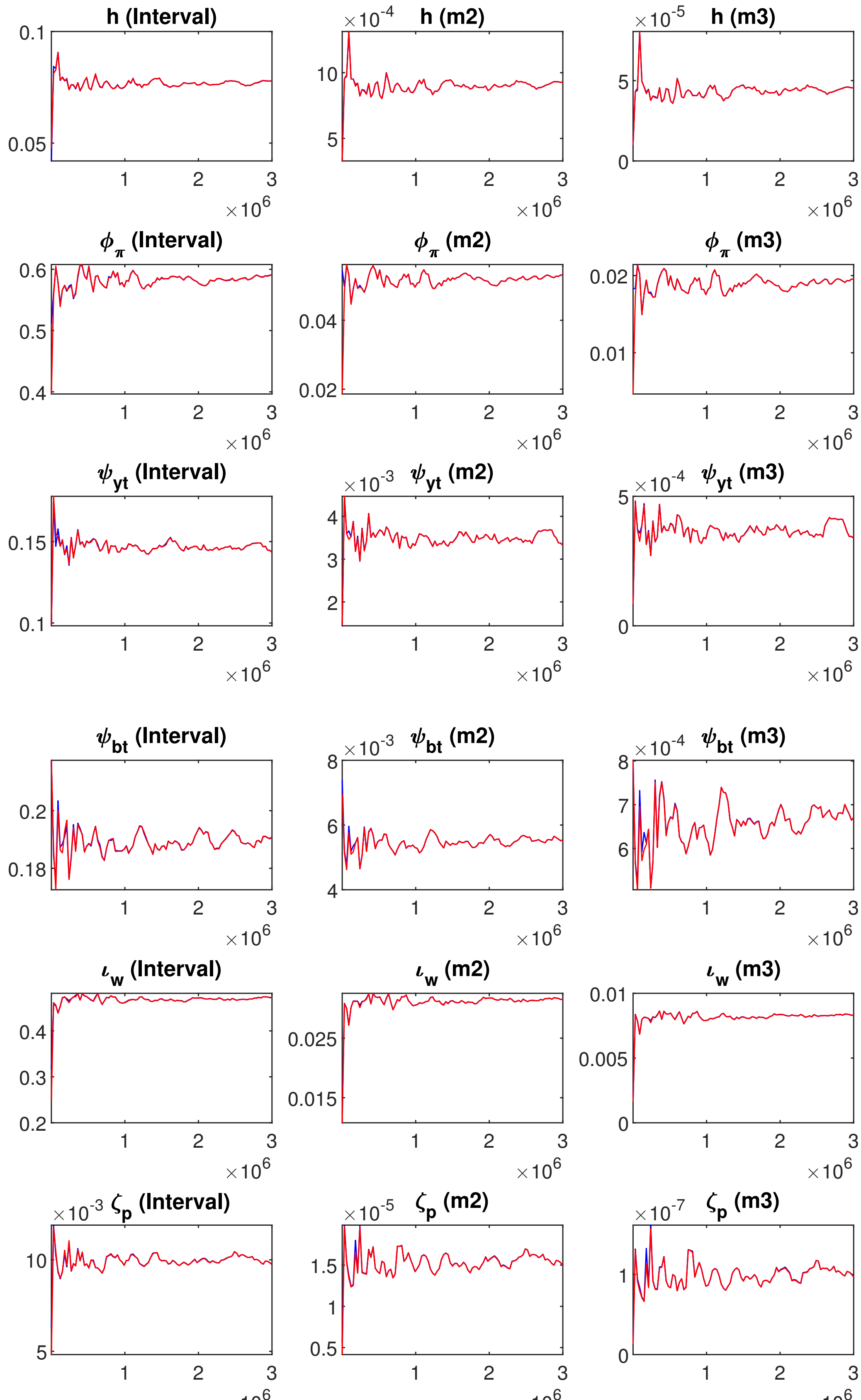
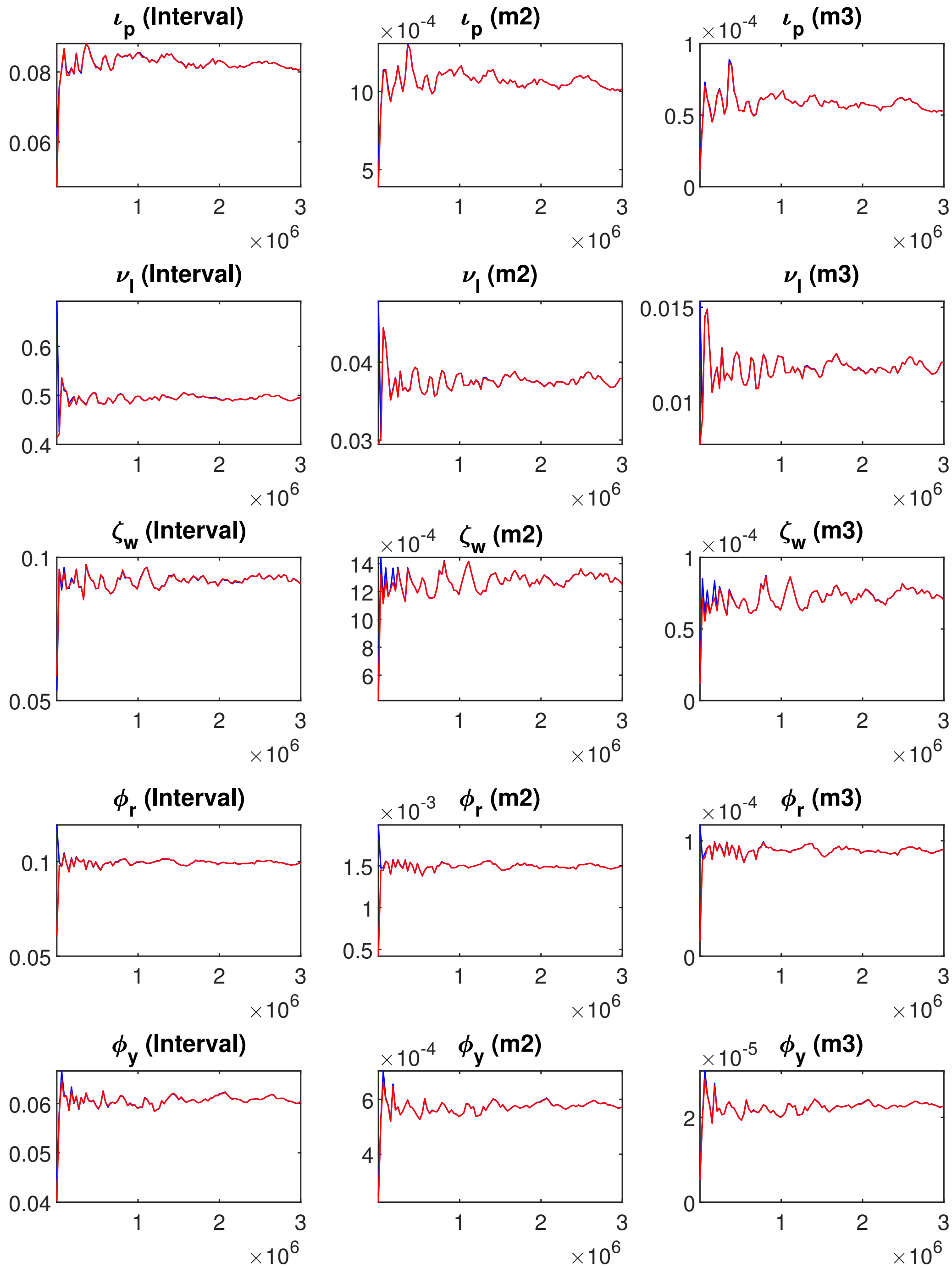


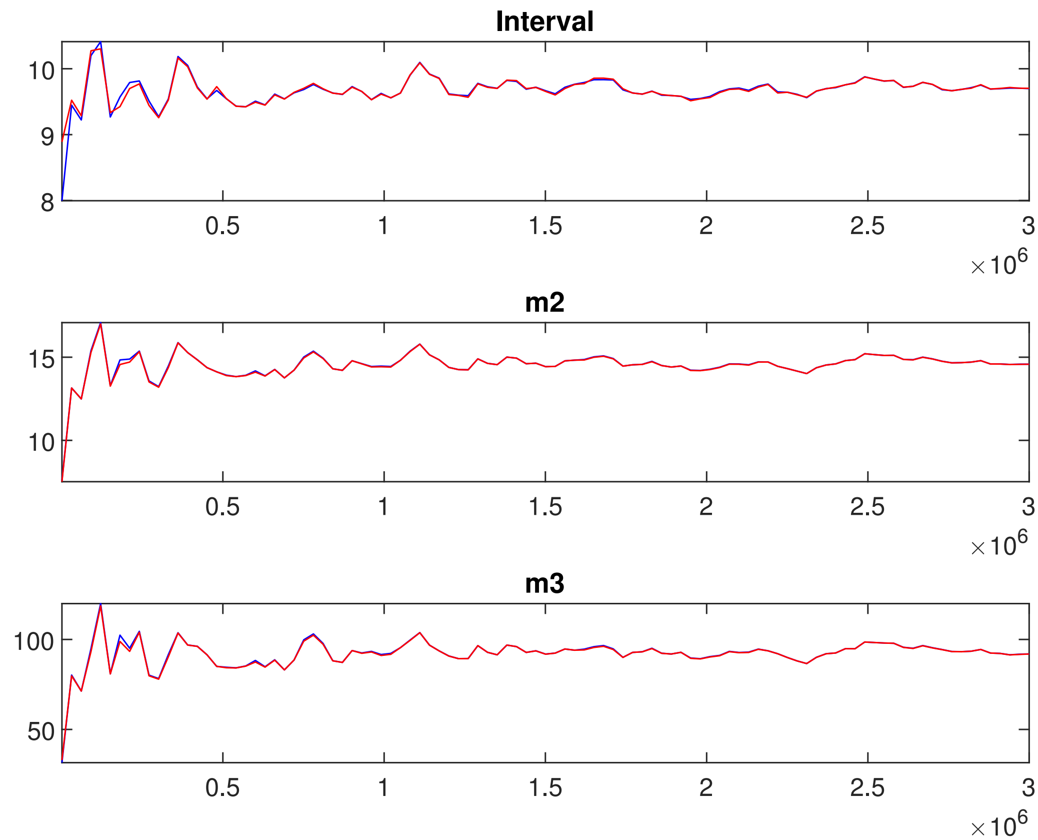
Figure 16: Univariate convergence diagnostics, 1960Q1-2019Q4



D.3 Multivariate convergence diagnostics

In the graphs below, the diagnostics is based on the range of the posterior likelihood function. The posterior kernel is used to aggregate the parameters.

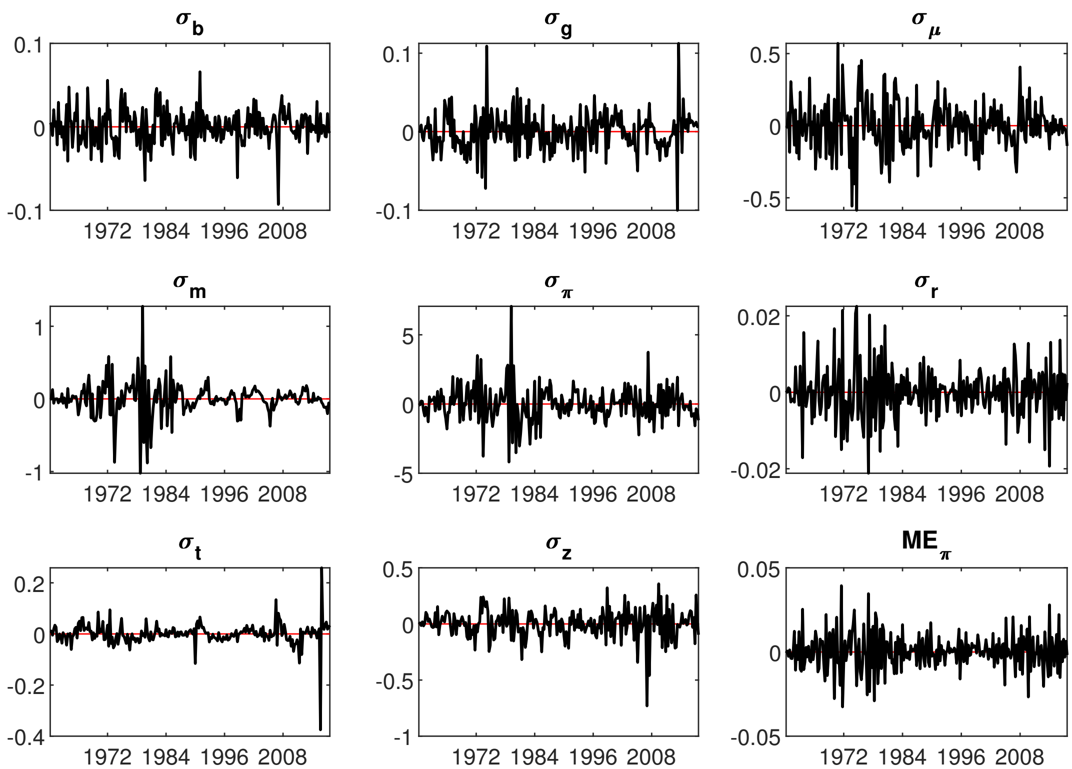
Figure 17: Multivariate convergence diagnostics, 1960Q1-2019Q4



D.4 Smoothed shocks

In the graphs below, the black lines represent the estimates of the smoothed structural shocks derived from the Kalman smoother.

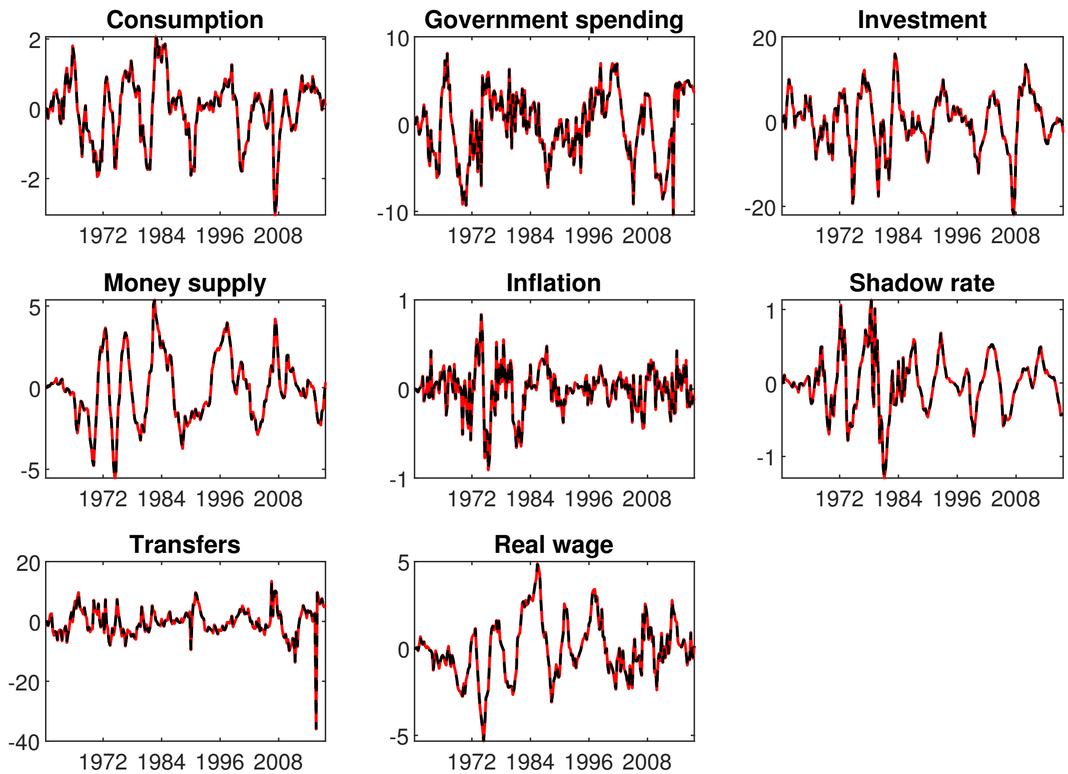
Figure 18: Smoothed shocks, 1960Q1-2019Q4



D.5 Historical and smoothed variables

In the graphs below, the dotted black lines indicate the observed data whereas the red lines indicate the estimates of the smoothed variables derived from the Kalman smoother.

Figure 19: Historical and smoothed variables,1960Q1-2019Q4



Appendix E Diagnostic tests 1960Q1-1979Q2

This section presents diagnostic tests for the first sub-sample, from 1960Q1 to 1979Q2.

E.1 Prior and posterior distributions

In the graphs below, the grey lines represent the prior distributions while the blue lines correspond to the posterior distributions.

Figure 20: Priors and posteriors plots, 1960Q1-1979Q2

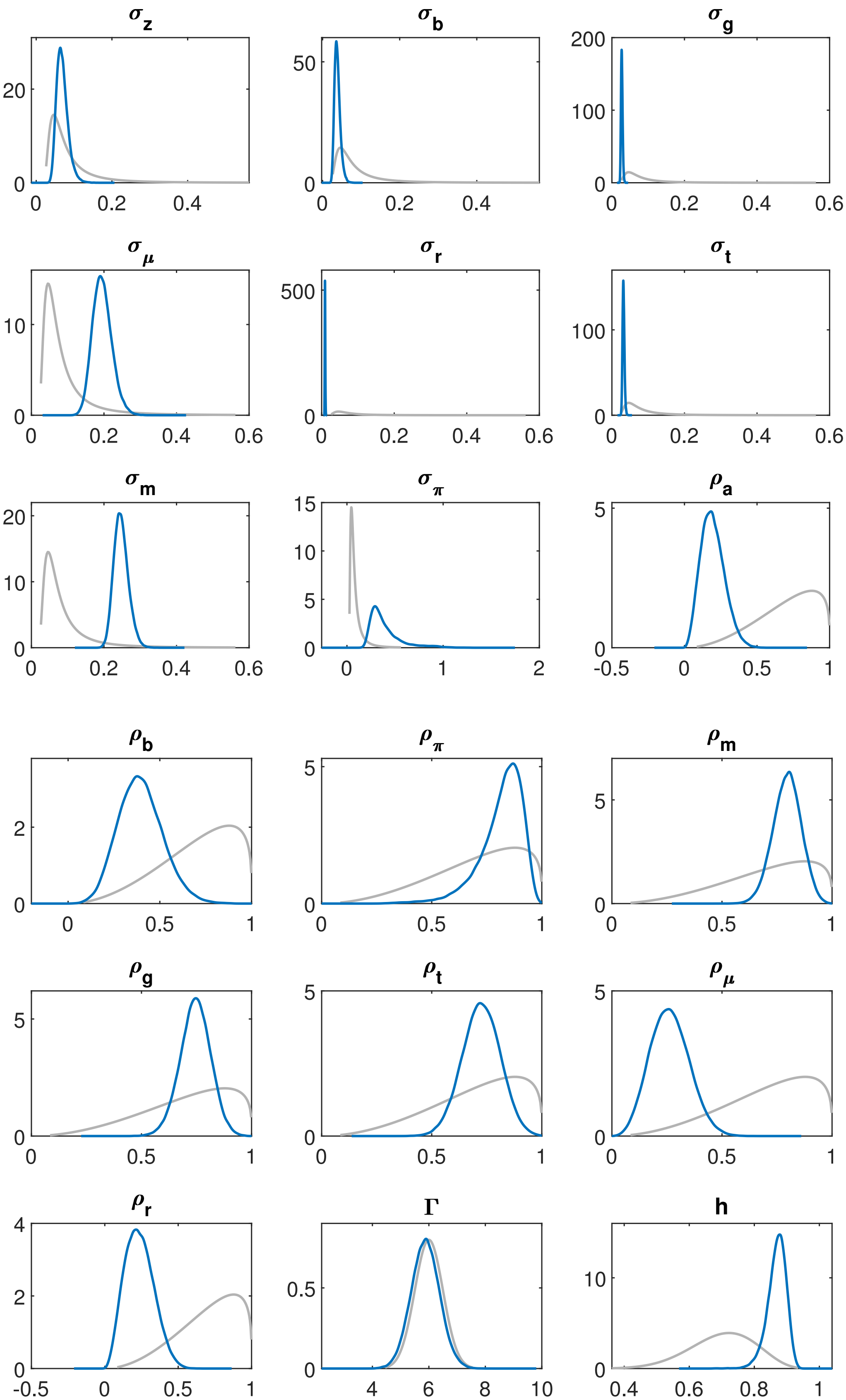
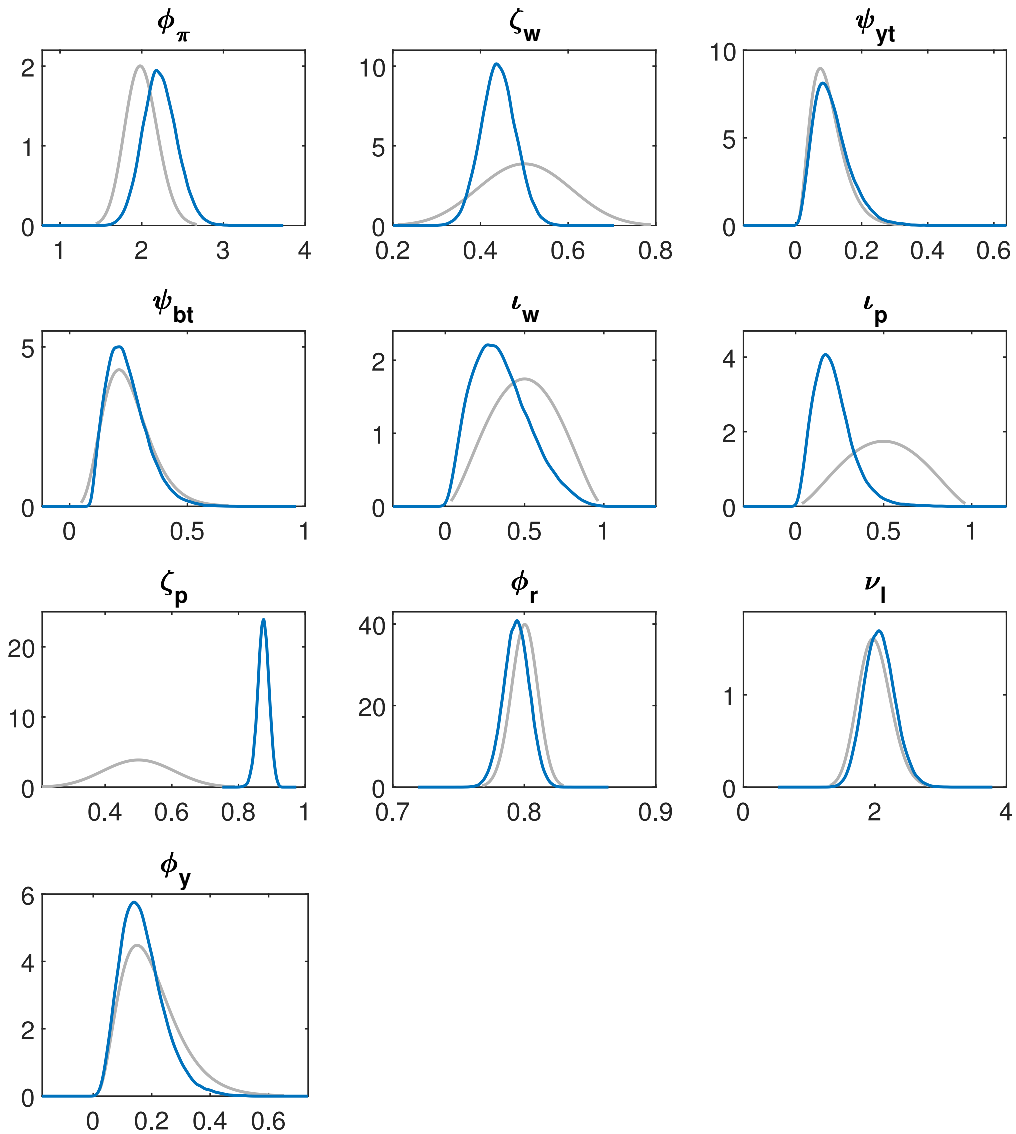


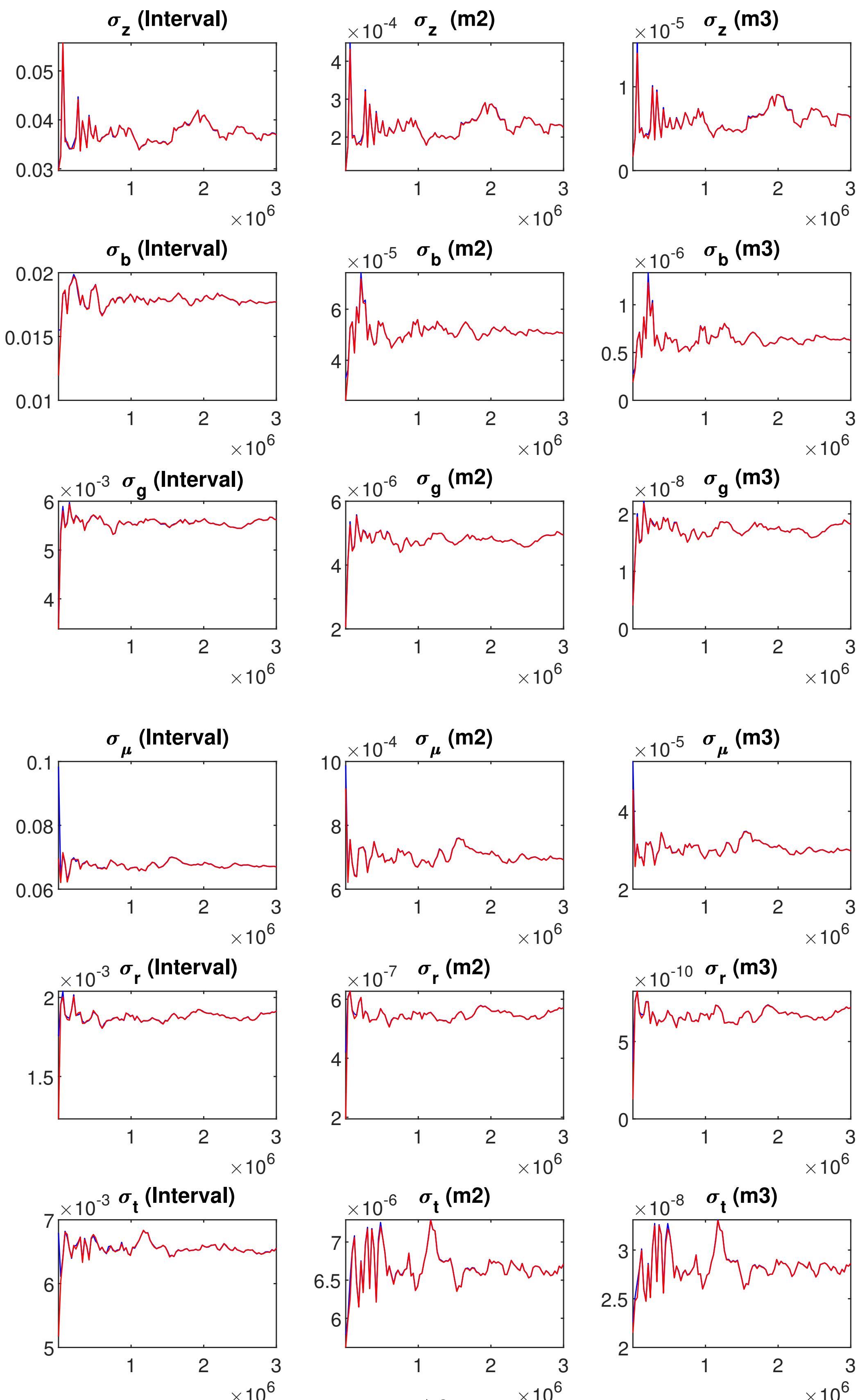
Figure 21: Priors and posteriors plots, 1960Q1-1979Q2

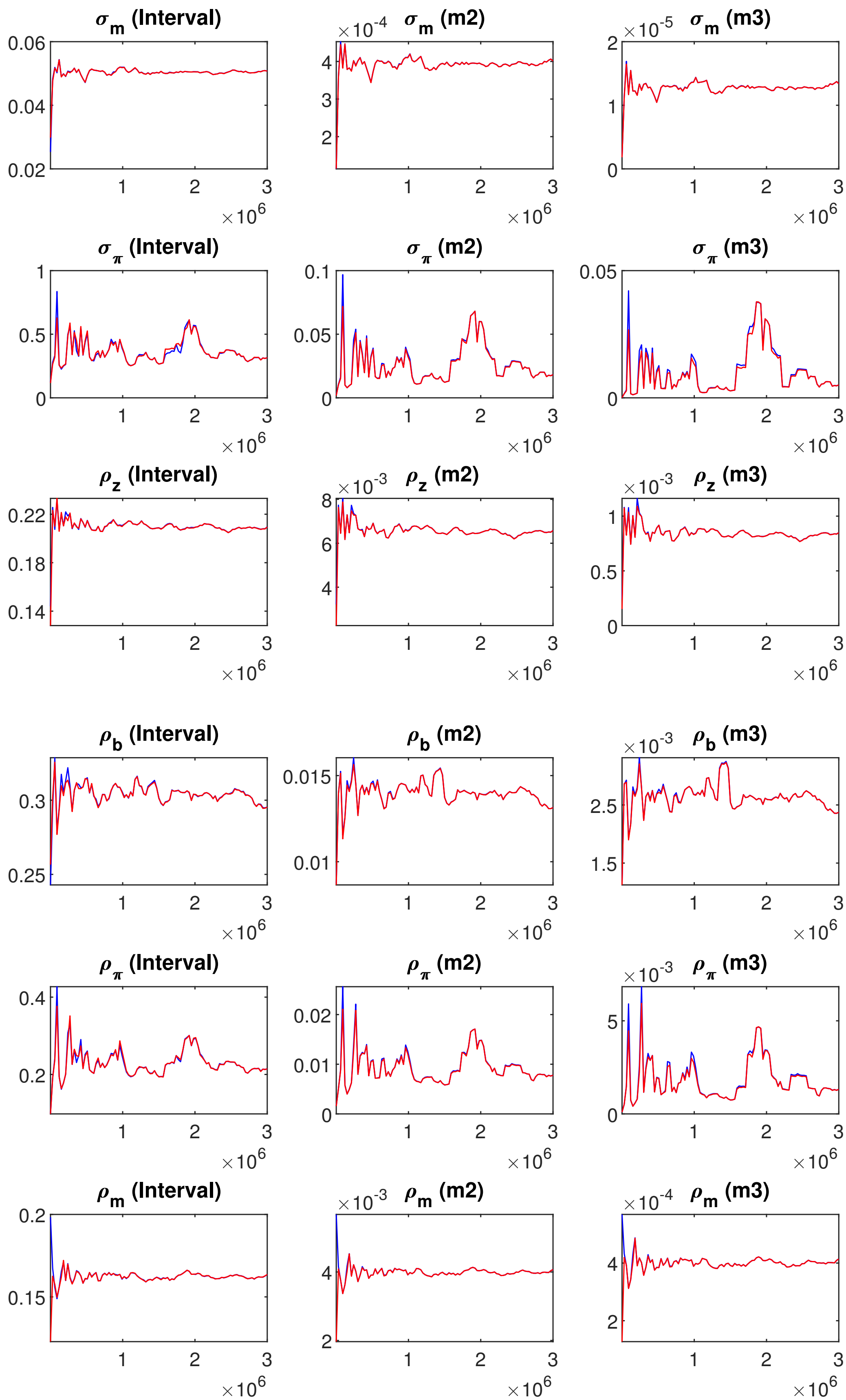


E.2 Monte Carlo Markov Chain univariate diagnostics

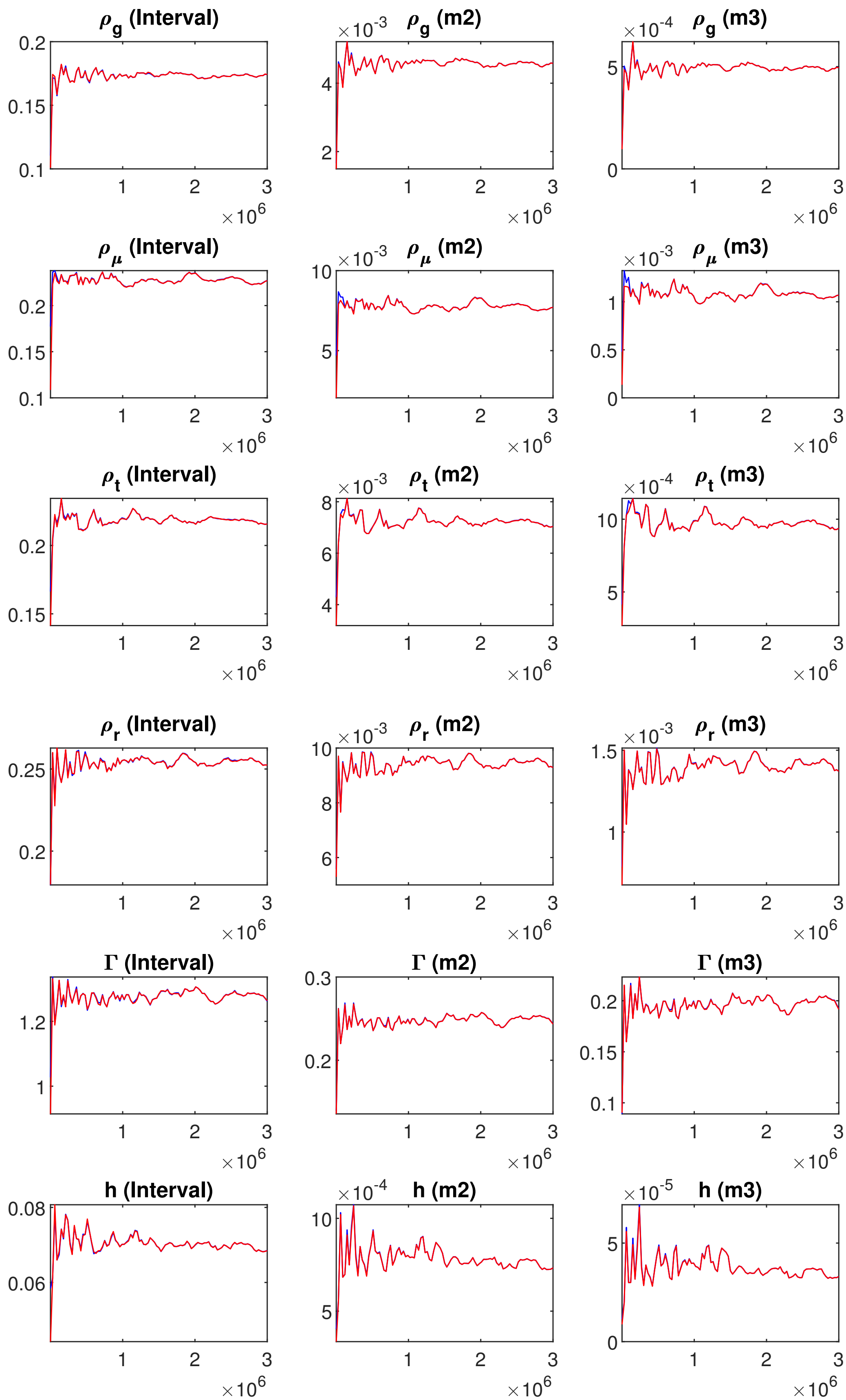
In the graphs below, the first column (Interval) shows the Brooks and Gelman (1998) convergence diagnostics for the 80% interval. The blue line represents the 80% interval range based on the pooled draws from all sequences, whereas the red line indicates the mean interval based on the draws of the individual sequences. The second and the third column with labels (m2 and m3, respectively) denote an estimate of the same statistics for the second and third central moments.

Figure 22: Univariate convergence diagnostics, 1960Q1-1979Q2

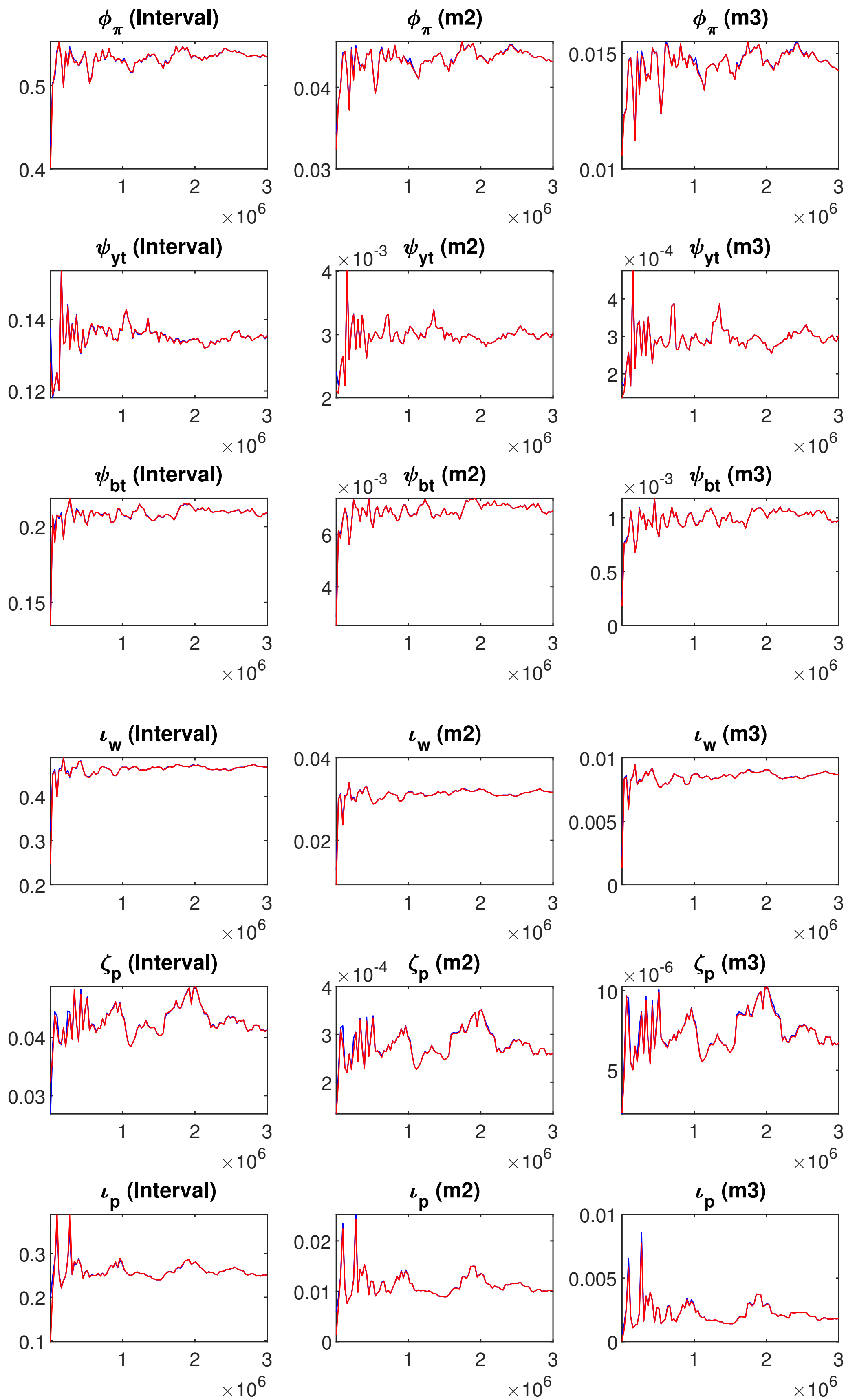


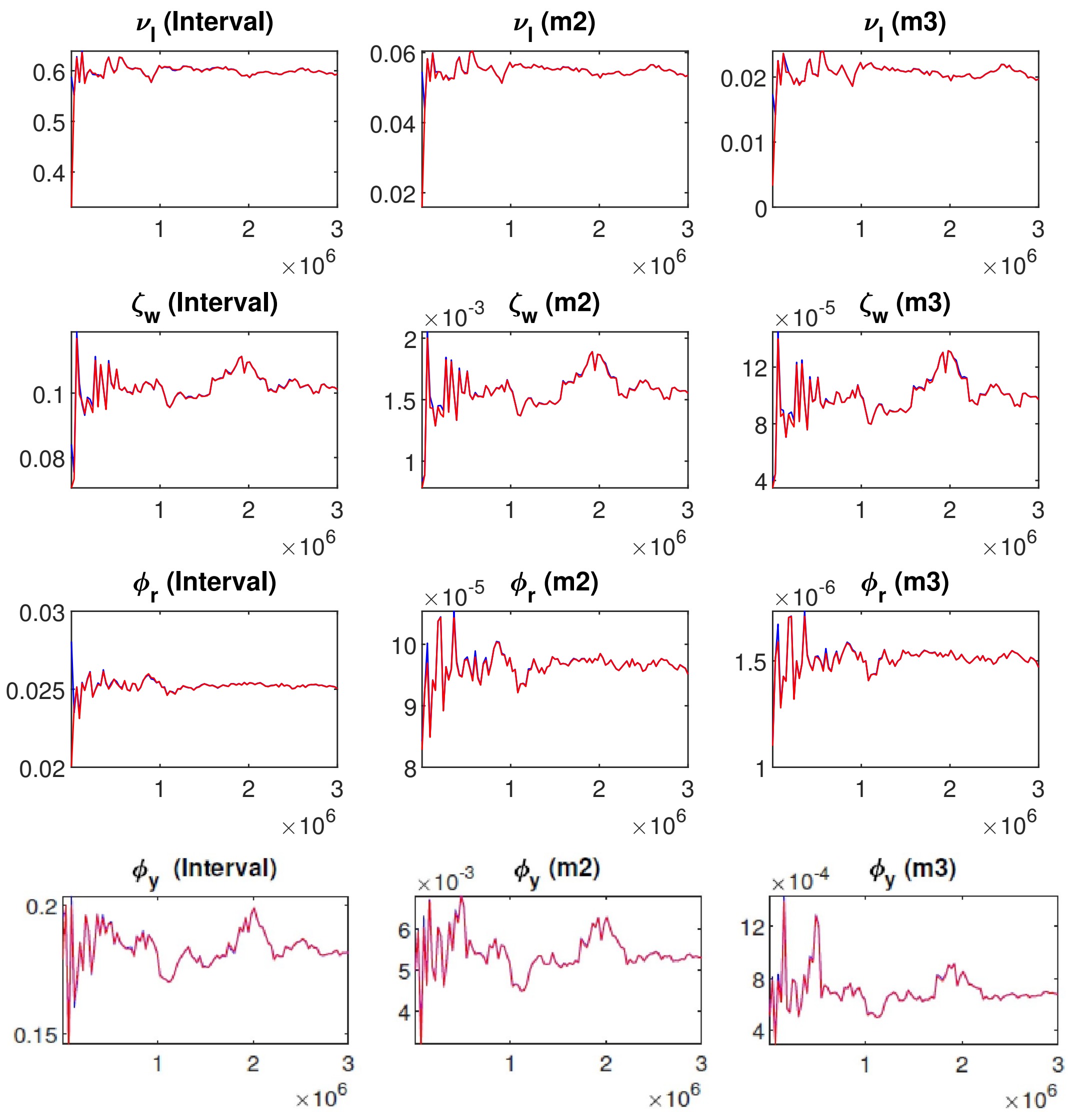


σ_m (Interval)
σ_m (m2)
$\times 10^{-4}$
σ_m (m3)
$\times 10^{-5}$
σ_π (Interval)
σ_π (m2)
σ_π (m3)
ρ_z (Interval)
ρ_z (m2)
$\times 10^{-3}$
ρ_z (m3)
$\times 10^{-3}$
ρ_b (Interval)
ρ_b (m2)
ρ_b (m3)
$\times 10^{-3}$
ρ_π (Interval)
ρ_π (m2)
ρ_π (m3)
$\times 10^{-3}$
ρ_m (Interval)
ρ_m (m2)
$\times 10^{-3}$
ρ_m (m3)
$\times 10^{-4}$
$\times 10^6$



ρg (Interval)
ρg (m2)
ρg (m3)
ρμ (Interval)
ρμ (m2)
ρμ (m3)
ρt (Interval)
ρt (m2)
ρt (m3)
ρr (Interval)
ρr (m2)
ρr (m3)
Γ (Interval)
Γ (m2)
Γ (m3)
h (Interval)
h (m2)
h (m3)
×10^-3
×10^-4
×10^-5
×10^6

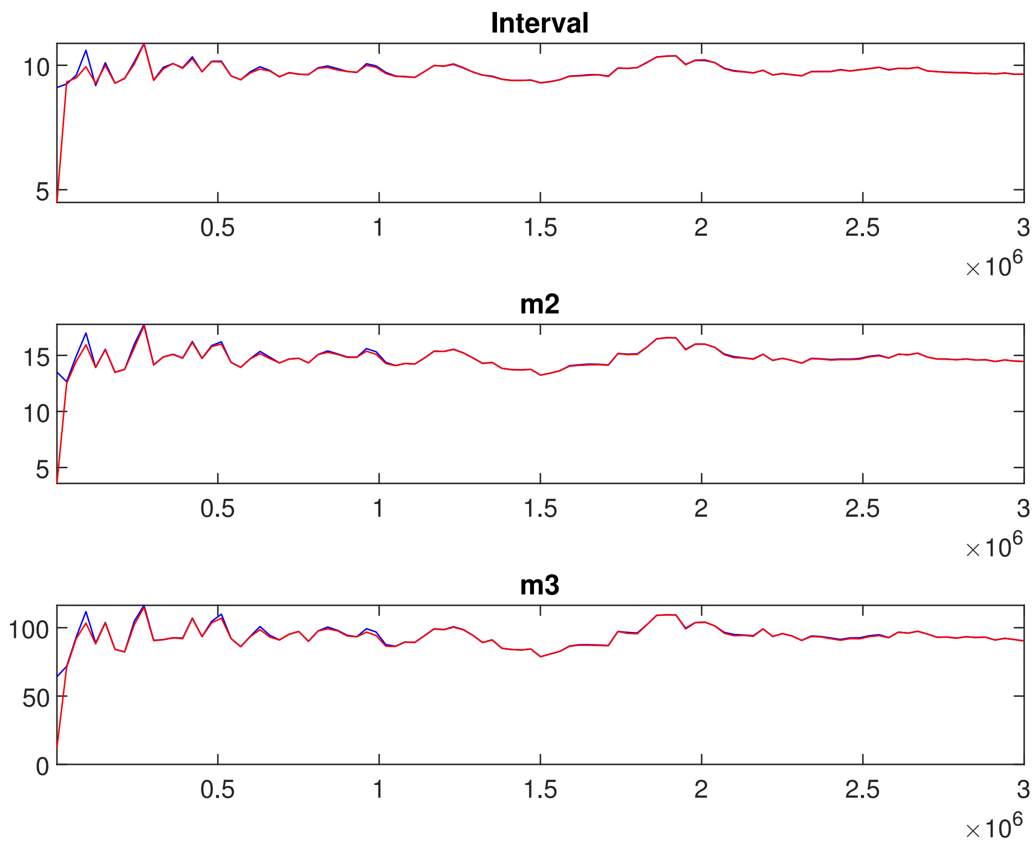

ϕ_π (Interval)
ϕ_π (m2)
ϕ_π (m3)
0.5
0.4
0.04
0.03
0.015
0.01
ψ_{yt} (Interval)
ψ_{yt} (m2)
ψ_{yt} (m3)
0.14
0.12
$\times 10^{-3}$
4
3
2
$\times 10^{-4}$
4
3
2
ψ_{bt} (Interval)
ψ_{bt} (m2)
ψ_{bt} (m3)
0.2
0.15
$\times 10^{-3}$
6
4
$\times 10^{-3}$
1
0.5
0
ι_w (Interval)
ι_w (m2)
ι_w (m3)
0.4
0.3
0.2
0.04
0.02
0.01
0.005
0
ζ_p (Interval)
ζ_p (m2)
ζ_p (m3)
0.04
0.03
$\times 10^{-4}$
4
3
2
$\times 10^{-6}$
10
5
ι_p (Interval)
ι_p (m2)
ι_p (m3)
0.3
0.2
0.1
0.02
0.01
0
0.01
0.005
0
1
2
3
$\times 10^6$


ν_l (Interval)
ν_l (m2)
ν_l (m3)
ζ_w (Interval)
ζ_w (m2)
ζ_w (m3)
φ_r (Interval)
φ_r (m2)
φ_r (m3)
φ_y (Interval)
φ_y (m2)
φ_y (m3)

E.3 Multivariate convergence diagnostics

In the graphs below, the diagnostics is based on the range of the posterior likelihood function. The posterior kernel is used to aggregate the parameters.

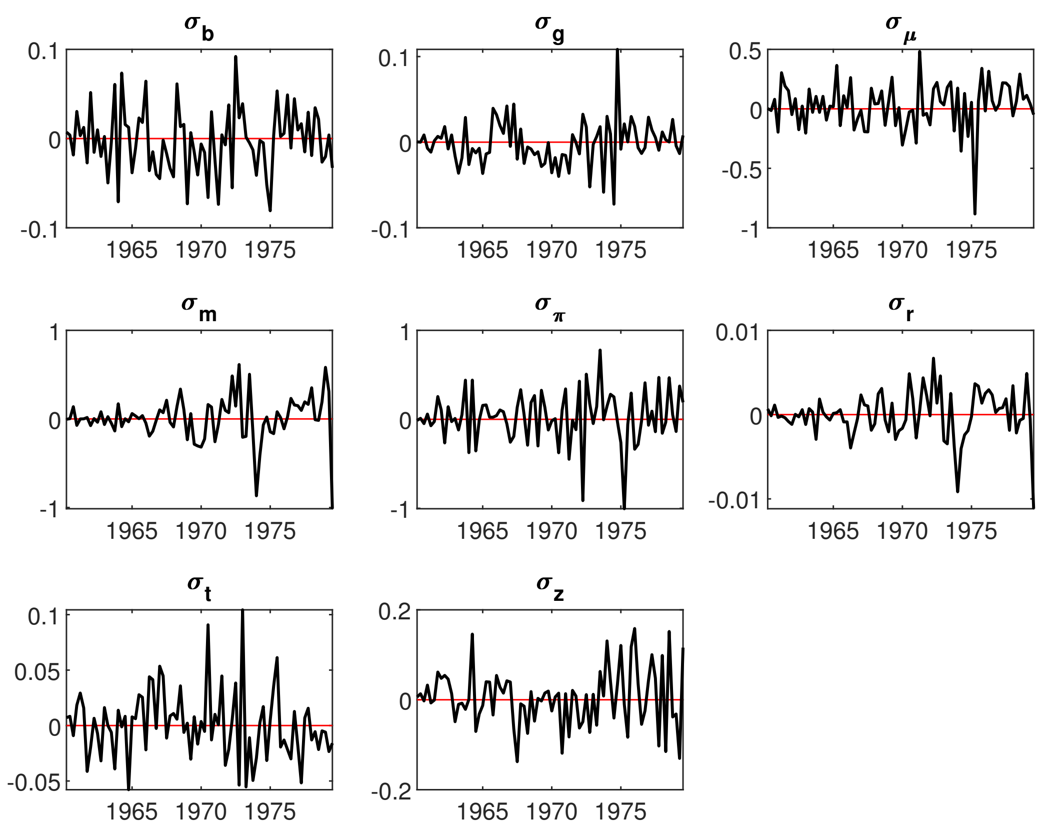
Figure 23: Multivariate convergence diagnostics, 1960Q1-1979Q2



E.4 Smoothed shocks

In the graphs below, the black lines represent the estimates of the smoothed structural shocks derived from the Kalman smoother.

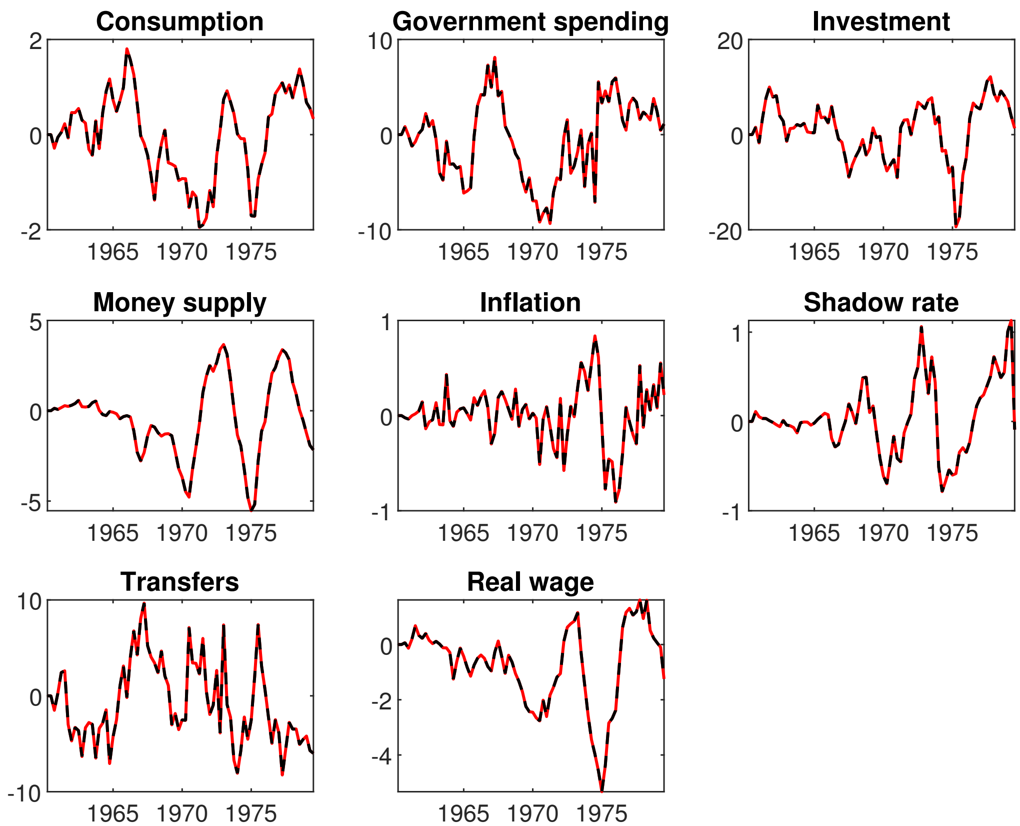
Figure 24: Smoothed shocks, 1960Q1-1979Q2



E.5 Historical and smoothed variables

In the graphs below, the dotted black lines indicate the observed data whereas the red lines indicate the estimates of the smoothed variables derived from the Kalman smoother.

Figure 25: Historical and smoothed variables, 1960Q1-1979Q2



Appendix F Diagnostic tests 1984Q1-2007Q2

This sections presents diagnostic tests for the second sub-sample, from 1984Q1 until 2007Q2.

F.1 Prior and posterior distributions

In the graphs below, the grey lines represent the prior distributions while the blue lines correspond to the posterior distributions.

Figure 26: Priors and posteriors plots, 1984Q1-2007Q2

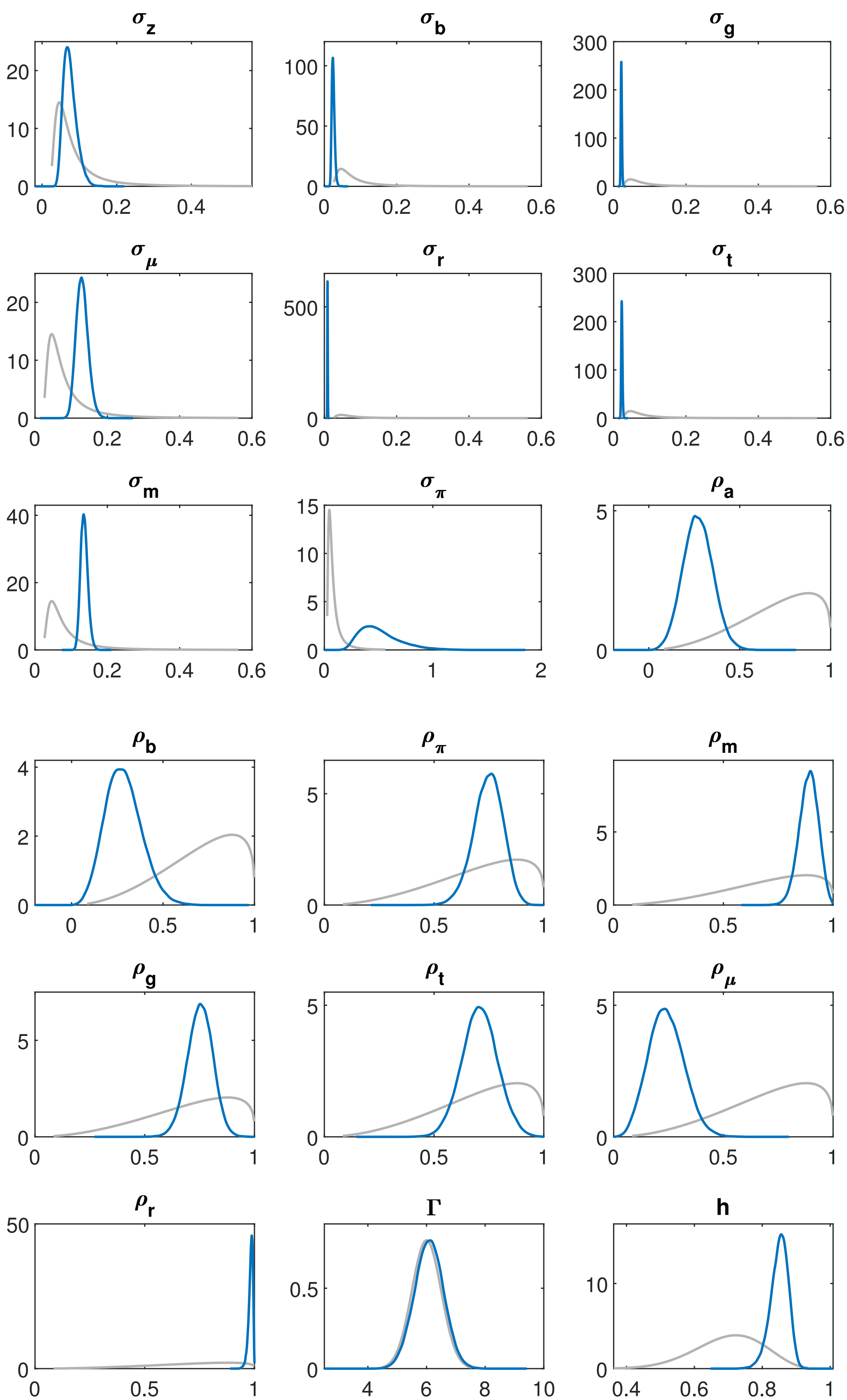
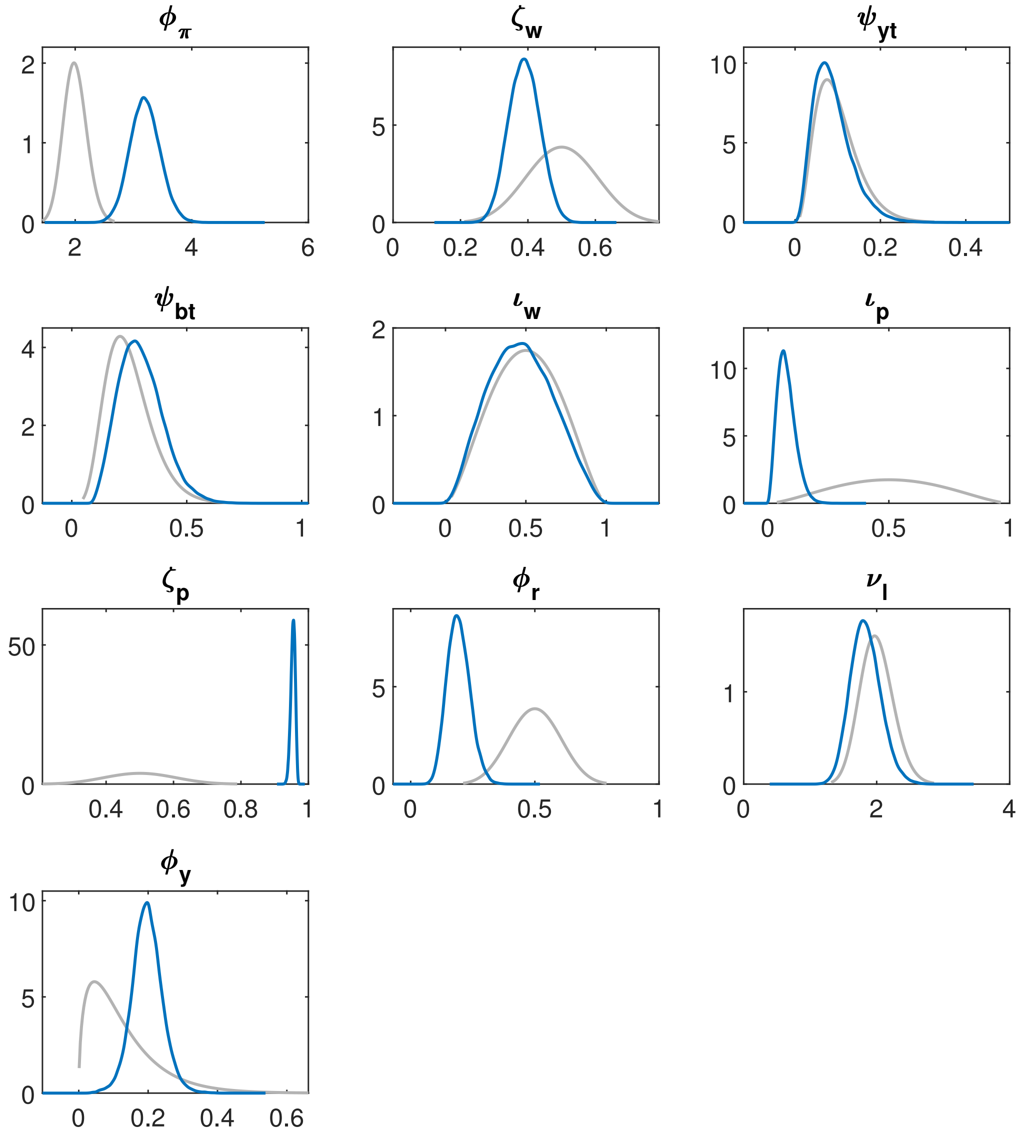


Figure 27: Priors and posteriors plots, 1984Q1-2007Q2



F.2 Monte Carlo Markov Chain univariate diagnostics

In the graphs below, the first column (Interval) shows the Brooks and Gelman (1998) convergence diagnostics for the 80% interval. The blue line represents the 80% interval range based on the pooled draws from all sequences, whereas the red line indicates the mean interval based on the draws of the individual sequences. The second and the third column with labels (m2 and m3, respectively) denote an estimate of the same statistics for the second and third central moments.

Figure 28: Univariate convergence diagnostics, 1984Q1-2007Q2

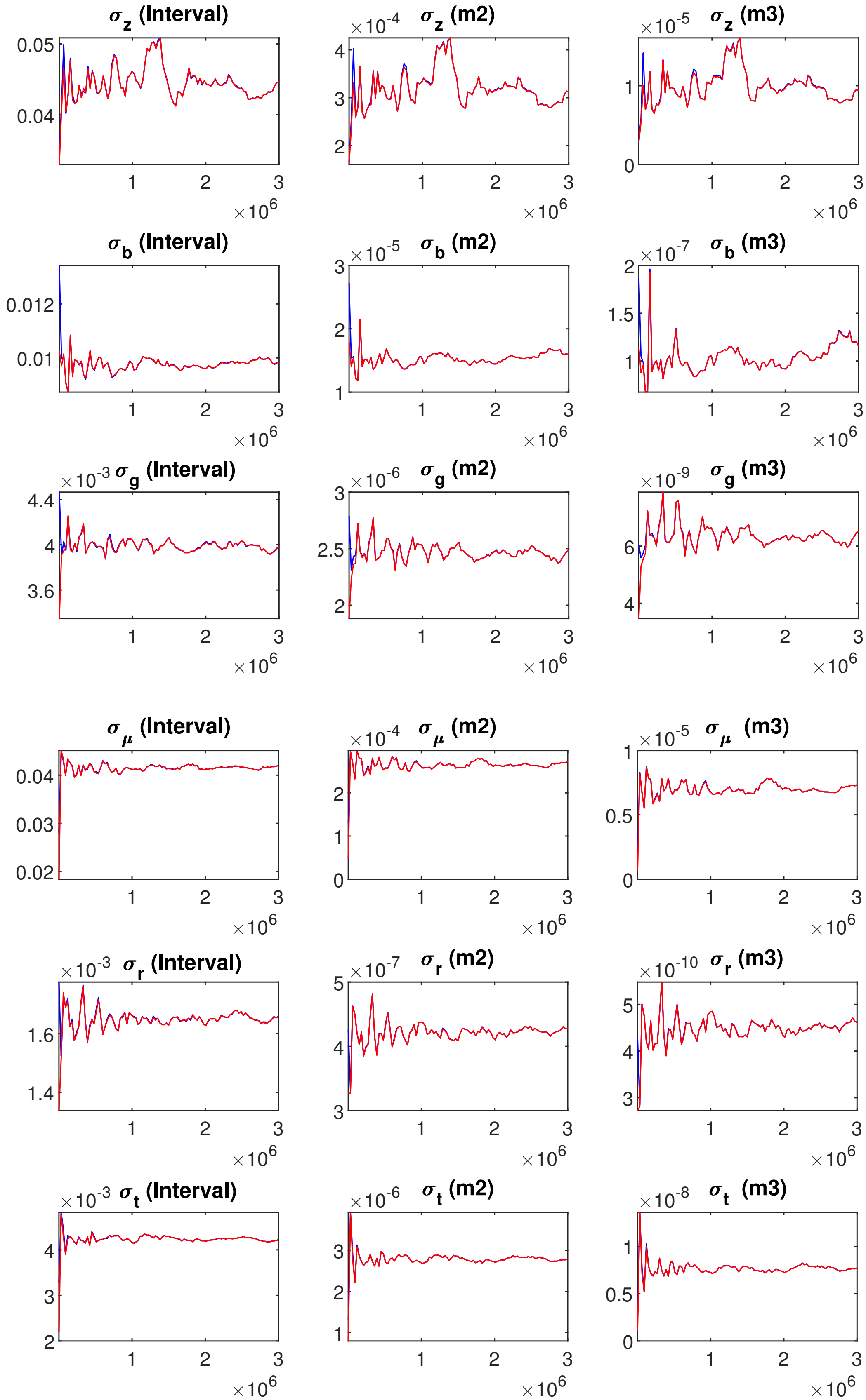


Figure 29: Univariate convergence diagnostics, 1984Q1-2007Q2

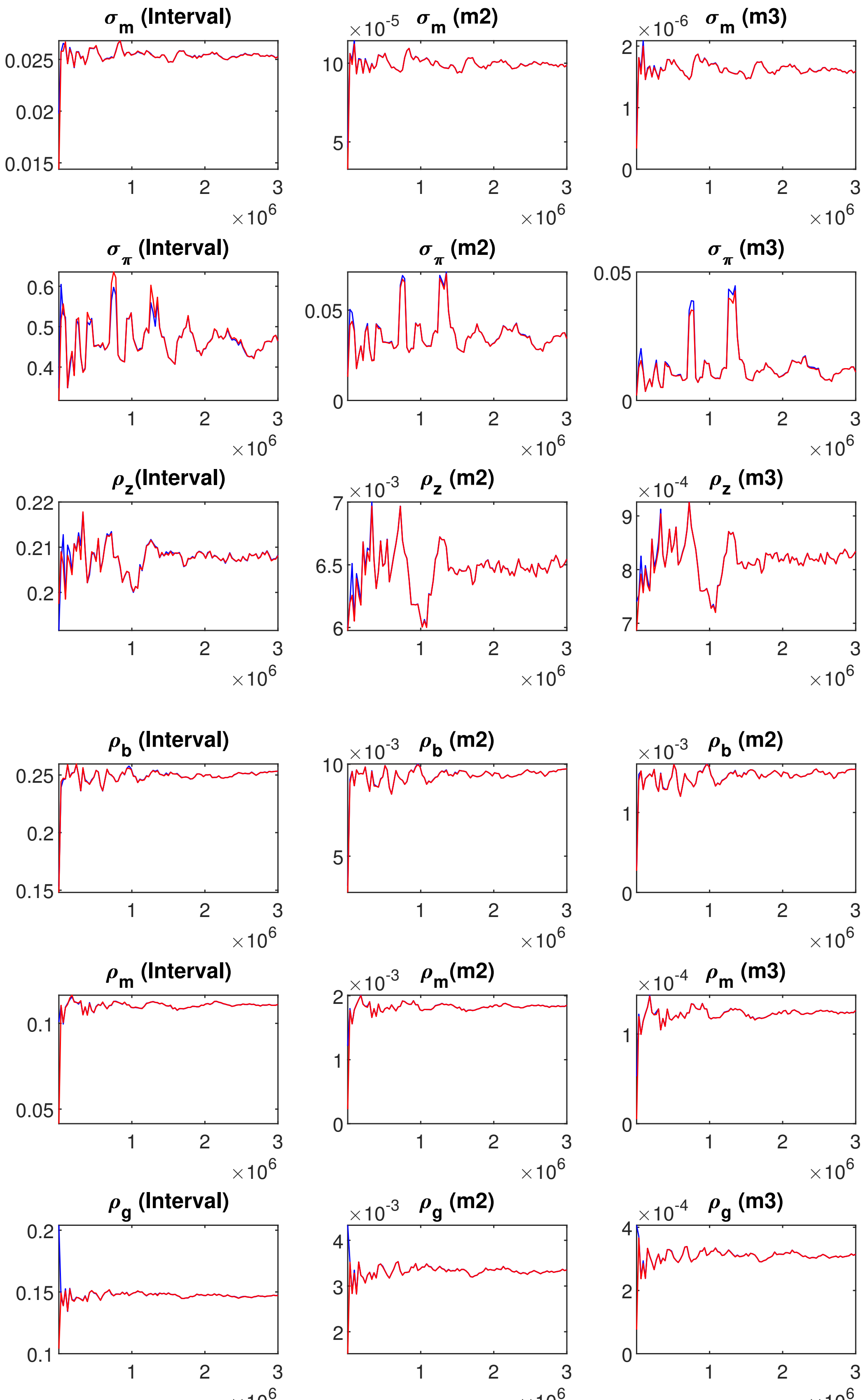


Figure 30: Univariate convergence diagnostics, 1984Q1-2007Q2

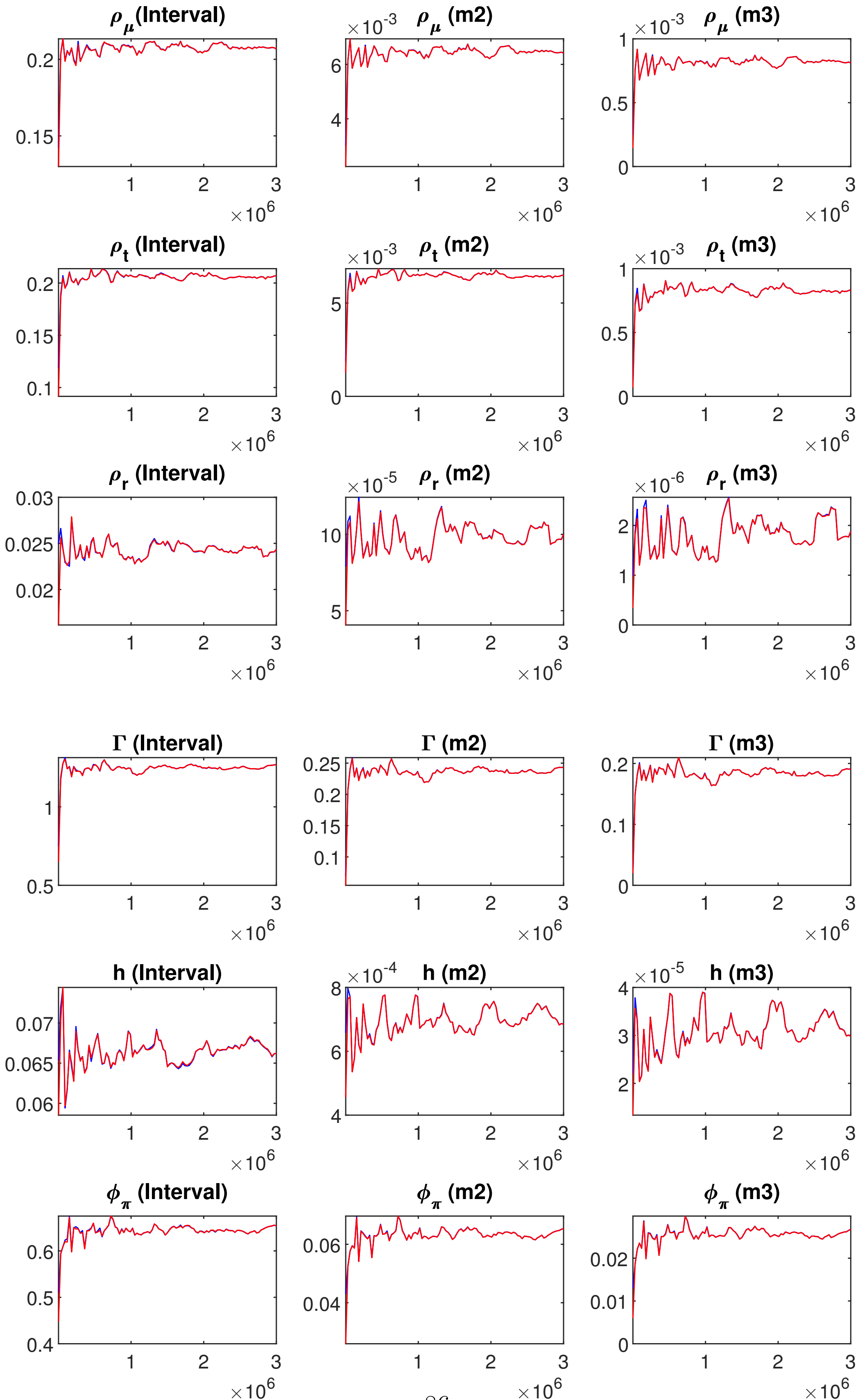


Figure 31: Univariate convergence diagnostics, 1984Q1-2007Q2

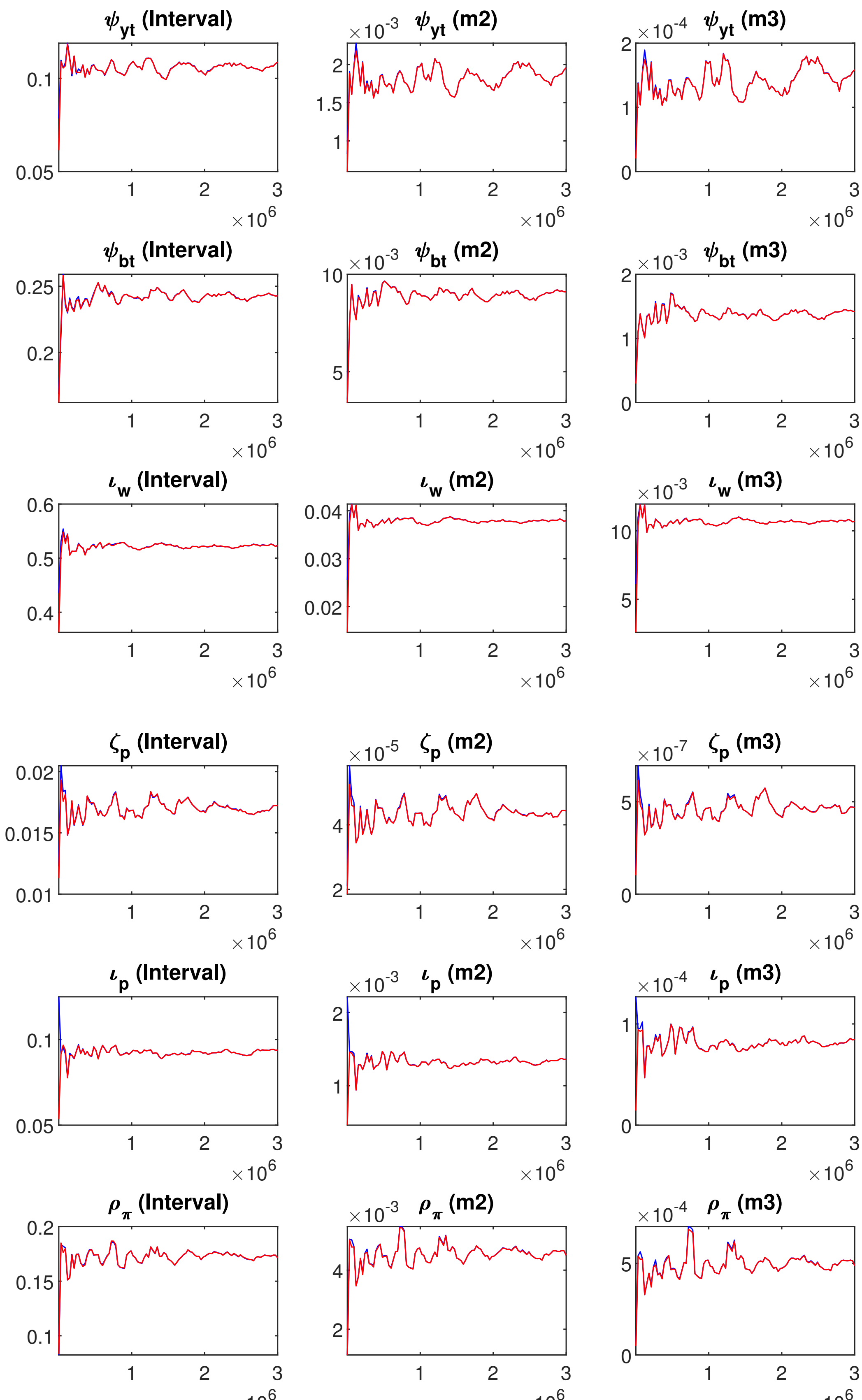
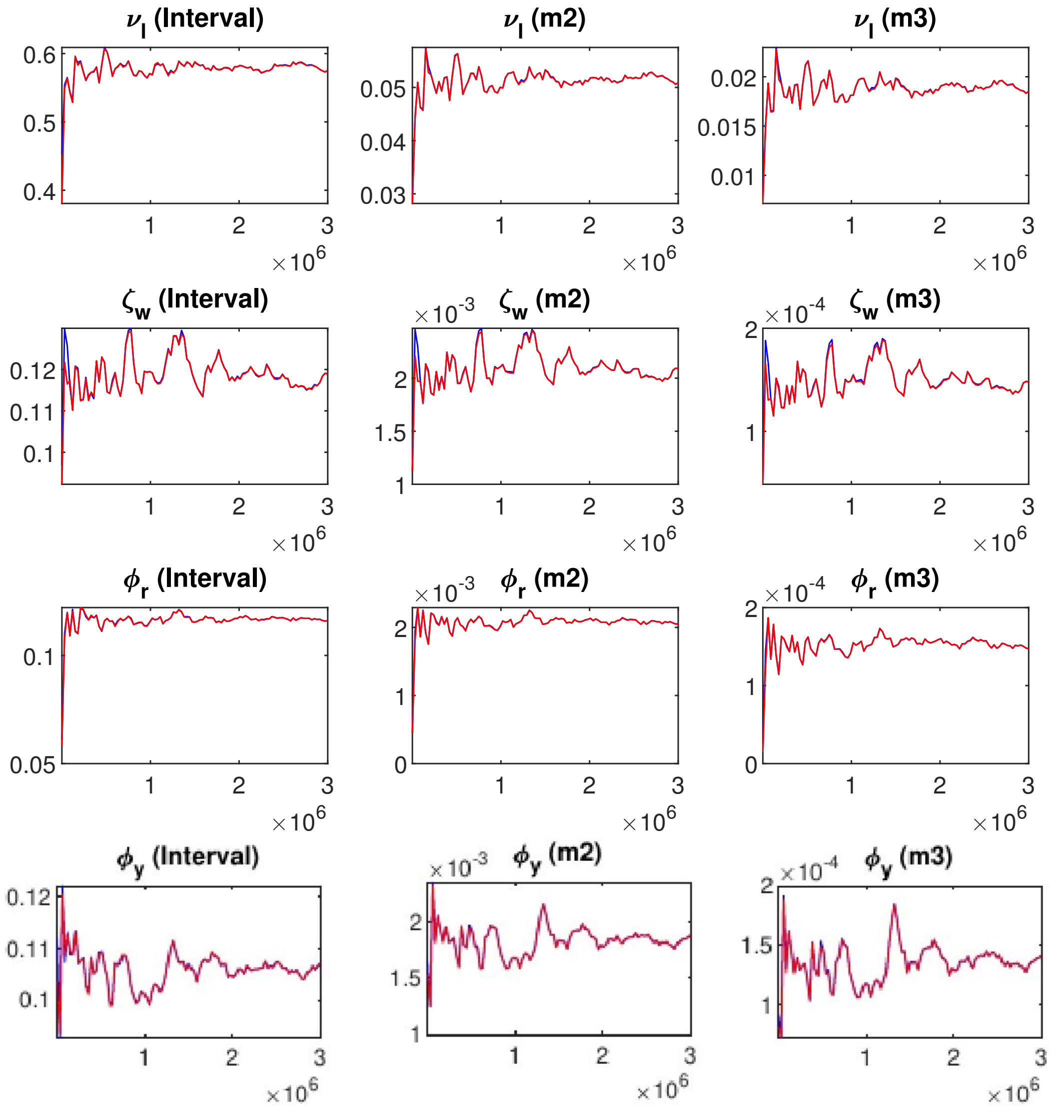


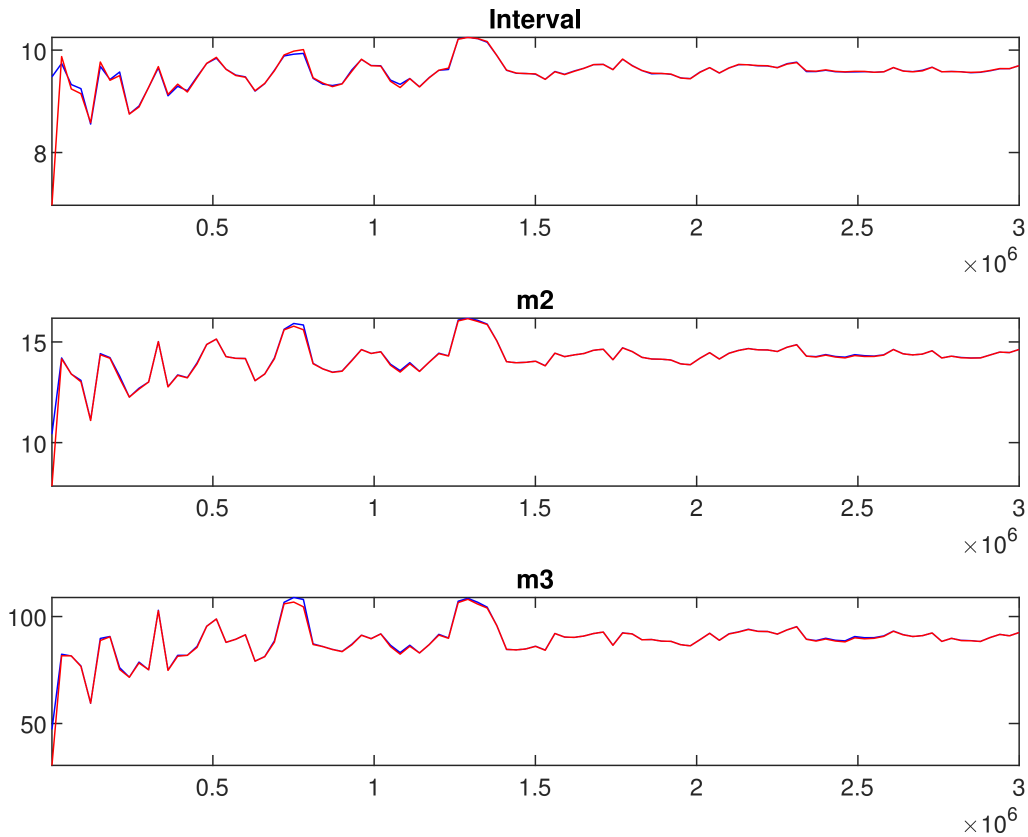
Figure 32: Univariate convergence diagnostics, 1984Q1-2007Q2



F.3 Multivariate convergence diagnostics

In the graphs below, the diagnostics is based on the range of the posterior likelihood function. The posterior kernel is used to aggregate the parameters.

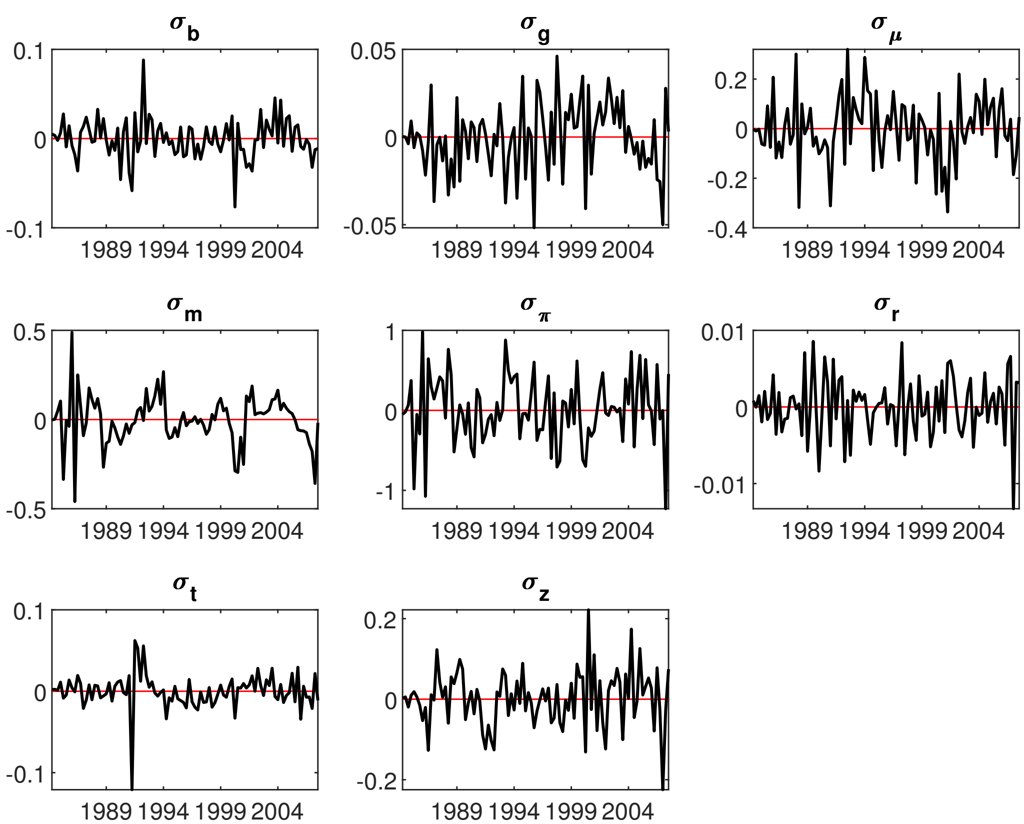
Figure 33: Multivariate convergence diagnostics, 1984Q1-2007Q2



F.4 Smoothed shocks

In the graphs below, the black lines represent the estimates of the smoothed structural shocks derived from the Kalman smoother.

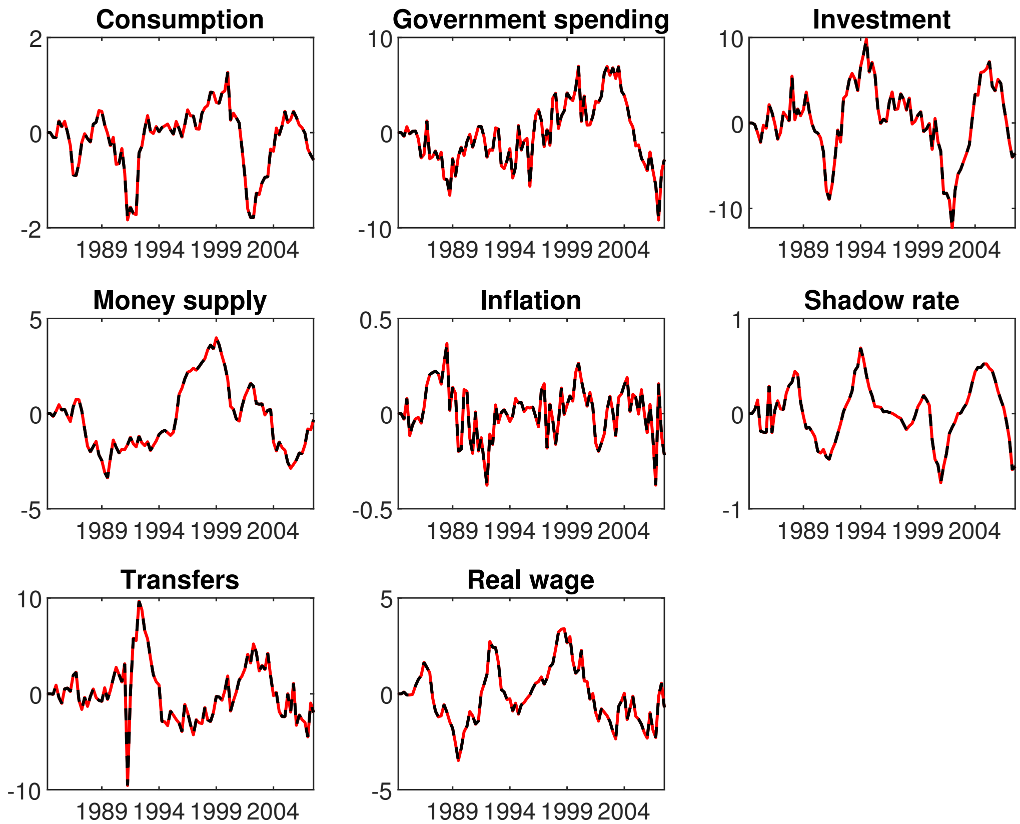
Figure 34: Smoothed shocks, 1984Q1-2007Q2



F.5 Historical and smoothed variables

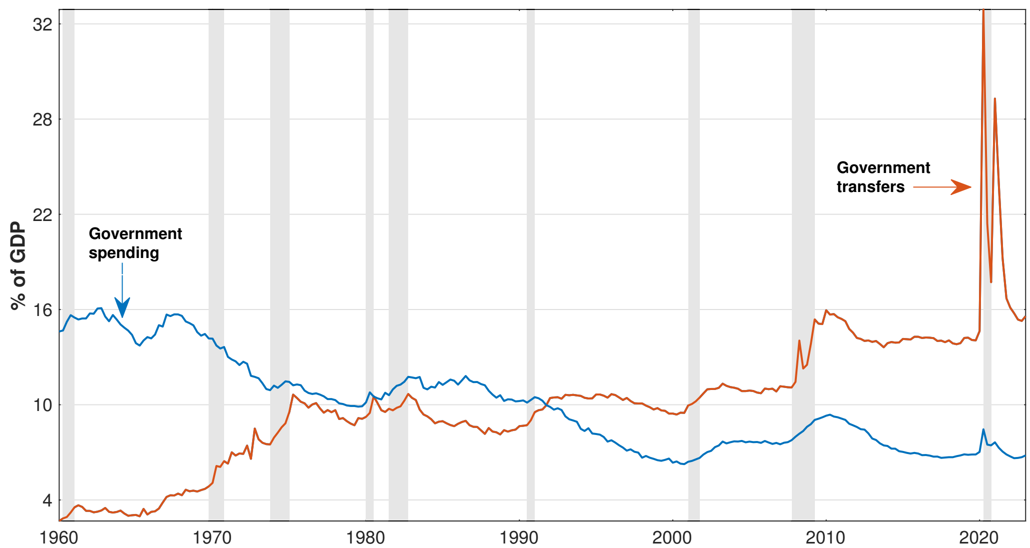
In the graphs below, the dotted black lines indicate the observed data whereas the red lines indicate the estimates of the smoothed variables derived from the Kalman smoother.

Figure 35: Historical and smoothed variables, 1984Q1-2007Q2



Appendix G Additional figures

Figure 36: Government spending and government transfers as a percent of US GDP, 1960Q1 - 2023Q1



Notes: Source of data: Economic Data from the Federal Reserve Bank of St. Louis database. Shaded areas represent NBER recessions.