Is monetary-financing a valuable alternative to debt-financing in response to fiscal stimuli?

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Abstract

The unprecedented increase in US sovereign debt has gained attention among policy-makers. In this paper, we investigate the use of the money supply issued by the central bank to support expansionary fiscal interventions. To do so, we develop and estimate a New Keynesian model using US data for the sample period 1960:Q1-2019:Q4. Then, we run 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 increases both in monetary-financed government spending and monetary-financed government transfers have positive economic impacts on private consumption and investment as well as output. However, the expansionary impact of monetary-financed fiscal shocks comes at a cost: an increase in inflation.

Keywords: Fiscal Policy, Money Supply, Fiscal Stimulus

JEL Codes: E24, J20, H24, H31

1 Introduction

Over the past 15 years, the global economy has experienced significant economic and financial changes, which were further exacerbated by the two recent economic crises: the

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Global Financial Crisis (GFC) and the COVID-19 pandemic. These disruptions affected both aggregate demand and aggregate supply, resulting in adverse global consequences, such as rising unemployment rates and increased income inequalities. Among others, Benigno and Nisticò (2020) highlight the ongoing debate among academics and policymakers, suggesting that cooperation between governments and central banks could lead to effective measures in mitigating the adverse impact of unexpected crises.

Our analysis primarily focuses on periods characterized by high levels of public debt, low inflation, and subdued aggregate demand. In this economic context, our model demonstrates the expansionary economic impact of a monetary-financed fiscal stimulus. We adopt the approach proposed by Benigno and Nisticò (2020), and abstract from central bank balance sheet implications. Benigno and Nisticò (2020) highlight that this is possible because the central bank is a unique entity, and its liabilities and reserves are not subject to nominal risks. In our analysis, we investigate the effects of monetary-financed government transfers and government spending on economic aggregates.

Figure 1 illustrates the evolution of these two time series in the United States since 1960. As discussed in Bianchi et al. (2023), the share of government transfers relative to GDP has been rising in recent decades, while the percentage of government spending with respect to output has been declining. Our model considers both fiscal stimuli. We consider transfers because of the increasing trend it experienced, which indicates the constant need for the government to intervene in the economy. We also consider government spending, because of its relevance as a share of GDP and of government public debt. Finally, our models allows for one fiscal stimulus to adjust when the other one is implemented.

Figure 2 shows the evolution of the M2 monetary aggregate and the public debt-to-GDP over the past six decades. The figure demonstrates a correlated evolution of the changes in M2 and in the public debt-to-GDP series. Moreover, the public debt-to-GDP ratio increased from 2008Q1 until 2019Q4 by 40 percentage points, rising from approximately 64% to 105%. In particular, over the past 15 years, central banks worldwide have undertaken various measures to address economic challenges. This included reducing interest rates to historically low levels and implementing policies aimed at facilitating lending procedures, both to businesses and financial institutions. Furthermore, central banks have undertaken substantial investments through asset-purchasing programs to support financial markets and stabilize the economy. Concurrently, governments have implemented significant fiscal stimuli, leading to a further increase in sovereign debt levels. Therefore, we find it pertinent to conduct a counterfactual analysis to examine the economic impact of fiscal stimuli financed through money supply from a quantitative perspective.

As highlighted in Ng (2021), it is crucial to treat COVID data as exogenous controls in a Vector Autoregressive setting. The author demonstrated that the response of economic aggregates to general economic shocks differs from their response to COVID shocks. For the same reason, Primiceri and Tambalotti (2020) propose a set of assumptions needed in order to perform forecasting analysis after the pandemic crisis. The authors introduce a "tilting" of the COVID-driven shock to accommodate the extraordinary nature of this period. Therefore, despite the significant impact of the recent economic crisis on the increase in public debt, our sample ends with 2019Q4. This is done because of the uniqueness of this period and the exceptional impact the period had on output and consumption.

From a theoretical point of view, we use a medium-scale New Keynesian model that includes habits on consumption, nominal rigidities, capital, and investment adjustment costs. Our model features a rich set of shocks, including fiscal shocks. These models have been proven to provide a relatively good fit for US business cycle fluctuations (Del Negro et al., 2007; Smets and Wouters, 2007; Christiano et al., 2011). We estimate the model with Bayesian techniques for the sample period 1960Q1:2019Q4 using US macroeconomic aggregate data. We proceed with a counterfactual analysis employing the estimated parameters derived from our model. To conduct this analysis, we extend the same model to incorporate a "monetary-financing" component, wherein the money supply becomes an integral part of the government budget constraint. Within this framework, the central bank accommodates fiscal policy and shifts its emphasis from setting the interest rate to controlling the money supply. This framework is similar to the one proposed by Galí (2020a), in which money supply is determined endogenously and finances the fiscal stimuli. We finally compare the impact on aggregate demand of an increase in government spending and lump-sum transfers financed by money supply, with the same fiscal stimulus financed by debt. Through our impulse response analysis, we validate the expansionary effects associated with this alternative monetary strategy. As expected, the expansionary impact of a monetary-financed fiscal stimulus comes at a cost, which is an amplified increase in inflation compared to the scenario in which the fiscal stimulus is debt-financed.

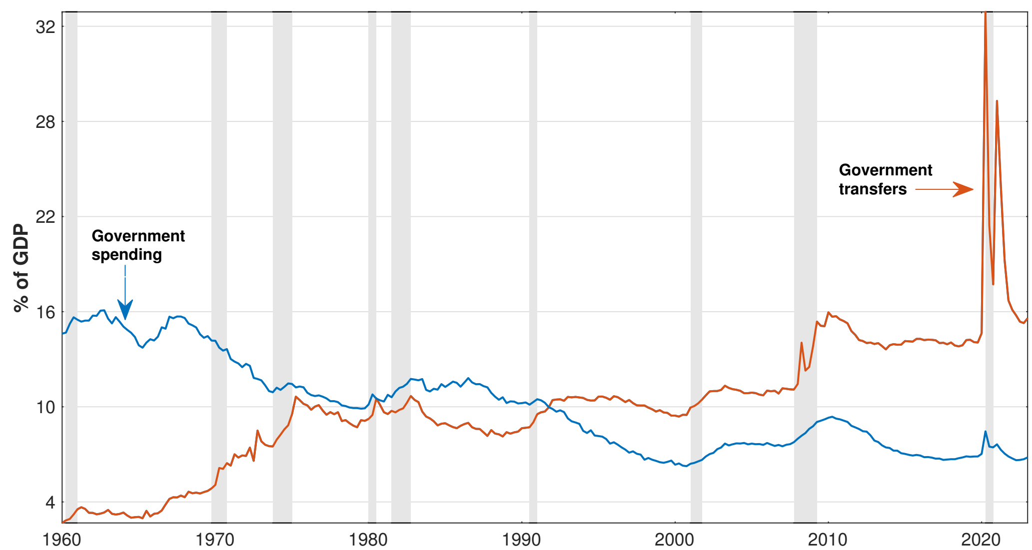
2 Literature review

The interactions between monetary policy and fiscal policy have been extensively examined in the economic literature. Notably, 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. 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 economic and non-economic shocks. In an economic landscape of high levels of public debt, and substantial fiscal stimulus, the concept of a "monetary-financed fiscal stimulus" Galí (2020a) has gained growing consensus among scholars.[1] According to Galí (2020b), in practice, the monetary-financed fiscal stimulus would involve a credit to the government account held at the central bank or the acquisition of non-redeemable government debt from the central bank. Consequently, this debt would be permanently held on the balance sheet of the central bank. Another line of literature, as proposed by 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 money supply experiences a permanent increase.[2] The use of monetary-financing is typically reserved for extreme circumstances when public debt levels are already high and interest rates are too low to provide an effective tool for economic recovery and combating

[1] Bernanke (2003) refers to this concept using Milton Friedman's terminology "Helicopter money", which refers to lump-sum transfers to households financed by newly printed money. Andolfatto et al. (2013) analyses the monetisation of public debt, which involves the permanent purchase of government bonds from the central bank. Giavazzi and Tabellini (2014) propose the issuance of long-term maturity debt, such as 30 years, which would be bought by the central bank. Cukierman (2020) and Galí (2020a) discuss about the seigniorage, which is the purchasing power of increased money supply used by the central bank to directly purchase newly issued government debt. In this case, the central bank would buy government debt and the government would not have to repay the debt, nor the interest on it.

[2] It is worth noting that this distinguishes monetary-financed fiscal stimuli from quantitative easing, which has only a temporary impact on the monetary base.

Figure 1: Government spending and government transfers as a percent of US GDP, 1960Q1 - 2023Q1



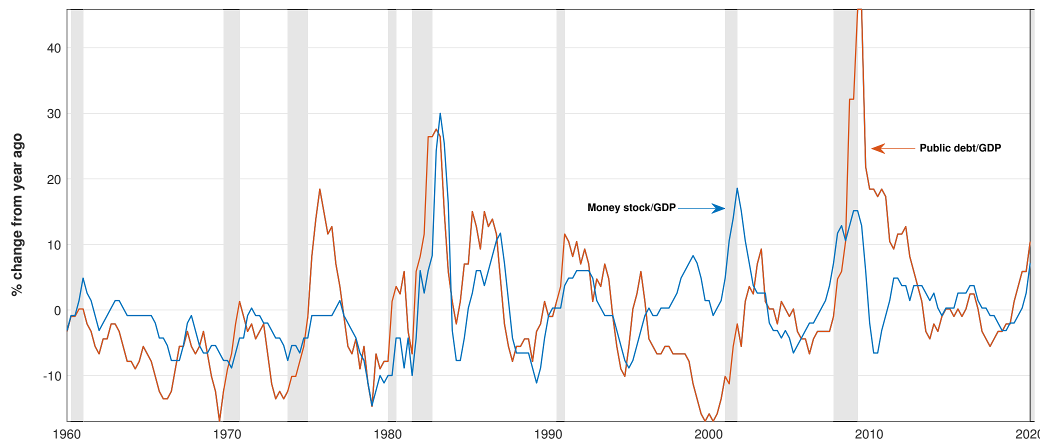
Note: Source of data: Economic Data from the Federal Reserve Bank of St. Louis database. Shaded areas represent NBER recessions.

low inflation. During times of aggregate demand disruptions, Woodford (2012) and Turner (2015) demonstrate that monetary-financing would stimulate aggregate demand to a greater extent compared to debt-financing. Turner (2015) further argues that monetary-financing is more desirable and optimal compared to alternative policies measures.

In the context of providing fiscal stimulus through a tax cut or an increase in government spending backed by money creation 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 that undermines the efficiency of fiscal stimuli.

A policy measure involving the cooperation between the central bank and the government to achieve monetary-financing of public debt has raised concerns regarding the potential consequences of hyperinflation (Sargent and Wallace, 1973). However, our analysis focuses on a counterfactual scenario involving monetary-financed fiscal stimuli during a period when

Figure 2: Money supply and public debt-to-GDP ratio in the US, 1960Q1 - 2019Q4



Note: Money supply aggregate is represented by the M2 money stock. The public debt is represented by the market value of marketable treasury debt, and GDP is the Gross Domestic Product. Source of data: Economic Data from the Federal Reserve Bank of St. Louis database. Shaded areas represent NBER recessions.

the central bank has limited scope to implement expansionary monetary policy due to low interest rates. This economic setting differs substantially from a high inflation period in which central banks raise policy rates to combat inflation and manage inflation expectations. Given the persistent low inflation and well-anchored inflation expectations observed over the past decade, as well as the recognition of the credibility and independence of central banks in developed countries by the market, Cukierman (2020) argues that the risk of hyperinflation may be of lesser concern. Lawson and Feldberg (2020) explain that when central banks are characterized by independence and credibility, there may be scope for monetisation without the need to give up their credibility. Furthermore, past instances of hyperinflation resulting from the monetisation of public spending occurred during periods when central banks and governments were not separate entities. The Zimbabwe hyperinflation and the Weimar Republic episode in the 1920s are two examples.

Giavazzi and Tabellini (2014) and Turner (2015) criticise the use of money to finance the government debt from a political point of view. They argue that the use of the money-financing policy may be misleading and lead to its excessive and unwarranted utilisation. 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 are overcome, the money-financing policy can become the optimal approach to stimulate aggregate demand.

As assessed in previous literature and corroborated in our analysis, a monetary-financed fiscal policy that does not increase the level of public debt has the potential to increase inflation levels. As mentioned earlier, the focus of this chapter is to evaluate the macroeconomic impact of a monetary-financed fiscal stimulus during periods of low aggregate demand and when interest rates are constrained by the effective lower bound. Given the limited scope for expansionary monetary policy in such a liquidity trap scenario, it becomes pertinent to quantitatively investigate this alternative proposal. In this particular setting, characterized by persistently low inflation levels (as observed in the US over the past decade), an inflationary effect resulting from monetary-financed fiscal stimuli can serve to mitigate a portion of the government debt burden through the process of "inflating-away". Bianchi et al. (2023) recently added to the literature about the fiscal theory of the price level by developing a theoretical framework that allows for partially unfunded fiscal shocks. Similar to the monetary financing scheme, unfunded fiscal shocks have a positive impact on real variables. In their model, the central bank controls monetary policy while the government controls fiscal policy. However, the central bank accommodates the necessary increase in inflation to support the unfunded fiscal shocks. 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 utilisation of money supply to finance fiscal stimuli, we provide insights into the potential implications and outcomes of such a policy approach.

The rest of the paper is structured as follows. Section 3 describes the theoretical model. Section 4 discusses the estimation results. Section 4.3 shows simulation results comparing a scenario in which fiscal stimulus is monetary-financed and a scenario in which fiscal stimulus is debt-financed. Section 8 concludes.

3 Theoretical model

In this section the theoretical model is described. The structure of the model is similar to medium-scale new Keynesian models present in the literature (Smets and Wouters, 2007; Christiano et al., 2005; Del Negro and Schorfheide, 2008; Leeper et al., 2017).

The economy is populated by a continuum of agents, intermediate good firms, a final good firm, a government and a central bank. Intermediate firms are monopolistically competitive, rent capital from households, produce goods by setting prices à la Calvo (Calvo, 1983). The final good is produced and packed by a final good firm and is then sold to households. The wage is set on a frictional labour market. The households in turn provide labour to intermediate firms, obtain dividends from the firms, and utility from consumption, real balances, labour and fiscal stimulus. We focus on two fiscal policy instruments: transfers and government spending. The government issuing (expansionary) fiscal policies faces a scenario in which additional public debt emerging from the expansionary fiscal policy is financed through issuance of government bonds. This is the traditional "debt-financed scenario". In the counterfactual scenario, the government finances the increase in public debt through an increase in money supply. This is the "monetary-financed scenario".

Henceforth, upper case variables with a time subscript are variables in levels, steady state variables are letters without a time subscript and lower case variables with a hat are linearized variables. Linearization is made in terms of log deviations of a variable from its steady state value.

3.1 Households

The household derives utility from consumption, real money balances and labour maximising the following utility function:

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

where C_t, $\frac{M_t}{P_t}$, L_t represent respectively consumption, real money balances and labour. β_t is the discount factor, b_t represents a preference shifter to the household's utility function and h is a parameter representing habits. ϕ_t and χ_t are two preference shifters affecting the marginal utility of leisure and money holdings. The preference shifters follow exogenous processes as follows:

$$ln\,\phi_t = (1-\rho_l)\,ln\,\phi + \rho_l\,ln\,\phi_{t-1} + \sigma_l\,\epsilon_{l,t}, \text{with}\,\epsilon_{l,t} \sim N(0,1) \tag{2}$$

$$ln\,b_t = (1-\rho_b)\,ln\,b + \rho_b\,ln\,b_{t-1} + \sigma_b\,\epsilon_{b,t}, \text{with}\,\epsilon_{b,t} \sim N(0,1) \tag{3}$$

$$ln\,\chi_t = (1-\rho_m)\,ln\,\chi + \rho_m\,ln\,\chi_{t-1} + \sigma_m\,\epsilon_{m,t}, \text{with}\,\epsilon_{m,t} \sim N(0,1) \tag{4}$$

In our model, consumption and real money balances enter the household's objective function in a separable way, following Del Negro and Schorfheide (2008) and Punzo and Rossi (2022).

The budget constraint faced by the household is given by:

$$P_tC_t + P_tI_t + B_t + M_t = R_{t-1}B_{t-1} + M_{t-1} + R_t^k K_{t-1} + W_tN_t + P_tD_t + P_tT_t \tag{5}$$

where I_t is investment, K_t is capital and R_t^k is the rate of return on capital. Bonds B_t pay a price of $R_t = 1 + i_t$. Households receive T_t transfers from the government and D_t represent dividends obtained from firms. W_t is the nominal wage obtained by the households. The equation for capital accumulation is given by:

$$K_t(j) = (1-\delta)\,K_{t-1}(j) + \mu_t\left(1 - S\left(\frac{I_t(j)}{I_{t-1}(j)}\right)\right)I_t(j) \tag{6}$$

$S(\cdot)$ is a function representing the investment adjustment costs, with $S''(\cdot) > 0$. δ is the depreciation rate of capital. μ_t represents a shock to investment, and follows the process:

$$ln\,\mu_t = (1-\rho_\mu)\,ln\,\mu + \rho_\mu\mu_{t-1} + \sigma_\mu\,\epsilon_{\mu,t}, \text{with}\,\epsilon_{\mu,t} \sim N(0,1) \tag{7}$$

3.2 Labour packers

The economy is populated by labour packers. The labour packers hire households providing labour, combine it into labour services, L_t, and provide it to intermediate firms. Assuming a continuum of households i, where $i \in [0,1]$, the aggregation of labour into labour services is given by:

$$L_t = \left[\int_0^1 L_t(j)^{\frac{1}{1+\lambda_w}} dj\right]^{1+\lambda_w} \tag{8}$$

where λ_w is a parameter. We obtain a labour demand function and the price of aggregated labour L_t:

$$L_t(j) = \left(\frac{W_t(j)}{W_t}\right)^{-\frac{1+\lambda_w}{\lambda_w}} L_t \tag{9}$$

with

$$W_t = \left[\int_0^1 W_t(j)^{-\frac{1}{\lambda_w}} di\right]^{-\lambda_w} \tag{10}$$

The wage setting is subject to nominal rigidities following Calvo (1983). Each period the labour union 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:

$$\begin{aligned}
&\max_{\tilde{W}_t(j)} \mathbb{E}_t \sum_{s=0}^{\infty} \zeta_w^s \beta^s b_{t+s} \left[-\frac{\phi_{t+s}}{1+\nu_l} L_{t+s}(j)^{1+\nu_l}\right] \\
&\text{s.t. } L_t(j) = \left(\frac{\tilde{W}_t(j)}{W_t}\right)^{-\frac{1+\lambda_w}{\lambda_w}} L_t \\
&\text{eq. (5) and} \\
&W_{t+s}(j) = \left(\prod_{l=1}^{s} (\pi^*)^{1-\iota_w} (\pi_{t+l-1})^{\iota_w}\right) \widetilde{W_t}(j)
\end{aligned} \tag{11}$$

3.3 Final good firms

Final good firms operate in a perfectly competitive market and produce an homogeneous good Y_t. The final good firms buy intermediate goods from intermediate firms and pack and sell the final good Y_t to consumers. Thus, Y_t is an index represented by a continuum of intermediate goods $Y_t(i)$:

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{1}{1+\lambda_t^p}} di\right]^{1+\lambda_t^p} \tag{12}$$

where λ_t^p is the mark-up shock and follows an AR (1) process:

$$ln\lambda_t^p = (1-\rho_\pi)ln\lambda^p + \rho_\pi \lambda_{t-1}^p + \sigma_\pi\, \epsilon_t^{\lambda^p}, \text{with}\, \epsilon_t^{\lambda^p} \sim N(0,1) \tag{13}$$

We obtain that

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

and the price of the final goods firm is:

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

where the price of the final good is P_t and the price of the intermediate good (i) is $P_t(i)$.

3.4 Intermediate good firms

The representative intermediate goods firm follows a Cobb Douglas technology that makes use of capital K_t and labour L_t through the following relation:

$$Y_t(i) = A_t^{1-\alpha} K_t(i)^\alpha L_t(i)^{1-\alpha} \tag{14}$$

where Y_t is the output produced in period t and A_t represents fixed technology across all firms. A_t follows an AR process:

$$lnA_t = (1-\rho_z)lnA + \rho_z lnA_{t-1} + \sigma_z \epsilon_{z,t},\, \epsilon_{z,t} \sim N(0,1)$$

The intermediate firm decides on the quantity of capital stock to rent from households and on the quantity of labour to employ. Capital and labour represent costs for the firms, and as a consequence the firm's problem is to maximize its profits, that are equal to:

$$\Pi_t(i) = P_t(i)Y_t(i) - W_t N_t(i) - R_t^k K_t(i)$$

that results in a capital-labour ratio which is equal for all firms:

$$\frac{K_t(i)}{L_t(i)} = \frac{\alpha}{1-\alpha}\frac{W_t}{R_t^k} \tag{15}$$

Intermediate goods firms set their prices à la Calvo (1983), thus similar to the wage setters. Calvo 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. Prices for the non-adjusting firms follow:

$$P_t(i) = \pi_{t-1}^{\iota^p}(\pi^*)^{1-\iota^p} \tag{16}$$

and the firms able to adjust their prices, follow the optimal price equation:

$$\max_{\tilde{P^*}_t(i)} \sum_{s=0}^{\infty} \zeta_p^s \beta^s \Xi_{t+s}^p \left(\tilde{P}_t(i) \left(\prod_{l=1}^{s} \pi_{t+l-1}^{\iota^p} \pi^{*1-\iota^p} \right) - MC_{t+s} \right) Y_{t+s}(i) \tag{17}$$

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.

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.

3.5 Monetary policy

The central bank sets up the nominal interest rate R_t according to changes in inflation and the difference between output and potential output (Taylor, 1993)

$$\frac{R_t}{R^*} = \left(\frac{R_{t-1}}{R^*}\right)^{\phi_r} \left[\left(\frac{\pi_t}{\pi^*}\right)^{\phi_\pi} \left(\frac{Y_t}{Y^*}\right)^{\phi_y} \right]^{1-\phi_r} e^{\lambda_t^r} \tag{18}$$

where R^* and Y^* are the steady state levels for the interest rate and the output, π^* is the inflation target, and ϕ_r captures the degree of interest rate smoothing. ϕ_π is the weight of inflation on the interest rate and ϕ_y is the weight of output gap on the interest rate. ϵ_t^r is a monetary policy exogenous shock and it is assumed to follow an AR (1) process:

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

3.6 Fiscal policy

The government budget constraint is:

$$P_tG_t + B_{t-1}(1+i_{t-1}) = P_tT_t + B_t + \Delta M_t \tag{19}$$

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

Transfers follow a fiscal rule, that we construct based on Leeper et al. (2010). In linearized form, the fiscal rule is the following:

$$T_t = -\frac{{B_{t-1}}^{\psi_{bt}}}{Y_t^{\psi_{yt}}}\,e^{t_t} \tag{20}$$

where t_t^* is a shock to transfers and it is assumed to follow the AR(1) process:

$$ln\,t_t = \rho_t ln\,t_{t-1} + \sigma_t\epsilon_{t,t},\ \epsilon_{t,t} \sim N(0,1) \tag{21}$$

The government spending shock follows an AR process:

$$ln\,g_t = \rho_g ln\,g_{t-1} + \sigma_g\epsilon_{g,t},\ \epsilon_{g,t} \sim N(0,1) \tag{22}$$

4 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 1960:Q1 - 2019:Q4. The observable variables are consumption, investment, hours worked, real wage, inflation, the shadow rate, government spending, government transfers and money supply. These time series match the corresponding model variables of consumption, investment, hours worked, real wage, inflation, the nominal interest rate, government spending and government transfers and money supply. The model features nine shocks for nine observable variables. All observable variables, except for the fiscal observables, are constructed as in Smets and Wouters (2007). Fiscal observable variables are computed following the methodology described in Leeper et al. (2010). We detrend each variable with the one-sided HP filter with a smoothing parameter equal to 1,600. A more detailed description of the time series and of the data transformation can be found in Appendix C.

The observable equation for each observable matching the model variable is:

$$X_{obs} = 100 * \hat{x}_t \tag{23}$$

where X_{obs} is the observable variable and $\hat{x}_t$ represents the log-linearized model variable.

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 for our analysis, as we can draw upon extensive literature on DSGE modelling to inform our choice of priors. We use multiple optimisation algorithms to find the mode. We employ Monte Carlo Markov Chain (MCMC) methods and the Metropolis Hastings (MH) algorithm. The model is estimated using 500000 draws from the posterior distributions. We run two parallel chains in the MCMC MH algoritm, and the acceptance rate of each of the chains is approximately 22%.

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 approximatively 4%. The 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).

Table 1: Calibrated parameters and source

Parameter	Value	Source
β Household's discount factor	0.99	to match 4% real annual int.rate
α Labour share in Cobb Douglas function	0.33	Del Negro et al. (2007)
δ Capital depreciation rate	0.025	Del Negro et al. (2007)
ν_m Inverse elasticity of substitution money	1	Galí (2015)
λ_w Wage markup	0.14	Bianchi et al. (2023)
λ_p Prices markup	0.14	Bianchi et al. (2023)
$\frac{B}{Y}$ Share of public debt on GDP annualized	2.4	Galí (2020a)
χ Steady state inverse velocity of money supply	0.52	Our sample
$\frac{G}{Y}$ Share of government spending on GDP	0.22	Our sample
$\frac{T}{Y}$ Share of government transfers on GDP	0.26	Our sample

We follow Galí (2015) to calibrate the inverse elasticity of substitution between money and consumption, and set the parameter to 1. The inverse velocity of money supply in steady state and the shares of government spending and transfers are set equal to our sample averages. We finally calibrate the share of public debt to GDP as in Galí (2020b).

Priors for the mean and the standard deviation of exogenous and persistence parameters are selected based on previous related literature. The priors for exogenous parameters align with Smets and Wouters (2007) and are presented in table 2. The priors for the persistence parameters are in line with Leeper et al. (2010) and are displayed in table 3. The first three columns of table 4 show priors 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).

4.3 Posterior estimates

Tables 2, 3, 4 display results for the estimated parameters. The first three columns of each table present information about the priors, as explained in the previous section. The last three columns show the posterior mean estimates and their 10% and 90% credible intervals.

Table 2: Standard errors of shocks

	Prior			Posterior		
Parameter	*Distribution*	*Mean*	*Std. Dev*	*Mean*	10%	90%
σ_z Productivity shock standard error	Inv. gamma	0.1	2	0.1276	0.0848	0.1696
σ_b Risk premium shock standard error	Inv. gamma	0.1	2	0.0223	0.0173	0.0271
σ_g Government spending shock standard error	Inv. gamma	0.1	2	0.0250	0.0232	0.0268
σ_μ Investment shock standard error	Inv. gamma	0.1	2	0.1699	0.1410	0.1983
σ_r Monetary policy shock standard error	Inv. gamma	0.1	2	0.0084	0.0076	0.0093
σ_π Cost push shock standard error	Inv. gamma	0.1	2	1.2758	0.7803	1.7616
σ_t Transfers shock standard error	Inv. gamma	0.1	2	0.0423	0.0391	0.0455
σ_m Money supply shock standard error	Inv. gamma	0.1	2	0.2180	0.2014	0.2343

Table 3: Persistence parameters

	Prior			Posterior		
Parameter	*Distribution*	*Mean*	*Std. Dev.*	*Mean*	10%	90%
ρ_z Productivity persistence parameter	Beta	0.7	0.2	0.3042	0.2011	0.4034
ρ_b Risk premium persistence parameter	Beta	0.7	0.2	0.4531	0.3269	0.5799
ρ_g Government spending persistence parameter	Beta	0.7	0.2	0.7484	0.6900	0.8085
ρ_μ Investment persistence parameter	Beta	0.7	0.2	0.2978	0.2040	0.3883
ρ_r Monetary policy persistence parameter	Beta	0.7	0.2	0.9950	0.9904	0.9998
ρ_π Cost push persistence parameter	Beta	0.7	0.2	0.6536	0.5618	0.7417
ρ_t Transfers persistence parameter	Beta	0.7	0.2	0.4821	0.3864	0.5784
ρ_m Money supply persistence parameter	Beta	0.7	0.2	0.8175	0.7584	0.8795

Table 4: Structural parameters

Parameter	Prior			Posterior		
	Distribution	*Mean*	*St. Dev*	*Mean*	10%	90%
h Consumption habits	Beta	0.7	0.1	0.7993	0.7481	0.8483
ϕ_r Interest rate smoothing parameter	Beta	0.5	0.1	0.1849	0.1242	0.2490
ϕ_π Weight of inflation on the interest rate	Gamma	2.00	0.2	3.3500	3.1560	3.9019
ϕ_y Weight of output on the interest rate	Gamma	0.125	0.1	0.1769	0.1360	0.2178
Γ Investment adjustment costs	Normal	6.00	0.5	6.1313	5.3633	6.9388
ψ_{bt} Transfers parameter for debt	Gamma	0.25	0.1	0.2658	0.1421	0.3803
ψ_{yt} Transfers parameter for output	Gamma	0.1	0.05	0.1213	0.0306	0.2082
ζ_w Wage stickiness	Beta	0.5	0.1	0.4794	0.4195	0.5389
ι_w Wage indexation	Beta	0.5	0.2	0.4542	0.1547	0.7397
ζ_p Price stickiness	Beta	0.5	0.1	0.9620	0.9555	0.9683
ι_p Price indexation	Beta	0.5	0.2	0.1127	0.0575	0.1659

Identification tests based on Qu and Tkachenko (2012) and Iskrev (2010) show that the jacobian matrices of the first two moments and of the spectral density have full rank. Therefore, the parameters are all identified. Moreover, trace plots for each of the estimated parameters display no trend, implying that the Metropolis Hastings algorithm converges to a stable distribution.

As it becomes evident from table 2, we obtain higher standard deviations for more volatile aggregates, such as investment, money supply and the labour supply, than for other variables. Table 3 shows that none of the AR processes for the shocks appear to be highly persistent. Money supply is an exception with an estimated posterior mean of 0.77. Structural parameters are mostly in line with literature, except the wage indexation and the price indexation parameters, which are estimated to be lower than estimates in Smets and Wouters (2007) and Del Negro et al. (2007), for instance. Graphs for prior and posterior distributions, together with other estimation output can be found in Appendix D.

5 Effects of monetary-financed fiscal stimuli

In this section we analyse two scenarios in which the government and the central bank work together to issue 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 our analysis into two scenarios. We call the first scenario the "debt-financed fiscal stimuli" scenario. In this setting, the central bank pursues a monetary policy based on inflation targeting, and focuses on controlling the policy rate. We estimate the model representing this scenario, and the estimation results are shown in the previous section. The second scenario is called "monetary-financed fiscal stimuli". Here, the central bank gives up of the control on the policy rate and focuses on the money supply. We adapt the second scenario to include the "monetary-financing" part and simulate the model with the parameters calibrated with the values of estimated parameters obtained from the "debt-financed fiscal stimuli" scenario.

In the "debt-financed fiscal stimuli" scenarios, the model features a Taylor rule, as described by equation (18). On the other hand, when the fiscal stimulus is financed by money supply, the fiscal and monetary authorities increase the money growth together with the fiscal stimuli in order to keep the public debt constant. Having constant debt implies that the deviation of the debt from its steady state value has to be equal to zero: $\hat{b}_t = 0$. In this case, the linearized version of equation (19) becomes:

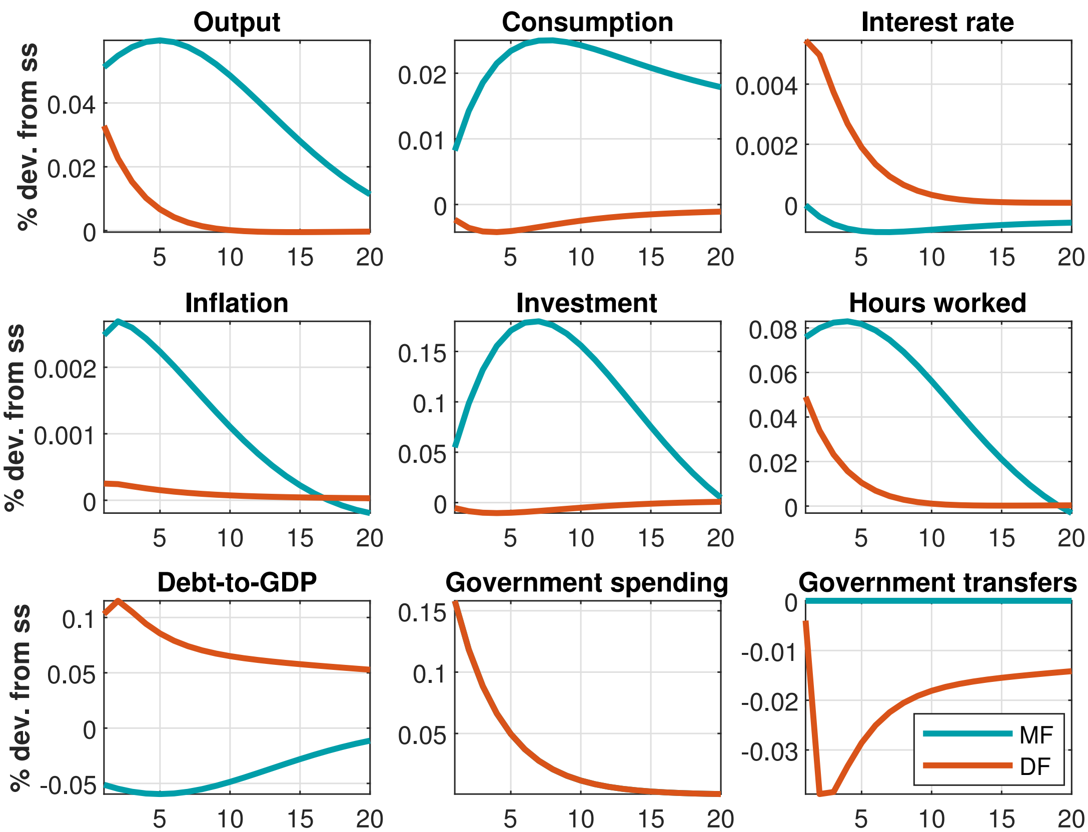
$$\Delta m_t = \frac{1}{\chi} \left[\frac{g}{y} g_t + \frac{t}{y} t_t + \frac{b}{y} \frac{r}{\pi} \left(i_{t-1} - \pi_t \right) \right] \tag{24}$$

Figure 3 shows the impact of an increase in government spending on the main economic aggregates in the two scenarios: when the government spending increase is financed by debt and when the government spending increase is financed by money supply. The magnitude of the shock is equal to its estimated value in the "debt-financed fiscal stimuli" scenario. Output increases in both scenarios, though the increase is much more persistent in the monetary-financing scenario. In the debt-financing scenario, after an increase in government spending and the increase in inflation due to the positive demand shock, inflation needs to be stabilized. The monetary authority increases the nominal interest rate, decreases the money supply and the government increases future taxes to finance the current expansionary government spending. As a result, real rates increase, driving consumption down. A monetary-financed government spending increase leaves public debt unchanged, while increasing inflation and lowering the real interest rate. The real interest rate here decreases as a consequence of the central bank's control of the money supply, and not of the nominal interest rate. Therefore the positive shift in the consumption response is driven by the nominal interest rate, which combined with the increase in inflation brings about a decrease in the real interest rate. The nominal interest rate increases only in response to an adjustment process inside the government budget constraint, thus by a smaller amount, as the government spending is not financed by debt. This is key for our analysis, as consumption is no longer crowded-out. Thus, monetary-financing represents one of the channels through which consumption reacts positively to an increase in government spending (Coenen and Straub, 2005; Galí et al., 2007; Asimakopoulos et al., 2020).

Figure 4 shows the impact of an increase in transfers on the main economic variables in the two scenarios: when the increase in transfers is financed by debt and when the increase in transfers is financed by money supply. The magnitude of the shock is again set to its estimated value.

In the first scenario, the lack of impact on economic variables is explained by the effect of the Ricardian equivalence. A debt-financed increase in transfers has no impact on economic variables, as consumers understand that a transfer increase today is payed back by higher future taxes. When the fiscal stimulus is debt-financed, the monetary authority pursues an inflation targeting strategy to control inflation through a response to inflation in the nominal interest rate rule. This causes output, consumption, and inflation to remain unchanged. Furthermore, neither money supply nor interest rates are adjusted. On the other hand, the increase in transfers financed by money supply has an expansionary impact on output and consumption, as the increase in transfers is perceived by households as a direct increase in their disposable income. After the increase in money supply, the nominal interest rate adjusts downwards. Given the increase in inflation, the real interest rate decreases. This has a positive impact on consumption and investment, which brings about an increase in output. The increase in output together with a constant debt level lowers the debt-to-output ratio.

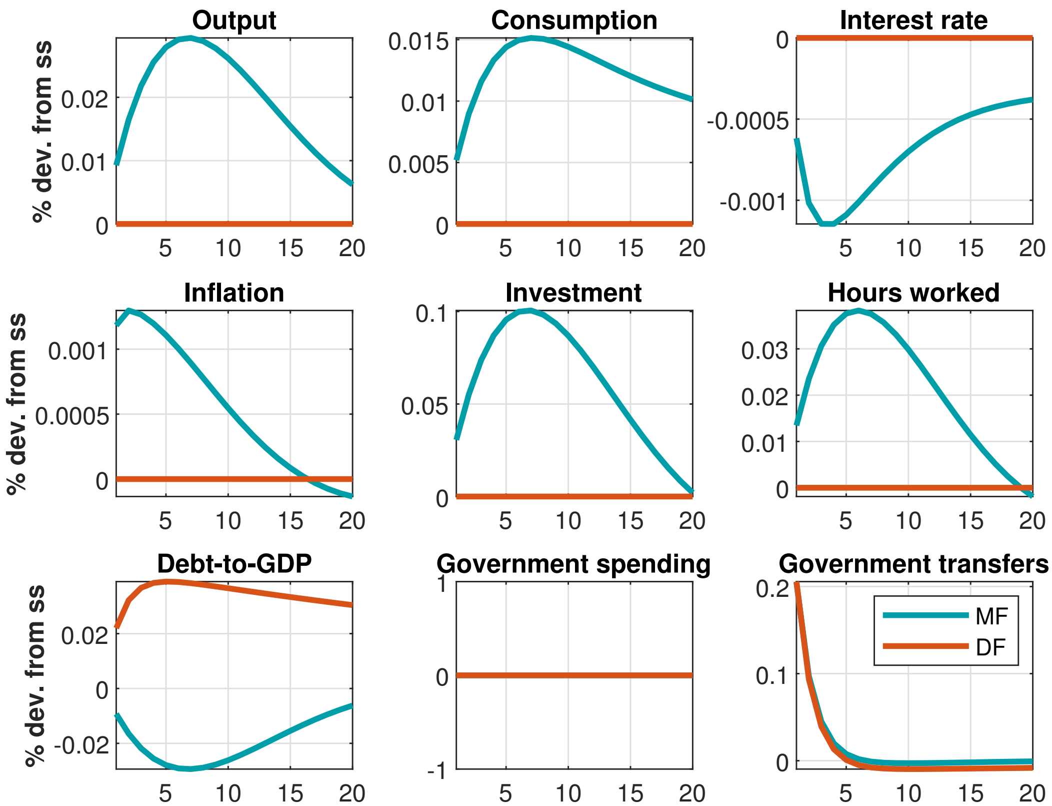
Figure 3: Government spending increase: debt vs monetary-financing



Note: The blue line represents the monetary-financed government spending, while the orange line is the debt-financed government spending.

Inflation expectations increase, which leads to an increase in inflation. The monetary-financed transfers shock explains the transmission mechanism of the expectations channel. Consumers understand that an increase in transfers in time t, that leaves public debt unchanged in time $t + k$ does not imply a taxes increase in the future. The result is that, without the Ricardian effect, the economy experiences an expansionary impact on nominal GDP and consumption. Inflation expectations rise, bringing about an increase in inflation and, since the nominal interest rate decreases, real interest rates remain low or decrease. Moreover, a higher inflation rate has an additional positive impact on levels of pre-existing debt, because it removes part of its value.

Figure 4: Transfers increase: debt vs monetary-financing

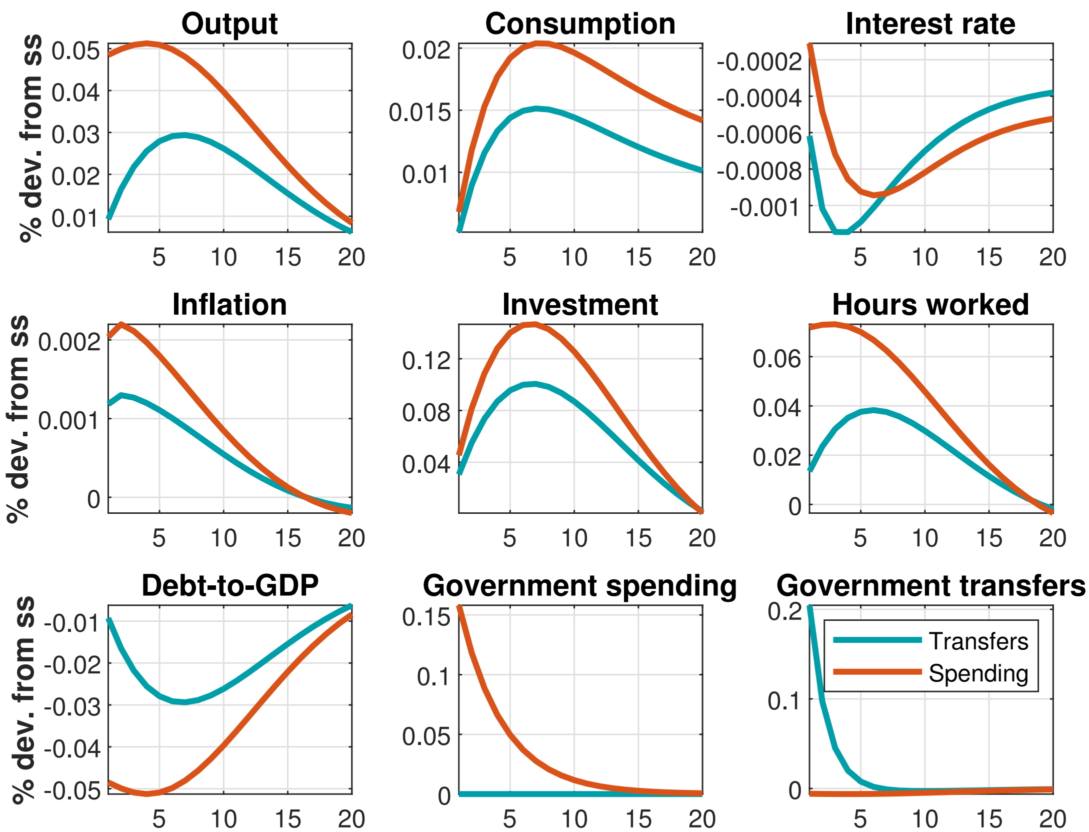


Note: The blu line represents the monetary-financed government transfers, while the orange line represents the debt-financed government transfers.

Figure 5 shows the difference between 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 shows the impact of a money-financed increase in government spending. As described in the previous figures, the case in which the fiscal stimulus (either increase in transfers or increase in government spending) is financed through money supply has an expansionary impact on the main economic variables. The response of consumption to an increase in government spending is lower compared to the impact of an increase in transfers. For output, the opposite holds: our model predicts a higher increase in output after an increase in government spending than after an increase in transfers.

The reason why Ricardian equivalence holds in the case of a debt-financed increase in

Figure 5: Monetary financing: government spending and transfers increase



Note: The blue line shows the response to a transfers increase in a monetary-financing scenario. The orange line shows the response to a government spending increase in the same scenario.

government transfers and not of a monetary-financed increase lies in the anticipation of households. In the first scenario, households anticipate that a future decrease in transfers (or increase in lump-sum taxes) will offset current increase in transfers. In the second case, an increase in money supply issued to fund the expansionary fiscal policy results in a corresponding increase in real balances. Since real balances contribute to consumers' wealth, the improvement in wealth translates into an increase in consumption and output.

6 Variance decomposition

Table 5: Unconditional variance decomposition, monetary financed spending shock, transfers muted

Period ∞	y	c	π	r	B/Y	$\Delta\ m$
σ_b	11.70	76.84	3.44	6.39	11.70	0.62
σ_i	6.91	0.27	2.35	0.05	6.91	0.20
σ_m	3.39	1.20	7.76	89.93	3.39	10.22
σ_π	0.08	0.04	2.75	0.02	0.08	0.23
σ_r	0.00	0.00	0.00	0.00	0.00	0.00
σ_z	0.06	0.07	6.77	0.03	0.06	0.57
σ_g	77.86	21.59	76.93	3.57	77.86	88.16

Table 6: Conditional variance decomposition, h = 1, monetary financed spending shock, transfers muted

Period 1	y	c	π	r	B/Y	$\Delta\ m$
σ_b	10.21	92.43	3.38	9.43	10.21	0.17
σ_i	7.26	0.03	1.74	0.00	7.26	0.09
σ_m	0.22	0.08	6.58	90.56	0.22	0.34
σ_π	0.02	0.01	4.80	0.00	0.01	0.25
σ_r	0.00	0.00	0.00	0.00	0.00	0.00
σ_z	0.00	0.01	15.19	0.01	0.00	0.78
σ_g	82.30	7.43	68.31	0.01	82.30	98.37

Table 7: Conditional variance decomposition, h = 5, monetary financed spending shock, transfers muted

Period 5	y	c	π	r	B/Y	$\Delta\ m$
σ_b	10.89	74.15	3.18	5.07	10.89	0.45
σ_i	4.70	0.20	2.66	0.02	4.70	0.26
σ_m	1.79	0.82	8.60	90.82	1.79	10.36
σ_π	0.05	0.04	1.97	0.02	0.05	0.20
σ_r	0.00	0.00	0.00	0.00	0.00	0.00
σ_z	0.02	0.06	4.60	0.05	0.02	0.49
σ_g	82.56	24.73	79.00	4.01	82.56	88.23

Table 8: Conditional variance decomposition, h = 12, monetary financed spending shock, transfers muted

Period 12	y	c	π	r	B/Y	$\Delta\ m$
σ_b	11.70	76.84	3.44	6.39	11.70	0.62
σ_i	6.91	0.27	2.35	0.05	6.91	0.20
σ_m	3.39	1.20	7.76	89.93	3.39	10.22
σ_π	0.08	0.04	2.75	0.02	0.08	0.23
σ_r	0.00	0.00	0.00	0.00	0.00	0.00
σ_z	0.06	0.07	6.77	0.03	0.06	0.57
σ_g	77.86	21.59	76.93	3.57	77.86	88.16

Table 9: Conditional variance decomposition, h = 30, monetary financed spending shock, transfers muted

Period 30	y	c	π	r	B/Y	$\Delta\ m$
σ_b	5.72	30.65	2.52	3.84	5.72	0.48
σ_i	2.21	2.01	4.40	0.91	2.21	0.52
σ_m	6.50	6.60	10.51	73.50	6.50	10.68
σ_π	0.11	0.11	1.33	0.07	0.11	0.21
σ_r	0.00	0.00	0.00	0.00	0.00	0.00
σ_z	0.13	0.19	3.09	0.12	0.13	0.51
σ_g	85.33	60.44	78.14	21.56	85.33	87.60

Table 10: Unconditional variance decomposition, monetary financed transfers shock, spending muted

Period ∞	y	c	π	r	B/Y	$\Delta\ m$
σ_b	31.00	89.20	7.12	6.11	31.00	0.28
σ_i	19.14	0.29	6.77	0.05	19.14	0.06
σ_m	6.30	0.95	13.25	87.25	6.30	4.98
σ_π	0.16	0.03	7.45	0.02	0.16	0.11
σ_r	0.00	0.00	0.00	0.00	0.00	0.00
σ_z	0.13	0.06	18.07	0.04	0.13	0.28
σ_t	43.28	9.48	47.33	6.53	43.28	94.29

Table 11: Unconditional variance decomposition, monetary financed BOTH transfers and spending shocks

Period ∞	y	c	π	r	B/Y	$\Delta\ m$
σ_b	11.37	75.88	3.03	5.89	11.37	0.20
σ_i	7.02	0.24	2.88	0.05	7.02	0.04
σ_m	2.31	0.81	5.64	84.00	2.31	3.54
σ_π	0.06	0.03	3.18	0.02	0.06	0.08
σ_r	0.00	0.00	0.00	0.00	0.00	0.00
σ_z	0.05	0.05	7.70	0.04	0.05	0.20
σ_t	15.87	8.06	20.17	6.29	15.87	67.10
σ_g	63.33	14.93	57.39	3.72	63.33	28.84

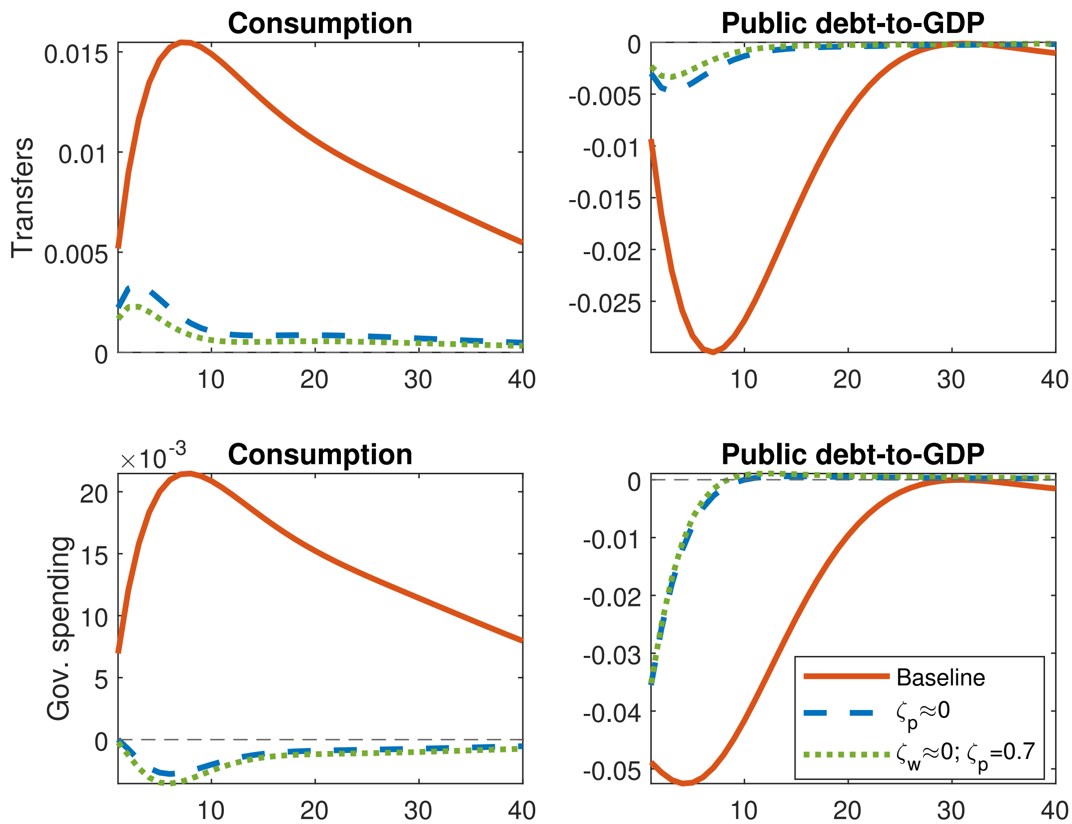
Table 12: Conditional variance decomposition, h = 1, monetary financed BOTH transfers and spending shocks

Period 1	y	c	π	r	B/Y	$\Delta\ m$
σ_b	10.40	91.85	3.00	9.30	10.40	0.08
σ_i	7.59	0.02	2.17	0.00	7.59	0.01
σ_m	0.11	0.02	4.69	89.01	0.11	0.06
σ_π	0.01	0.00	5.53	0.00	0.01	0.07
σ_r	0.00	0.00	0.00	0.00	0.00	0.00
σ_z	0.00	0.01	17.22	0.01	0.00	0.22
σ_t	2.89	2.89	16.67	1.62	2.89	74.11
σ_g	79.00	5.20	50.72	0.05	79.00	25.46

7 Robustness analysis

Nominal rigidities are important for the consumption to be crowded out or crowded it.

Figure 6: Robustness with different degrees of rigidities



Note: The orange line represents the model with price stickyness and wage stickyness. The blue line is the impact in the model without price rigidites. The green line is the model without wage rigidites and a Calvo parameter for prices equal to 0.7.

8 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 years, we consider it pertinent to conduct a counterfactual analysis of monetary-financed fiscal stimuli. To carry out this analysis, we develop a New Keynesian model that incorporates fiscal policy. We employ Bayesian methods to estimate its parameters using US data. Subsequently, we conduct a simulation analysis by augmenting the model with a model part representing a monetary-financed fiscal stimulus, using the previously estimated parameters. This allows us to quantitatively evaluate the expansionary impact of this alternative method of financing fiscal stimuli. We demonstrate that a monetary financing scheme for fiscal stimuli has positive impacts on the economic aggregates. However, this comes at a cost: an increase in inflation. 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.

Appendices

Appendix A Maximisation problems and first order conditions

Households The household's problem is:

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

and the first order conditions read:

$$[\partial C_t]\quad \lambda_t=b_t\frac{1}{C_t-hC_{t-1}}-\beta h\mathbb{E}_t\left(b_{t+1}\frac{1}{C_{t+1}-hC_t}\right) \tag{A.25}$$

$$[\partial M_t]\quad \lambda_t-\beta\mathbb{E}_tP_{t+1}\lambda_{t+1}=\chi_tb_t\left(\frac{M_t}{P_t}\right)^{-\nu_m} \tag{A.26}$$

$$[\partial B_t]\quad \lambda_t=\beta R_t\mathbb{E}_tP_{t+1}\lambda_{t+1} \tag{A.27}$$

$$[\partial I_t]\quad \lambda_t=\lambda_t^k\mu_t\left[1-S\left(\frac{I_t}{I_{t-1}}\right)-S'\left(\frac{I_t}{I_{t-1}}\right)\frac{I_t}{I_{t-1}}\right]+\beta\mathbb{E}_t\left[\lambda_{t+1}^k\mu_{t+1}S'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right] \tag{A.28}$$

$$[\partial K_t]\quad \lambda_t^k=\beta\mathbb{E}_t\left[\lambda_{t+1}\frac{R_{t+1}^k}{P_{t+1}}+\lambda_{t+1}^k(1-\delta)\right] \tag{A.29}$$

Where $\lambda_t=P_t\varrho_t$.

Labour union The first order condition for the labour union derived from the main text is:

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

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:

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

Intermediate goods firms The costs 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:

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

Moreover, intermediate firms choose a price that maximises the expected present discounted value of profits. The price setting problem is:

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

and the first order conditions is:

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

$$\left[\tilde{P}_t\left(\prod_{l=1}^{s}\pi_{t+l-1}^{\iota_p}\pi_*^{1-\iota_p}\right)-\left(1+\lambda_{p,t}\right)MC_{t+s}\right]Y_{t+s}=0$$

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

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

Appendix B Log-linearized equations

Euler equation

$$\begin{aligned}&\left(1-h\beta\right)\left(1-h\right)\,\xi_t=\\&\left(1-h\right)\,b_t-\left(\beta\,h^2\right)c_t+h\,c_{t-1}-\beta h\left(1-h\right)\mathbb{E}_t\left[b_{t+1}\right]+\beta h\,\mathbb{E}_t\left[c_{t+1}\right]\end{aligned}\tag{B.33}$$

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

Money demand

$$\nu_m m_t=\chi_t+b_t-\frac{1}{R-1}r_t-\xi_t\tag{B.34}$$

Investment FOC

$$i_t-\frac{\beta}{1+\beta}\,\mathbb{E}_t\left[i_{t+1}\right]=\frac{1}{1+\beta}i_{t-1}+\frac{1}{\Gamma\left(1+\beta\right)}q_t-\frac{1}{\Gamma\left(1+\beta\right)}\xi_t+\frac{1}{\Gamma\left(1+\beta\right)}\epsilon_{\mu,t}\tag{B.35}$$

Law of motion of capital

$$k_t=\left(1-\frac{i}{k}\right)k_{t-1}+\frac{i}{k}i_t+\frac{i}{k}\epsilon_{\mu,t}\tag{B.36}$$

Production function

$$y_t=a_t+\alpha k_t+\left(1-\alpha\right)n_t\tag{B.37}$$

Capital-labour relation

$$r_t^k=w_t+n_t-k_t\tag{B.38}$$

Household's FOC for capital

$$q_t = \frac{r^k}{r^k + (1-\delta)} \mathbb{E}_t \left[r^k_{t+1} \right] + \frac{(1-\delta)}{r^k + (1-\delta)} \mathbb{E}_t \left[q_{t+1} \right] + \frac{r^k}{r^k + (1-\delta)} \mathbb{E}_t \left[\xi_{t+1} \right] \tag{B.39}$$

Marginal cost

$$\Lambda_t = \alpha r^k_t + (1-\alpha) w_t - a_t \tag{B.40}$$

Wages

$$\begin{aligned} & w_t - w_{t-1} + \pi_t - \iota^w \pi_{t-1} = \\ & \frac{1-\zeta_w}{\zeta^w} \frac{1-\beta\zeta^w}{1+\nu_l \frac{1+\lambda^w}{\lambda^w}} \left(b_t + \phi_l + \nu_l n_t - \xi_t - w_t \right) + \beta \, \mathbb{E}_t \left(w_{t+1} - w_t + \pi_{t+1} - \iota^w \pi_t \right) \end{aligned} \tag{B.41}$$

New Keynesian Phillips curve

$$\pi_t = \frac{(1-\zeta_p \beta)(1-\zeta_p)}{(1+\beta \, \iota^p) \ \zeta_p} \left(\Lambda_t + \frac{\lambda_p}{1+\lambda_p} \epsilon_{\lambda^p_t} \right) + \frac{\iota^p}{1+\iota^p \beta} \pi_{t-1} + \frac{\beta}{1+\beta \, \iota^p} \ \mathbb{E}_t \left[\pi_{t+1} \right] \tag{B.42}$$

Aggregate economy

$$y_t = \frac{c}{y} c_t + \frac{i}{y} i_t + \frac{g}{y} g_t \tag{B.43}$$

Monetary policy

$$r_t = (1-\phi_r)(\phi_\pi \pi_t + \phi_y y_t) + \phi_r r_{t-1} + \lambda^r_t \tag{B.44}$$

Government budget constraint

$$\frac{b}{y} \frac{r}{\pi} \left(b_{t-1} + r_{t-1} - \pi_t \right) + \frac{g}{y} g_t + \frac{t}{y} t_t = \frac{b}{y} b_t + \chi \Delta m_t \tag{B.45}$$

Fiscal rules

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

$$g_t = -\psi_{yg} y_t - \psi_{bg} b_{t-1} + g^*_t$$

Law of motion of money

$$m_{t-1} = m_t + \pi_t - \Delta m_t \tag{B.46}$$

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: $\lambda_t^r = \rho_r \, \lambda_{t-1}^r + \epsilon_{r,t}$

Equity premium: $b_t = \rho_b \, b_{t-1} + \epsilon_{b,t}$

Technology: $a_t = \rho_z \, a_{t-1} + \epsilon_{z,t}$

Money demand: $\chi_t = \rho_m \, \chi_{t-1} + \epsilon_{m,t}$

Labour: $\phi_t = \rho_l \, \phi_{t-1} + \epsilon_{l,t}$

Transfers: $t_t = \rho_t t_{t-1} + \epsilon_{t,t}$

Gov. 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 FRED data series are used: GDPDEF is the implicit price deflator that 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 series is non seasonally adjusted, and it is expressed in thousands. The variables are constructed as follows:

1. Consumption:

$$100\text{*LN}\left(\frac{\text{Non durable goods and services/GDPDEF}}{\text{POPINDEX}}\right) \tag{C.47}$$

2. Investment:

$$100\text{*LN}\left(\frac{\text{Fixed Private Investment(FPI)}}{\text{POPINDEX}}\right) \tag{C.48}$$

3. Hours worked:

$$100*\text{LN}\left(\frac{\text{Nonfarm Business: Average Weekly Hours(PRS85006023)*Employment(CE16OV)}}{\text{POPINDEX}}\right) \tag{C.49}$$

4. Real wage:

$$100*\text{LN}\left(\frac{\text{Nonfarm Business Sector: Real Hourly Compensation (COMPRNFB)}}{\text{GDPDEF}}\right) \tag{C.50}$$

5. Inflation:

$$100*\text{LN}\left(\Delta\text{GDPDEF}\right) \tag{C.51}$$

For a first analysis, considering the prolonged period with interest rates hitting their effective lower bound, we use the Shadow rate as in Wu and Xia (2016)[3]. 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:

$$\frac{\text{Shadow rate}}{4} \tag{C.52}$$

$$\frac{\text{Effective federal funds rate (FEDFUNDS)}}{4} \tag{C.53}$$

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:

$$100*\text{LN}\left(\frac{\text{GS/GDPDEF}}{\text{POPINDEX}}\right) \tag{C.54}$$

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

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

8. Transfers:

$$100^{*}\text{LN}\left(\frac{\text{T/GDPDEF}}{\text{POPINDEX}}\right) \tag{C.55}$$

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 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:

$$100^{*}\text{LN}\left(\frac{\text{M2(M2SL)/GDPDEF}}{\text{POPINDEX}}\right) \tag{C.56}$$

Appendix D Additional figures

Figure 1: Identification strength

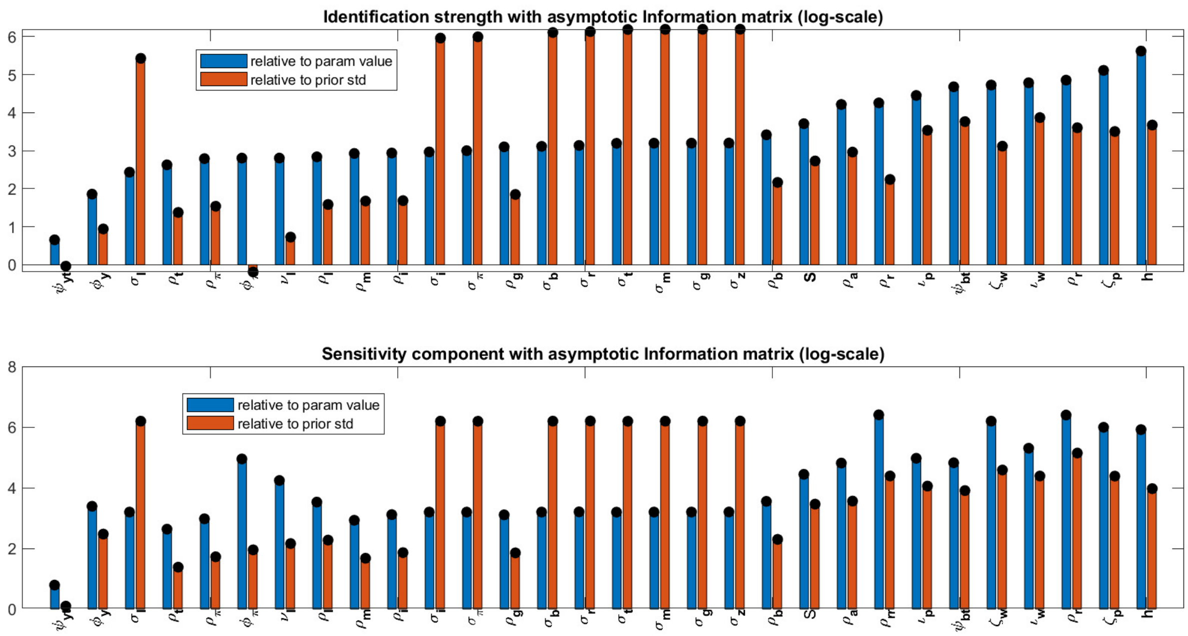


Figure 2: Multivariate convergence diagnostics

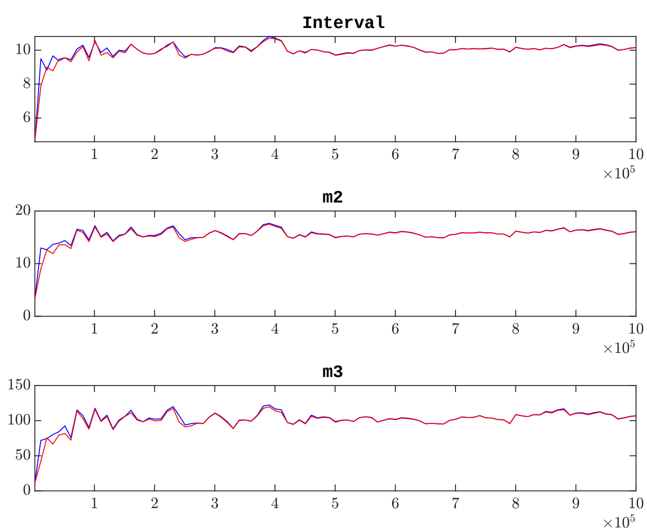
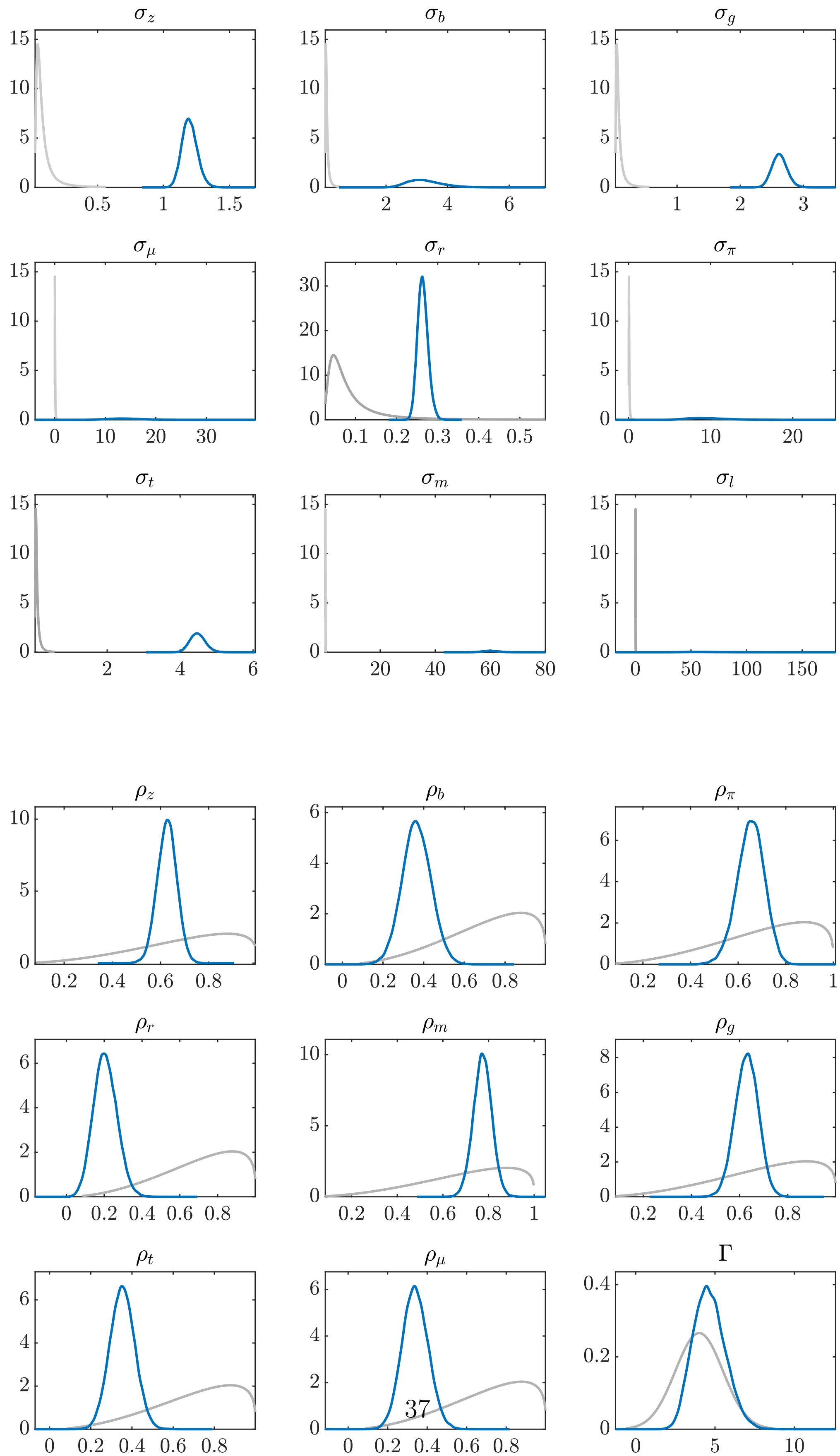
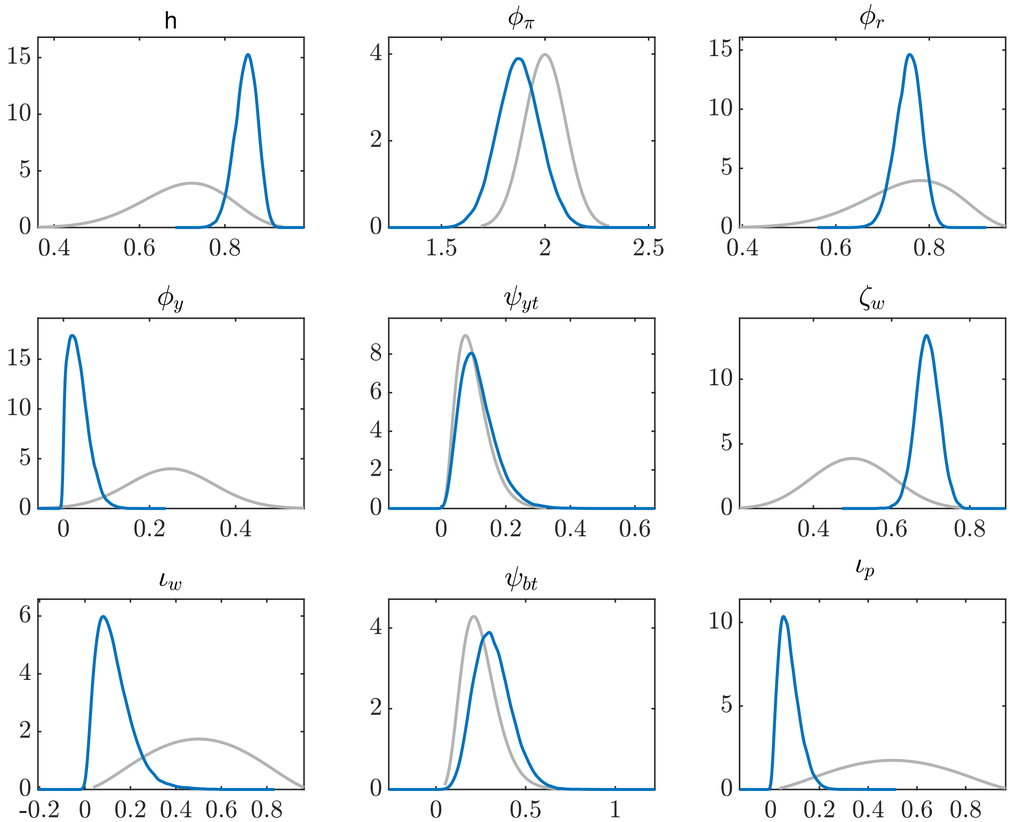


Figure 3: Priors and posteriors plots




h
ϕ_π
ϕ_r
ϕ_y
ψ_{yt}
ζ_w
ι_w
ψ_{bt}
ι_p

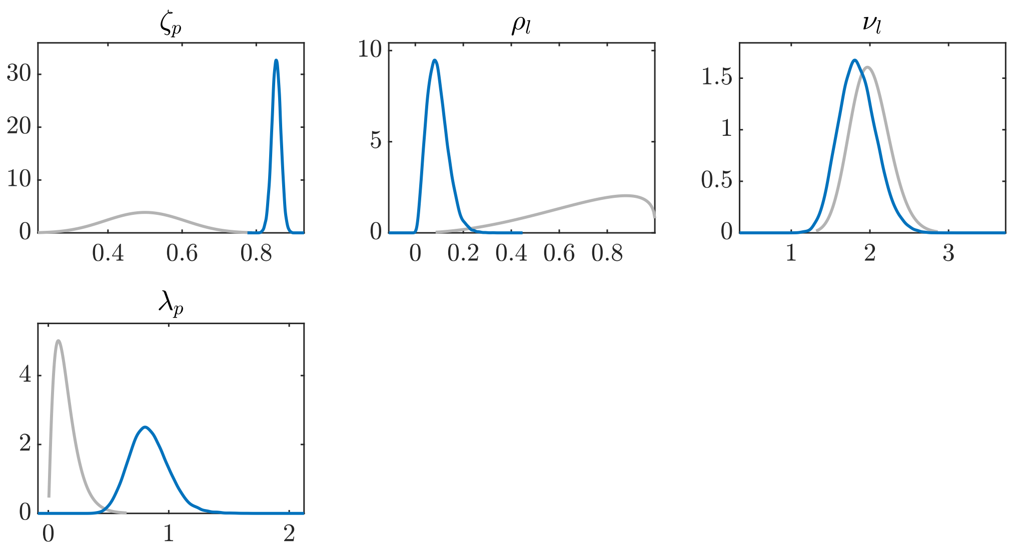

ζ_p
ρ_l
ν_l
λ_p

Figure 4: Smoothed shocks

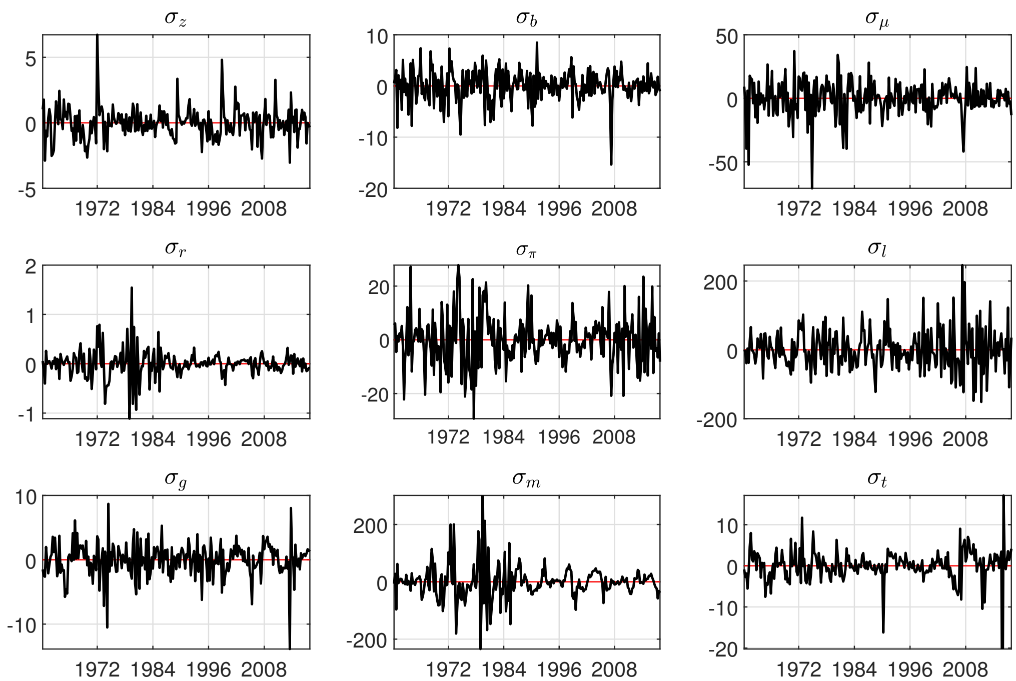
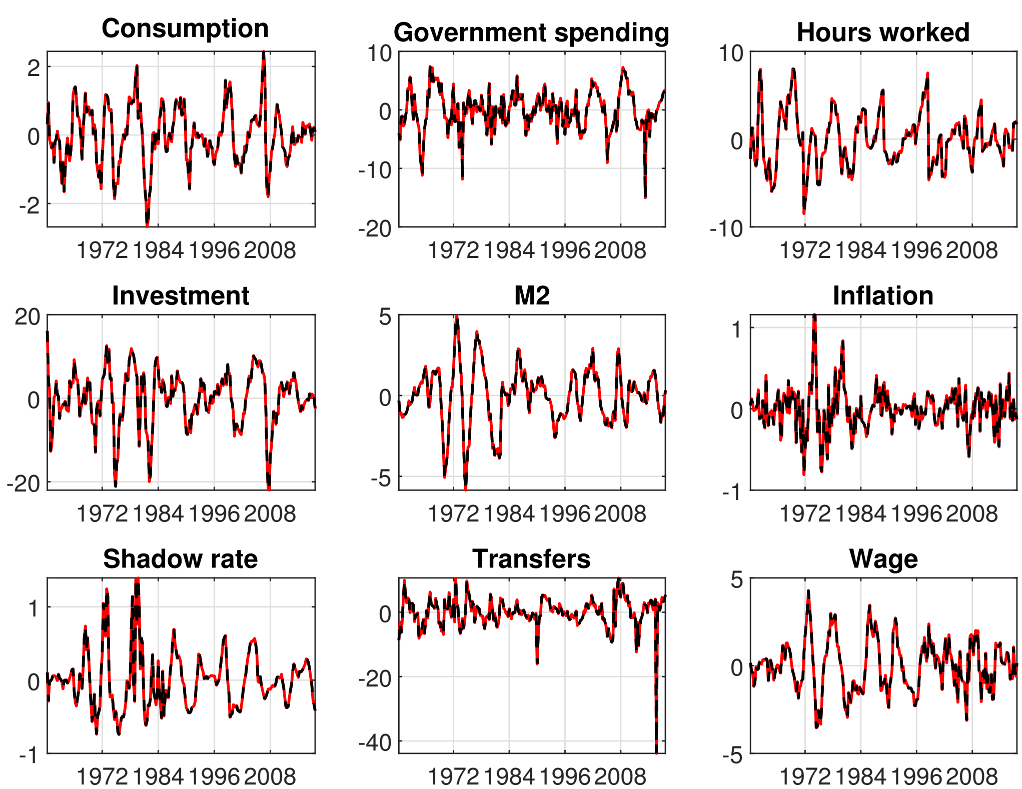


Figure 5: Historical and smoothed variables



Note: The time sample for figure 4 and figure 5 is 1960Q1:2019Q4.

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