ISSN 2704-7407

UNIVERSITÀ CATTOLICA DEL SACRO CUORE
Dipartimento di Economia e Finanza

Working Paper Series

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Working Paper n. 120

November 2022

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del Sacro Cuore

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Money *versus* debt financed regime: Evidence from an estimated DSGE model*

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November 8, 2022

Abstract

We estimate a money-financing versus debt-financing medium-scale dynamic stochastic general equilibrium for the US with Borrower-Saver framework. Our results suggest that the share of net borrowers in a MF regime (17%) is lower than the one in a DF regime (19%). The MF regime enhances the positive effects of fiscal and risk premium shocks with respect to the DF regime. After an inflationary shock the MF regime leads to a mild recession while the DF regime leads to a temporary expansion followed by a sharp recession.

The fiscal shock mainly explains the variance in output and borrower's consumption in a MF regime. The variance of the saver's consumption remains mainly linked to the risk premium shock in both regimes. In a DF regime, the wage mark-up shock plays the major role.

JEL CODES: E32; E42; E52

KEYWORDS: Borrowers-Savers; Bayesian Estimation; Monetary Policy

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*The authors thank Alice Albonico, Lorenza Rossi and Patrizio Tirelli for valuable insights. The views expressed in this paper are those of the authors and do not reflect those of the Bank of England.

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1 Introduction

The severe economic challenges posed by the global financial crisis, and more recently the pandemic, sparked a debate on whether central banks should expand their unconventional monetary policy toolkit to include monetary finance - the financing of government via money creation. Most countries embarked on asset purchases in secondary markets within the framework of quantitative easing (QE) programs. QE increases the monetary base. However, QE does not change the quantum of public debt, but involves de-funding a part of it by financing it through bank overdrafts in place of long-term bonds. So the main difference between QE and monetary finance, in strictly macroeconomic theoretical terms, is that the former does not prevent the increase in public debt while the definition of the latter does.

The literature estimating QE dynamic stochastic general equilibrium (DSGE) models is not extensive but does exist (see Hohberger et al. 2019, 2020). We therefore find it relevant to conduct a conterfactual analysis of US data over the period in which QE policies were conducted (2008:Q1-2019:Q4)[1] assuming that debt did not increase at that time. And we label this regime monetary financing (MF). We therefore compare the results deriving from this analysis with the standard benchmark of the DSGE models which envisages the Taylor rule to describe monetary policy, and the endogenous and unconditional increase in public debt. We label this regime debt financing (DF). Like Hohberger et al. (2020), we find it relevant to conduct our analysis in presence of two groups of households. But unlike them and the now consistent literature of Bayesian estimation of two-agent DSGE models, we consider the Borrower-Saver framework (Bilbiie et al. 2013), and not Rule-of-Thumb (ROT) or Hand-to-Mouth agents. In our model, the two agents differ in their degree of impatience, they are both intertemporal maximizers so that borrowing and lending take place in equilibrium, and financial markets are imperfect. Borrowers face a suitable defined borrowing limit, and it is important to highlight that, differently from the standard ROT framework, the distribution of debt/saving across agents is

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[1] We decided to end our sample in 2019 to exclude the shock related to the Covid-19 as it led to a sharp increase in the volatility of most macroeconomic variables and this would affect our estimation results.

endogenous. We develop and estimate, using Bayesian methods, a dynamic stochastic general equilibrium model of the US economy that explicitly models a medium scale closed economy akin to Smets and Wouters (2003, 2007) by incorporating the Borrower-Saver framework and, to analyze the MF regime, the mechanism presented by Galì (2020b). Our goal is threefold. First, we want to analyze how a MF regime can influence the estimation of the structural parameters and the shock processes with respect to a standard DF regime. In particular, we are interested in the share of borrowing households in light of what Punzo and Rossi (2022) found. Second, we want to understand how the difference in the estimation results between the two regimes can influence the impact of shocks of particular policy interest at the moment such as the fiscal shock, the risk premium shock and the inflationary shock. Finally, we want to understand what are the driving forces of the output and two agents' consumption growth in the two alternative regimes.

Our results in a nutshell. First, the share of borrower in a MF regime is lower than the one in a DF regime. The share of borrowers in a MF and DF regime is, respectively, 17% and 19%.

Second, we show that the MF regime enhances the positive effects of fiscal and risk premium shocks with respect to the DF regime. Instead, after an inflationary shock the MF regime leads to a mild recession while the DF regime leads to a temporary expansion followed by a sharp recession.This result is also motivated by the estimated persistence of the shocks. The risk premium shock in a MF regime is estimated to be strongly persistent. This is not the case with the DF regime. The opposite is true for an inflationary shock, which is estimated to be much more persistent in a DF regime than in a MF regime. .

Finally, we show that the fiscal shock explains 60% of the variance in output in a MF regime while it explains 30% in a DF regime. The fiscal shock explains more than 40% of the borrower's variance in consumption in a MF regime, but only 0.5% in a DF regime. The variance of the saver's consumption, on the other hand, remains mainly linked to the risk premium shocks in both regimes. In a DF regime, the wage mark-up shock plays the major role.

In the next section, we discuss the DSGE model that is subsequently estimated.

In Section 3, the prior and posterior distribution of the structural parameters and the shock processes are discussed. Finally, in Section 4 and 5, we use the estimated model to discuss a number of key issues in business cycle analysis. Section 6 contains the concluding remarks.

2 The Model

We develop a Dynamic Stochastic General Equilibrium (DSGE) model following Smets and Wouters (2007) that has become the workhorse model for the empirical analysis of the U.S. economy. The model includes all the standard features and frictions of New-Keynesian models, while still remaining tractable. We depart from their model only in few aspects. First, we introduce a Borrower-Saver framework, on the footsteps of Bilbiie et al.(2013). Both agents are intertemporal maximizers but a fraction of agents λ face a suitably defined borrowing limit and the distribution of debt/saving across agents is endogenous. Second, we consider a MF regime in which seigniorage is adjusted every period in order to keep real debt b_t unchanged (Galì, 2020b).

The model includes the usual frictions considered in New-Keynesian medium-scale models: external habits in consumption, variable capital utilization, investment adjustment costs, sticky wages and prices, indexation on past and trend inflation.

2.1 Households

Households maximize a separable utility function with three arguments (goods, money holdings and labor effort) over an infinite life horizon. Consumption appears in the utility function relative to a time-varying external habit variable. There is a continuum of households $[0, 1]$ indexed by j . 1-λ households (savers) hold money and asset holdings (bonds and shares). The remaining λ households (borrowers) do not hold money (see Punzo and Rossi(2022)) and face a borrowing constraint at all times. Households derive utility from consumption $c_{j,t}$ and from their holdings of real money balances $m_{j,t}$ but experience disutility from the hours they spend working,

$n_{j,t}$. Households preferences are described by the following equation

$$E_0 \sum_{t=0}^{\infty} \beta_j^t \left[\frac{1}{1-\sigma_c} \left(c_{\iota,t} - \gamma_c c_{\iota,t-1} \right)^{1-\sigma_c} - \frac{l^{1+\varphi}}{1+\varphi} - \frac{\chi_\iota}{(1+\sigma)\, \varepsilon_t^m} \left(\bar{\chi} - \frac{m_{j,t}}{c_{j,t}} \right)^{1+\sigma_m} \right]$$

where $\varphi > 0$ is the inverse of the labour supply elasticity and ε_t^m represents a monetary policy shock. The agents differ only in their discount factors $\beta_j \in (0,1)$. Specifically, we assume that there are two types of agents $j = s, b$, $\beta_s > \beta_b$ and $\chi_s > \chi_b = 0$. Following English et al. (2017), the final term of the equation implies that real balances - expressed as a ratio to j's consumption - are valued at the margin until reaching a stochastic bliss point of $\bar{\chi}$.

2.1.1 Savers

Savers allocate their resources between consumption $c_{s,t}$, money holdings $m_{s,t}$, asset holdings (private assets, $a_{s,t}$, public bonds, $b_{s,t}$), investment $i_{s,t}$ and capital utilization z_t. They receive income from labor services, from holding government bonds, capital services, private assets and money. Their budget constraint in real terms is:

$$\begin{aligned} c_{s,t} + i_{s,t} + \frac{b_{s,t}}{\varepsilon_t^b} + a_{s,t} + m_{s,t} \leq\ & \frac{1+i_{t-1}}{\pi_t} b_{s,t-1} + \frac{1+r_{t-1}}{\pi_t} a_{s,t-1} \\ & + \frac{1+r_{t-1}^k}{\pi_t} z_t k_{t-1} - a z_t k_{t-1} \\ & + \frac{m_{s,t}}{\pi_t} + w_t l_{s,t} - \tau_{s,t} \end{aligned}$$

Here w_t is the real wage and r_{t-1} is the nominal interest rate received on each type of asset, π_t is the net inflation rate and $\tau_{s,t}$ represents the lump-sum taxation. Savers rent capital services to firms and decide how much capital to accumulate given the capital adjustment costs they face. As the rental price of capital changes, the utilization of the capital stock can be adjusted at increasing cost.

Savers maximize utility function with respect to $c_{s,t}$, $b_{s,t}$, $m_{s,t}, i_t, l_{s,t}, z_t$ subject to the budget constraint and the capital accumulation equation. The log-linearized accumulation of installed capital is a function not only of the flow of investment but also of the relative efficiency of these investment expenditures as captured by the investment-specific technology disturbance

$$k_t = \frac{1-\delta}{\gamma} k_{t-1} + \left(1 - \frac{1-\delta}{\gamma}\right) i_t + \left(1 - \frac{1-\delta}{\gamma}\right) \left(1 + \beta_s \gamma^{1-\sigma_c}\right) \gamma^2 \varphi \varepsilon_t^i, \tag{1}$$

where δ stands for the depreciation rate of capital, γ is the steady-state growth rate and φ is the steady-state elasticity of the capital adjustment cost function. Finally, ε_t^i represents a disturbance to the investment-specific technology process and is assumed to follow a first-order autoregressive process with an IID-Normal error:

$$\ln \varepsilon_t^i = \rho_i \ln \varepsilon_{t-1}^i + \eta_t^i, \eta_t^i \sim N(0, \sigma_i).$$

The log-linearized dynamics of saver's consumption follows from the consumption Euler equation is given by

$$c_{s,t} = \frac{\gamma_c}{\gamma_c + \gamma} c_{s,t-1} + \left(\frac{\gamma}{\gamma_c + \gamma}\right) E_t c_{s,t+1} - \frac{\gamma - \gamma_c}{\sigma_c (\gamma + \gamma_c)} \left(r_t - E_t \pi_{t+1} + \varepsilon_t^b\right) \tag{2}$$

Following English et al.(2017), log-linearized savers' money demand can be expressed as:

$$-\left(\bar{\chi} - \frac{\bar{m}_s}{c}\right) \left(\frac{\sigma_m \bar{m}_s}{c}\right) (c_{s,t} - m_{s,t}) = \frac{r_t}{r} - \varepsilon_t^m \tag{3}$$

The log-linearized dynamics of investment comes from the investment Euler equation and is given by

$$i_t = \frac{1}{1 + \beta_s \gamma^{1-\sigma_c}} i_{t-1} + \frac{\beta_s \gamma^{1-\sigma_c}}{1 + \beta_s \gamma^{1-\sigma_c}} E_t i_{t+1} + \frac{1}{\left(1 + \beta_s \gamma^{1-\sigma_c}\right) \gamma^2 \varphi} q_t + \varepsilon_t^i \tag{4}$$

A higher elasticity of the cost of adjusting capital reduces the sensitivity of investment, i_t, to the real value of the existing capital stock, q_t. Modeling capital adjustment costs as a function of the change in investment rather than its level introduces additional dynamics in the investment equation, which is useful in capturing the hump-shaped response of investment to various shocks.

The corresponding log-linearized arbitrage equation for the value of capital is given by

$$q_t = \beta_s \gamma^{-\sigma^c} (1-\delta) E_t q_{t+1} + \left(1 - \beta_s \gamma^{-\sigma^c} (1-\delta)\right) E_t r^k_{t+1} - \left(r_t - E_t \pi_{t+1} + \varepsilon^b_t\right). \quad (5)$$

The current value of the capital stock, q_t, depends positively on its expected future value and the expected real rental rate on capital, $E_t r^k_{t+1}$, and negatively on the ex ante real interest rate and the risk premium disturbance.

2.1.2 Borrowers

At all times, borrowers (or impatient households) will borrow, $a_{b,t}$, and consume, $c_{b,t}$. They receive income from labor out of lump-sum taxes and interest paid on discounted borrowing. Their budget constraint is:

$$c_{b,t} + a_{b,t} + m_{b,t} \leq \frac{1 + r_{t-1}}{\pi_t} a_{b,t-1} + \frac{m_{b,t}}{\pi_t} + w_t l_{b,t} - \tau_{b,t} \quad (6)$$

At all times, borrowers maximize utility function with respect to $c_{b,t}$, $a_{b,t}, m_{b,t}$ and $l_{b,t}$ subject to Equation (6) as well as the additional borrowing constraint (on borrowing in real terms):

$$-a_{b,t} \leq \bar{d}.$$

The log-linearized dynamics of borrower's consumption is given by

$$c_{b,t} = \frac{\gamma_c}{\gamma_c + \gamma} c_{b,t-1} + \left(\frac{\gamma}{\gamma_c + \gamma}\right) E_t c_{b,t+1} - \frac{\gamma - \gamma_c}{\sigma_c (\gamma + \gamma_c)} \left(r_t - E_t \pi_{t+1} + \varepsilon^b_t\right) - \phi_t \quad (7)$$

where ϕ_t takes a positive value whenever the constraint is binding.

Both borrower, $c_{b,t}$, and saver, $c_{s,t}$, consumption depend on a weighted average of their relative past and expected future consumption, the ex ante real interest rate, $(r_t - E_t\pi_{t+1})$, and a disturbance term ε_t^b. Under the assumption of no external habit formation ($\gamma_c = 0$), $\frac{\gamma_c}{\gamma_c+\gamma} = 0$ and the traditional purely forward-looking consumption equation is obtained. With steady-state growth, the growth rate γ marginally affects the reduced-form parameters in the linearized consumption equation. Finally, the disturbance term ε_t^b represents a wedge between the interest rate controlled by the central bank and the return on assets held by the household. A positive shock to this wedge increases the required return on assets and reduces current consumption. At the same time, it also increases the cost of capital and reduces the value of capital and investment[2]. This shock has similar effects as so-called net-worth shock in Bernanke et al. (1999) and Christiano et al. (2003), which explicitly model the external finance premium. The disturbance is assumed to follow a first-order autoregressive process with an IID-Normal error term:

$$\ln \varepsilon_t^b = \rho_b \ln \varepsilon_{t-1}^b + \eta_t^b, \eta_t^b \sim N\left(0, \sigma_b\right).$$

2.2 Intermediate labour union sector

Labor is differentiated by a union, so there is some monopoly power over wages, which results in an explicit wage equation and allows for the introduction of sticky nominal wages à la Calvo (1983). The log-linearized wage mark-up will be equal to the difference between the real wage and the marginal rate of substitution between working and consuming, mrs_t,

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[2] This latter effect makes this shock different from a discount factor shock, which affects only the intertemporal consumption Euler Equation. In contrast to a discount factor shock, the risk premium shock helps to explain the comovement of consumption and investment.

$$\begin{aligned} \mu_t^w &= w_t - mrs_t \\ &= w_t - \left(\sigma_l l_t + \frac{1}{1-\gamma_c/\gamma}\left(c_t - \frac{\gamma_c}{\gamma c_{t-1}}\right)\right) \end{aligned} \tag{8}$$

where σ_l is the elasticity of labor supply with respect to the real wage and γ_c is the habit parameter in consumption.

Due to nominal wage stickiness and partial indexation of wages to inflation, log-linearized real wages adjust only gradually to the desired wage mark-up.

$$\begin{aligned} w_t \;=\; & \frac{1}{1-\beta_s\gamma^{1-\sigma_c}} w_{t-1} - \frac{\beta_s\gamma^{1-\sigma_c}}{1-\beta_s\gamma^{1-\sigma_c}}\left[E_t w_{t+1} + E_t\pi_{t+1}\right] \\ & - \frac{1+\beta_s\gamma^{1-\sigma_c}\iota_w}{1+\beta_s\gamma^{1-\sigma_c}}\pi_t + \frac{\iota_w}{1+\beta_s\gamma^{1-\sigma_c}}\pi_{t-1} - \frac{1}{1+\beta_s\gamma^{1-\sigma_c}}\left[\frac{\left(1-\beta_s\gamma^{1-\sigma_c}\xi_w\right)\left(1-\xi_w\right)}{\xi_w\left[\left(\phi_w-1\right)\varepsilon_w+1\right]}\right]\mu_w + \varepsilon_t^w \end{aligned} \tag{9}$$

The real wage, w_t, is a function of expected and past real wages, expected, current and past inflation, the wage mark-up, and a wage-markup disturbance, ε_t^w. If wages are perfectly flexible, $\xi_w = 0$, the real wage is a constant mark-up over the marginal rate of substitution between consumption and leisure. In general, the speed of adjustment to the desired wage mark-up depends on the degree of wage stickiness, ξ_w, and the demand elasticity for labor, which itself is a function of the steady-state labor market mark-up $(\phi_w - 1)$ and the curvature of the Kimball labor market aggregator, ε_w. When wage indexation is zero $(\iota_w = 0)$, real wages do not depend on lagged inflation. The wage-markup disturbance, ε_t^w, is assumed to follow an ARMA (1,1) process with an IID-Normal error term: $\varepsilon_t^w = \rho_w\varepsilon_{t-1}^w + \eta_t^w - \mu_w\eta_{t-1}^w$. As in the case of the price mark-up shock, the inclusion of an MA term allows us to pick up some of the high-frequency fluctuations in wages[3].

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[3] Alternatively, we could interpret this disturbance as a labor supply disturbance coming from changes in preferences for leisure.

2.3 Production

2.3.1 Intermediate goods producers

The log-linearized aggregate production function is given by

$$y_t = \phi_p \left[\alpha k_t^s + (1-\alpha) l_t + \varepsilon_t^a \right]. \tag{10}$$

Output, y_t, is produced using capital, k_t^s, and labor services, l_t. Total factor productivity, ε_t^a, is assumed to follow a first-order autoregressive process:

$$\varepsilon_t^a = \rho_a \varepsilon_{t-1}^a + \eta_t^a, \eta_t^a \sim N(0, \sigma_a)$$

The parameter α captures the share of capital in production, and the parameter ϕ_p is one plus the share of fixed costs in production, reflecting the presence of fixed costs in production.

As newly installed capital becomes effective only with a one-quarter lag, log-linearized current capital services used in production, k_t^s, are a function of capital installed in the previous period, k_{t-1}, and the degree of capital utilization, z_t :

$$k_t^s = k_{t-1} + z_t. \tag{11}$$

Cost minimization by savers that provide capital services implies that the log-linearized degree of capital utilization is a positive function of the rental rate of capital,

$$z_t = \frac{1-\psi}{\psi} r_t^k \tag{12}$$

and ψ is a positive function of the elasticity of the capital utilization adjustment cost and normalized to be between zero and one. When $\psi = 1$, it is extremely costly to change the utilization of capital and, as a result, the utilization of capital remains constant. In contrast, when $\psi = 0$, the marginal cost of changing the utilization of capital is constant and, as a result, in equilibrium the rental rate on capital is constant.

Turning to the monopolistic competitive goods market, cost minimization by firms implies that the log-linearized price mark-up, μ_t^p, defined as the difference between the average price and the nominal marginal cost or the negative of the real marginal cost, is equal to the difference between the marginal product of labor, mpl_t, and the real wage, w_t :

$$\begin{aligned} \mu_t^p &= mpl_t - w_t \\ &= \alpha\left(k_t^s - l_t\right) + \varepsilon_t^a - w_t \end{aligned} \tag{13}$$

The marginal product of labor is itself a positive function of the capital-labor ratio and total factor productivity.

Due to the price stickiness, as in Calvo (1983), and partial indexation to lagged inflation of those prices that can not be reoptimized, as in Smets and Wouters (2003), prices adjust only sluggishly to their desired mark-up. Profit maximization by price-setting firms gives rise to the following log-linearized New-Keynesian Phillips curve:

$$\begin{aligned} \pi_t &= \frac{\iota_p}{1+\beta_s\gamma^{1-\sigma_c}\iota_p}\pi_{t-1} + \frac{\beta_s\gamma^{1-\sigma_c}}{1+\beta_s\gamma^{1-\sigma_c}\iota_p}E_t\pi_{t+1} \\ &\quad - \frac{1}{1+\beta_s\gamma^{1-\sigma_c}\iota_p}\left[\frac{\left(1-\beta_s\gamma^{1-\sigma_c}\xi_p\right)\left(1-\xi_p\right)}{\xi_p\left(\left(\phi_p-1\right)\varepsilon_p+1\right)}\right]\mu_t^p + \varepsilon_t^p \end{aligned} \tag{14}$$

Inflation, π_t, depends positively on past and expected future inflation, negatively on the current price mark-up, and positively on a mark-up disturbance, ε_t^p. The price mark-up disturbance is assumed to follow an ARMA (1,1) process:

$$\varepsilon_t^p = \rho_p\varepsilon_{t-1}^p + \eta_t^p - \mu_p\eta_{t-1}^p$$

where η_t^p is an IID-Normal price mark-up shock. The inclusion of the MA term is designed to capture the high-frequency fluctuations in inflation.

When the degree of indexation to past inflation is zero $\left(\iota_p = 0\right)$, equation (14) reverts to a standard, purely forward-looking Phillips curve. The assumption that all prices are indexed to either lagged inflation or the steady-state inflation rate ensures that the Phillips curve is vertical in the long run. The speed of adjustment to the desired mark-up depends, among others, on the degree of price stickiness, ξ_p, the curvature of the Kimball goods market aggregator, ε_t^p, and the steady-state mark-up, which in equilibrium is itself related to the share of fixed costs in production $\left(\phi_p - 1\right)$ through a zero-profit condition. A higher ε_p slows down the speed of adjustment because it increases the strategic complementarity with other price setters. When all prices are flexible, $\xi_p = 0$, and the price mark-up shock is zero, equation (14) reduces to the familiar condition that the price mark-up is constant, or equivalently that there are no fluctuations in the wedge between the marginal product of labor and the real wage.

Cost minimization by firms will also imply that the log-linearized rental rate of capital is negatively related to the capital-labor ratio and positively to the real wage (both with unitary elasticity):

$$r_t^k = -\left(k_t - l_t\right) + w_t \tag{15}$$

2.4 Policy-makers

The government - henceforth understood as combining the fiscal and monetary authority, acting in a coordinated way - is assumed to finance its expenditures through three sources: (i) lump-sum taxes, (ii) the issuance of riskless one-period bonds with a nominal yield i_t, which are held only by savers and (iii) the issuance of (non-interest bearing) money[4]. Hence, the government budget constraint in real terms is:

$$\varepsilon_t^g + \frac{1 + r_{t-1}}{\pi_t} b_{t-1} = b_t + \tau_t + \left(m_t - \frac{m_{t-1}}{\pi_t}\right) \tag{16}$$

We also introduce a fiscal rule according to which tax variation is endogenous and varies in response to deviations of the debt ratio from its long run target

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[4] $\left(M_{t+1} - \frac{M_t}{\pi_t}\right)$ represents period t's seigniorage, the purchasing power of newly issued money.

$$\hat{\tau}_t = \phi_B \hat{b}_t, \tag{17}$$

where τ_t is aggregate tax, $\tau_t = \lambda \tau_{b,t} + (1-\lambda)\tau_{s,t}$, $\hat{\tau}_t = \frac{\tau_t - \tau}{y}$ and $\hat{b}_t^h = \frac{b_t^h - b^h}{y}$

We assume that exogenous spending follows a first-order autoregressive process with an IID-Normal error term and is also affected by the productivity shock as follows:

$$\ln \varepsilon_t^g = \rho_g \ln \varepsilon_{t-1}^g + \eta_t^g + \rho_{ga}\eta_t^a, \eta_t^g \sim N(0, \sigma_g).$$

The latter is empirically motivated by the fact that, in estimation, exogenous spending also includes net exports, which may be affected by domestic productivity developments.

2.4.1 MF *versus* DF regime

The effects of each type of shock are analyzed under two alternative regimes, that jointly describe how monetary policy is conducted.

MF regime. *Money financing* is the main focus of the present paper. Following Galì (2020), we define that regime as one in which seigniorage is adjusted every period in order to keep real debt b_t unchanged. In terms of the notation above, this requires:

$$\hat{b}_t = 0 \tag{18}$$

where $\hat{b}_t = \frac{b_t - b}{y}$. Monetary policy has to give up control of the nominal interest rate, instead adjusting the money supply in order to meet the government's financing needs. Note that the previous assumption, combined with (17), implies that under the money financing regime, taxes do not vary, neither in the short run nor in the long run, relative to their initial level.

DF regime. Under the alternative financing scheme considered, which we refer to as *debt financing,* the fiscal authority issues debt in order to finance the fiscal stimulus, eventually adjusting the path of taxes in order to attain the long run debt target, as implied by (17). The monetary authority, on the other hand, is assumed to pursue an independent price stability mandate.

$$\begin{aligned} r_t &= \phi_R r_{t-1} + (1-\phi_R)\left[\phi_\pi \pi_t + \phi_y \left(y_t - y_t^p\right)\right] \\ &\quad +\phi_{gy}\left[\left(y_t - y_t^p\right) - \left(y_{t-1} - y_{t-1}^p\right)\right] + \varepsilon_t^r \end{aligned} \tag{19}$$

The monetary authorities follow a generalized Taylor rule by gradually adjusting the policy-controlled interest rate, r_t, in response to inflation and the output gap, defined as the difference between actual and potential output (Taylor, 1993). Consistently with the DSGE model, potential output is defined as the level of output that would prevail under flexible prices and wages in the absence of the two "mark-up" shocks. The parameter ϕ_R captures the degree of interest rate smoothing. In addition, there is a short run feedback from the change in the output gap. Finally, we assume that the monetary policy shocks, in case of debt financing, do not appear in Equation (3) as in money financing case, but they appear in Equation (19), and in any case, they follow a first-order autoregressive process with an IID-Normal error term:

$$\varepsilon_t^m = \rho_m \varepsilon_{t-1}^m + \eta_t^m.$$

2.5 Equilibrium

The aggregate resource constraint is given by

$$y_t = \frac{c}{y}c_t + \frac{i}{y}i_t + \frac{z}{y}z_t + \varepsilon_t^g.$$

Output, y_t, is absorbed by consumption, c_t, investment, i_t, capital utilization costs that are a function of the capital utilization rate, z_t, and exogenous spending, ε_t^g. c_t is aggregate consumption, $cc_t = \lambda c_b c_{b,t} + (1-\lambda) c_s c_{s,t}$.

3 Estimation

3.1 Methods and Data

The model presented in the previous section is log-linearized around its steady state and then estimated with Bayesian methods. As it is common, the likelihood function is evaluated through the Kalman filter and then it is combined with the prior distributions to obtain the posterior distributions. The posterior distributions are evaluated with Markov-Chain Monte Carlo methods. In particular, we rely on a Metropolis-Hasting algorithm with 300.000 replications for 2 chains with 25% of the draws discarded as burn-in (see An and Schorfheide, 2007, for further details on the estimation techniques).

The model is estimated on US data. Our observables are the seven macroeconomic variables at quarterly frequency used by Smets and Wouters (2007): the growth rate of real GDP, consumption, investment, wages, the log of hours worked, the inflation rate as measured by the GDP deflator and the federal funds rate.

Following Smets and Wouters (2007), output, consumption, investment, wages and hours are expressed in per-capita terms[5]. Accordingly, the measurement equations are as follows:

$$Y_t = \begin{bmatrix} \Delta\left(100 \cdot \ln GDP_t\right) \\ \Delta\left(100 \cdot \ln CONS_t\right) \\ \Delta\left(100 \cdot \ln INV_t\right) \\ \Delta\left(100 \cdot \ln WAG_t\right) \\ \ln HOURS_t \\ \Delta\left(100 \cdot \ln P_t\right) \\ FEDFUNDS_t \end{bmatrix} = \begin{bmatrix} \bar{\gamma} \\ \bar{\gamma} \\ \bar{\gamma} \\ \bar{\gamma} \\ \bar{h} \\ \bar{\pi} \\ \bar{r} \end{bmatrix} \begin{bmatrix} y_t - y_{t-1} \\ c_t - c_{t-1} \\ i_t - i_{t-1} \\ w_t - w_{t-1} \\ h_t \\ \pi_t \\ r_t \end{bmatrix}$$

Here $\Delta \ln$ denotes the first difference of the variables in brackets. The element $\bar{\gamma} = 100\left(\gamma - 1\right)$ is a deterministic growth trend common to some of the real variables, $\bar{h}$ is the log steady-state of hours worked, $\bar{\pi}$ is the quarterly steady-state net inflation

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[5] Further details about data transformations and sources can be found in Appendix A

rate and $\bar{r}$ is the quarterly steady-state nominal interest rate.

To avoid stochastic singularity, we consider the same number of observables and shocks. Hence, we include seven structural shocks: a technology shock, a risk premium shock, an investment shock, a wage mark-up shock, an inflationary shock, a fiscal shock and an monetary shock.

The model is estimated over the sample 2008Q1-2019Q4. We decided to focus on this sample to better characterize the effects of a MF fiscal stimulus. As a matter of fact, Punzo and Rossi (2021), in a two agent economy, show that a MF fiscal stimulus is strongly effective in a ZLB scenario. The theoretical regimes analyzed, i.e. an injection of liquidity, aimed at avoiding an increase in public debt and an increase in public debt under interest rate control to target inflation are both present in the period under consideration. Therefore our analysis aims at theoretically isolate the two regimes and evaluate their contribution Furthermore, we decided to end our sample in 2019 to exclude the shock related to the Covid-19 as it led to a sharp increase in the volatility of most macroeconomic variables and this would affect our estimation results.

3.2 Calibrated Parameters

The money demand long-run elasticity with respect to consumption χ and the short run interest rate semi-elasticity of money demand σ_m are borrowed from English et al.(2017). The curvature of the Kimball aggregators in the goods and labor market, ε_w and ε_p; and the depreciation rate, δ are borrowed from Smets and Wouters (2007). The public debt feedback coefficient, ϕ_B, is borrowed from Galì (2020)

We fix these parameters because they are either notoriously difficult to estimate (the curvature of the Kimball aggregators and the depreciation rate) or because they are better identified using other information (the utility function and fiscal parameters).

Table (1) summarizes our calibration. Table (2) displays the steady-state ratios of the model. We set the steady-state labor market mark-up as in Smets and Wouters (2007). The parameters of the measurement equations, i.e. the quarterly growth

Parameter	Value
σ_m	0.6
$\bar{\chi}$	1
ε_w	10
ε_p	10
δ	0.025
ϕ_B	0.02

Table 1: Calibrated Parameters

Parameter	Interpretation	Value
ϕ_w	Labor market mark-up	1.5
γ	Quarterly growth trend	0.2%
$\bar{\pi}$	Inflation rate	0.4%
$\bar{h}$	Hours worked	0
M^s/GDP	Money share	18%
C/GDP	Consumption share	65%
B^H/GDP	Household debt share	60%
N/GDP	Labor supply share	100%
G/GDP	Government expenditure share	20%
T/GDP	Taxes share	20%

Table 2: Steady-State Ratios

trend, the steady-state inflation rate and the steady state of hours worked, are set according to the average of the variables observed in our estimation sample. The remaining shares are set according to the values prevailing before the financial crisis.

3.3 Prior Distributions

Our priors are in Tables (3) and (4). Overall, they are consistent with previous studies. We use inverse gamma priors for the standard errors of the shocks. For the persistence, we choose a beta-distribution with a prior mean of 0.5 and standard deviation of 0.2. We set the prior of the habit parameter in consumption, γ_c, at 0.7. For the monetary policy rule, we base our priors on a Taylor rule responding gradually to inflation, so that the prior means of ϕ_R, ϕ_π, ϕ_y and ϕ_{gy} are, respectively,

	Priors			MFFS			DFFS		
	shape	mean	st. dev.	post. mean	90% HPD Interval		post. mean	90% HPD interval	
ϕ_π	norm	1.5	0.25	-	-	-	1.12	1.00	1.25
ϕ_y	norm	0.125	0.05	-	-	-	0.15	0.11	0.19
ϕ_{gy}	norm	0.125	0.05	-	-	-	0.00	0.00	0.01
ϕ_R	beta	0.75	0.1	-	-	-	0.97	0.97	0.97
σ_l	norm	2.0	0.75	2.56	1.53	3.61	1.13	0.29	1.89
γ_c	beta	0.7	0.1	0.57	0.47	0.68	0.71	0.60	0.81
φ	norm	4.0	1.5	9.13	6.61	11.47	5.51	3.77	7.90
ξ_p	beta	0.5	0.1	0.53	0.50	0.56	0.72	0.67	0.79
ξ_w	beta	0.5	0.1	0.48	0.38	0.58	0.71	0.62	0.82
ι_p	beta	0.5	0.15	0.55	0.33	0.79	0.33	0.14	0.51
ι_w	beta	0.5	0.15	0.53	0.29	0.78	0.61	0.32	0.86
ϕ_p	norm	1.25	0.125	1.48	1.31	1.64	1.68	1.56	1.79
ψ	beta	0.5	0.15	0.07	0.02	0.12	0.85	0.77	0.94
σ_c	norm	1.5	0.375	1.89	1.75	2.00	0.93	0.64	1.15
λ	beta	0.35	0.05	0.17	0.12	0.21	0.19	0.15	0.24

Table 3: Prior and Posterior Distribution of Structural Parameters

$0.75, 1.5, 0.125$, and 0.125. We set a prior on the capital adjustment costs, φ, of around 4. We choose a loose beta prior for the utilization parameter (ψ) between zero (capacity utilization can be varied at no cost) and one (capacity utilization never changes). The elasticity of labor supply, σ_l, is assumed to be around 2. We select the prior mean of the Calvo price, ξ_p, and wage, ξ_w parameter at 0.5, suggesting an average length of price and wage contracts of half a year. The priors for the indexation parameters, ι_p and ι_w, are loosely centered around 0.5, as in Smets and Wouters (2007). The intertemporal elasticity of substitution, σ_c, is set at 1.5 and the share of fixed costs in the production function, ϕ_p, is assumed to have a prior mean of 1.25.

We set the prior mean for the share of borrowing households to be 0.35, with a standard error of 0.05 as in Iacoviello and Neri (2010).

	Priors			MFFS			DFFS		
	shape	mean	st. dev.	post. mean	90% HPD Interval		post. mean	90% HPD interval	
Shocks persistence									
ρ_b	beta	0.5	0.2	0.94	0.89	0.99	0.14	0.05	0.23
ρ_i	beta	0.5	0.2	0.86	0.77	0.96	0.53	0.37	0.70
ρ_p	beta	0.5	0.2	0.57	0.26	0.88	0.89	0.84	0.95
ρ_w	beta	0.5	0.2	0.97	0.94	0.99	0.99	0.99	1.00
ρ_g	beta	0.5	0.2	0.89	0.84	0.93	0.91	0.86	0.96
ρ_a	beta	0.5	0.2	0.65	0.54	0.75	0.79	0.72	0.86
Shocks other parameters									
ρ_{ma}^p	beta	0.5	0.2	0.42	0.17	0.67	0.47	0.21	0.70
ρ_{ma}^w	beta	0.5	0.2	0.87	0.77	0.98	0.99	0.99	1.00
Shocks standard deviations									
σ_b	invg	0.1	2	0.05	0.03	0.07	0.28	0.22	0.34
σ_i	invg	0.1	2	0.28	0.16	0.40	0.39	0.28	0.54
σ_m	invg	0.1	2	0.22	0.18	0.27	0.02	0.01	0.02
σ_p	invg	0.1	2	0.19	0.15	0.23	0.08	0.05	0.11
σ_w	invg	0.1	2	0.69	0.55	0.83	0.56	0.44	0.66
σ_g	invg	0.1	2	0.70	0.56	0.84	0.44	0.37	0.52
σ_a	invg	0.1	2	0.50	0.41	0.59	0.36	0.30	0.41

Table 4: Prior and Posterior Distribution of Shock Processes

3.4 Posterior Distributions

Tables (3) and (4) report the mean, and the 5th and 95th percentiles of the posterior distribution of the structural parameters, together with the mean and standard deviation of the priors distributions

Our key parameter relates to the share of borrowing households. Our estimate of λ in a MF and DF regime is, respectively, 0.17 and 0.19. This result demonstrates that our data are very informative with respect to this parameter. Both values are lower than our prior mean. However, the share of borrower in a MF regime is lower than in a DF regime. Figure 1 and 2 plot the complete posterior distributions, respectively, in a MF and DF regime.

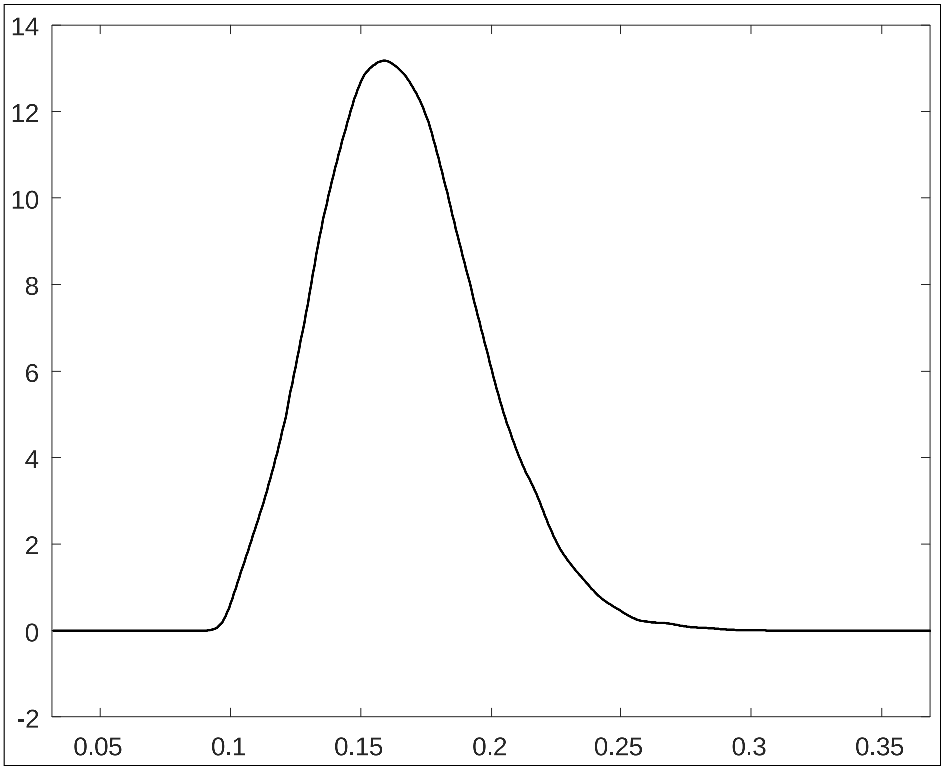

Figure 1: Posterior distributions of λ in MF regime

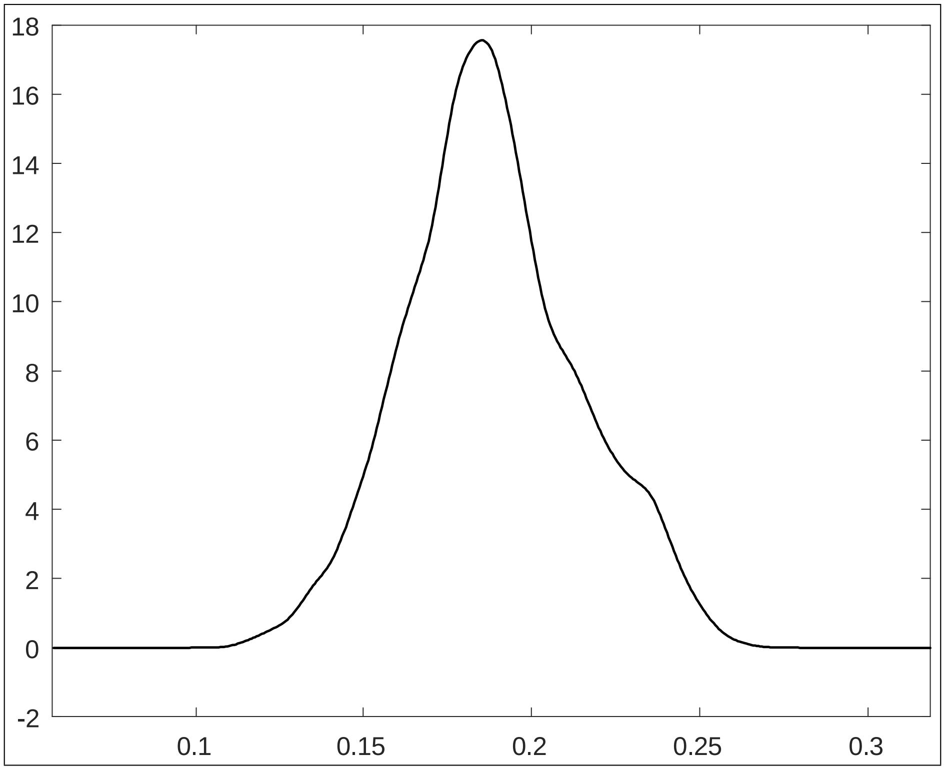

Figure 2: Posterior distributions of λ in DF regime

Both regimes exhibit a moderate degree of habit formation in consumption, as shown by the value of γ_c. The intertemporal elasticity of substitution is estimated to be lower than assumed by the prior but smaller than one ($\sigma_c > 1$) which means that consumption and hours worked are complements in utility and consumption depends positively on current hours worked and negatively on expected growth in hours worked (see Basu and Kimball, 2002) in a MF regime ($\sigma_c^{MF} = 1.89$). The opposite is true in a DF regime ($\sigma_c^{DF} = 0.93$) as the intertemporal elasticity of substitution is estimated to be higher than one ($\sigma_c < 1$). One explanation may be that since in a MF regime savers - who are the firms owners - do not hold public debt, they can smooth consumption less than in a DF regime. In a MF regime, the elasticity of labor supply with respect to the real wage is estimated to be higher ($\sigma_l^{MF} = 2.56$) than assumed by the prior (2) suggesting a slower response of labor supply to changes in the real wage. Conversely, in a DF regime, it is estimated to be lower ($\sigma_l^{DF} = 1.13$) than assumed by the prior, suggesting a faster response of labor supply to changes in real wages.

The estimate of ξ_p ($\xi_p^{MF} = 0.53$ and $\xi_p^{DF} = 0.72$) implies that prices are reoptimized once every two quarters in a MF regime and once every three quarters in a DF regime and, given the positive indexation coefficient ($\iota_p^{MF} = 0.55$ and $\iota_p^{DF} = 0.33$) confirms that prices change faster in a MF regime than in a DF regime. As for wages, we find that stickiness in a DF regime ($\xi_w^{DF} = 0.71$) is higher than in a MF regime ($\xi_w^{MF} = 0.48$), although wage indexation is larger in a DF regime than in a MF regime ($\iota_w^{MF} = 0.53$ and $\iota_w^{DF} = 0.61$). In a MF regime, the adjustment cost of changing investment ($\varphi^{MF} = 9.13$) is estimated to be much higher than assumed by the prior (4) suggesting an even slower response of investment to changes in the value of capital. The same observation cannot be made for a DF regime ($\varphi^{DF} = 5.51$), where it is closer to what is assumed by the prior. The cost elasticity to change the utilization of capital is estimated to be far less ($\psi^{MF} = 0.07$) than assumed by the prior, 0.5, suggesting a minimal cost to change the utilization of capital in a MF regime. Conversely, in a DF regime, it turns out to be greater ($\psi^{DF} = 0.85$) than assumed by the prior, suggesting a high cost to change the use of capital.

The wage mark-up shock is estimated to be the most persistent in both regimes, with autocorrelation coefficients ranging between 0.94 and 1. Equally, albeit less, the fiscal shock is estimated to be highly persistent, with autocorrelation coefficient ranging between 0.89 and 0.96. The technology shock does not show strong persistence in either regimes (0.65 in MF regime and 0.79 in DF one).

As regards the risk premium, investment and inflationary shock, the differences in terms of persistence between the two regimes are significant. The risk premium shock in a MF regime is estimated to be strongly persistent, with an autocorrelation coefficient of 0.94. This is not the case with the DF regime in which that shock is estimated to be weakly persistent, with an autocorrelation coefficient of 0.14. The investment shock displays a similar pattern with an autocorrelation coefficient of 0.86 in the MF regime and 0.53 in the DF regime. The opposite is true for the inflationary shock: it is much more persistent in the DF regime than in the MF regime and its autocorrelation coefficients are 0.89 and 0.57, respectively.

4 Impulse Responses

In this section we describe the effects of exogenous shocks on the economy under the two financing regimes. We focus only on the fiscal, risk-premium and inflationary shock for several different reasons. The analysis of alternative monetary regimes that can finance a fiscal shock is at the origin of our analysis (see Gali, 2020, and Punzo and Rossi, 2022). We consider it relevant to focus on the risk premium shock because it represents another crucial driving force in our model, as we will see in the analysis of the historical decomposition. We can think of the choices of the fiscal authority and the strength of the financial markets as two complementary forces of this model, both coming from the demand side. The demand side is the object of this paper which is why we decided not to dwell too much on the wage mark-up shock. However, we have decided to focus on the price mark-up shock due to the strong relevance it has in terms of policy at the moment.

Fiscal shock - Figure 3 plots impulse responses to the estimated fiscal shock. Consistently with Punzo and Rossi (2021), Figure 3 shows that the positive reaction of output is higher in a money-financed regime than in a debt-financed one. The unexpected increase in income - due to the fiscal stimulus - is higher in a money-financed fiscal stimulus than in a debt-financed fiscal stimulus, because of the injection of liquidity in a sticky prices environment that a money-financed fiscal stimulus entails. Under the money financing scheme, the larger expansion in output and consumption leads to an increase of inflation which reinforces the expansion in aggregate demand by lowering the real rate. In the DF regime, the fiscal shock is financed by the issuance of new public debt. A positive fiscal shock exerts upward pressure on output and inflation. However, since there is a Taylor rule, the nominal rate increases. Since both are maximizing agents, the Ricardian equivalence holds for the saver and also explains why the increase in borrower consumption is contained.

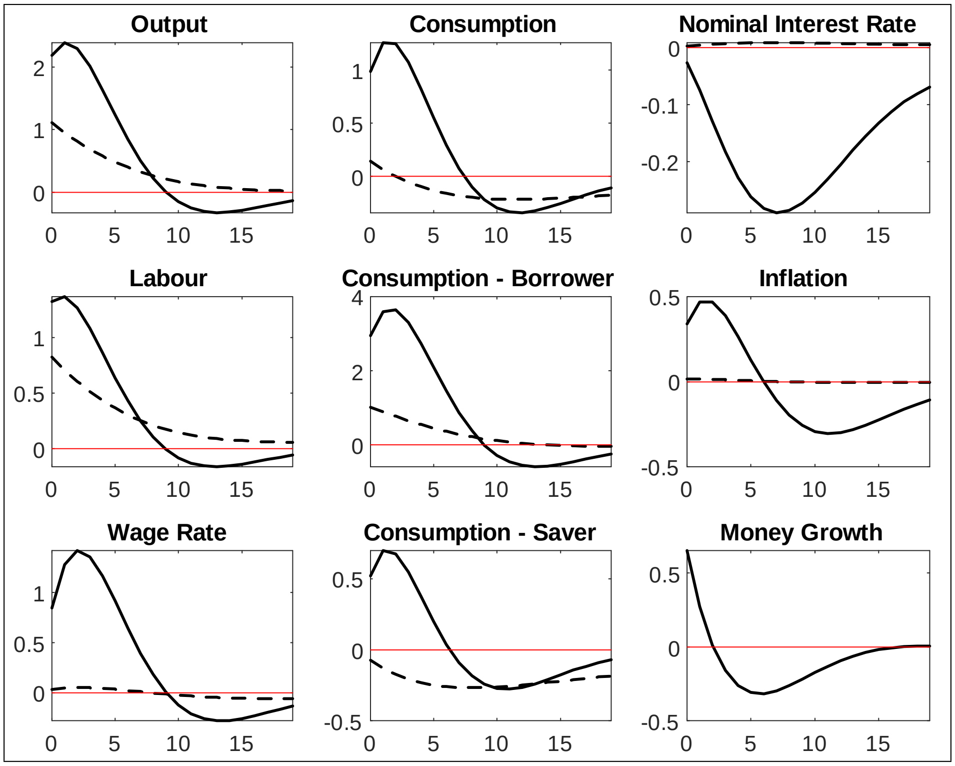

Figure 3: The estimated mean impulse responses to a fiscal shock: money financing (solid line) *versus* debt-financing (dashed line)

Risk premium shock.- Figure 4 shows that the positive reaction of output to a risk premium shock is higher in a money-financed regime than in a debt-financed one. Indeed, by definition, a positive risk premium shock has a negative impact on the money market. When risk is rewarded more in financial markets, the demand for liquid assets, which are mainly represented by money, falls. In a MF regime, in which the nominal rate is determined as any price by the match between supply and demand, a reduction in the demand for money leads to a reduction in the nominal rate. This will consequently have a negative impact on real rates which explains the significant increase in consumption, especially for the borrower. This is different from the standard effects of risk premium shock in a debt-financed regime (see Smets and Wouters, 2007) where movements in real GDP are primarily driven by the shock that affects the intertemporal Euler equation, i.e. the risk premium shock which affects both the consumption and investment Euler equation.

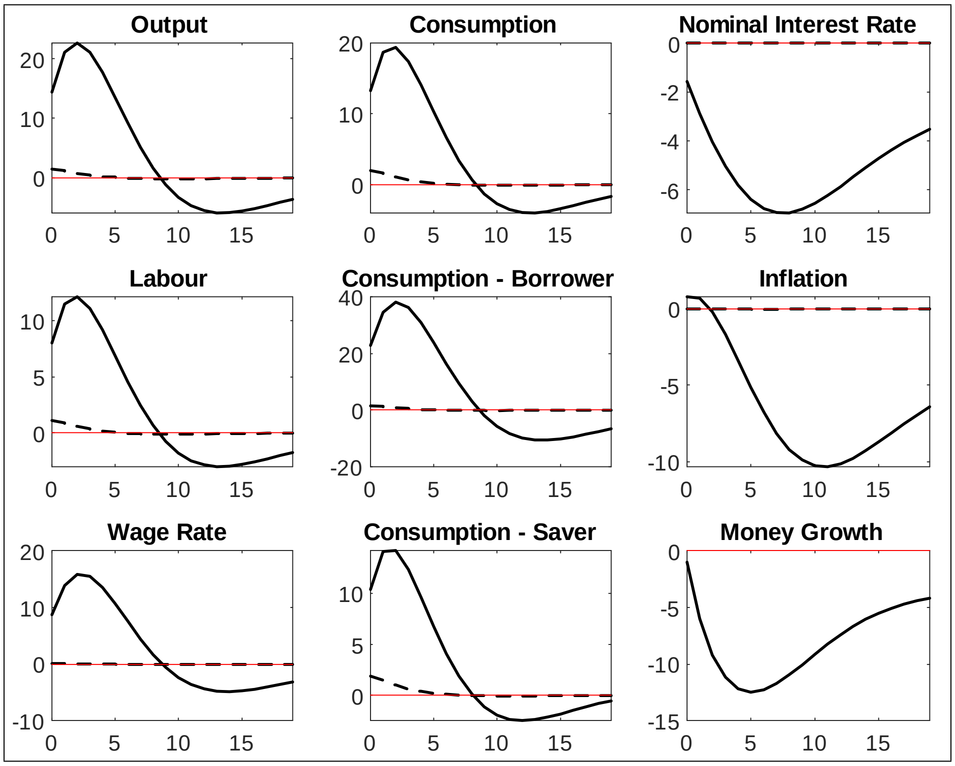

Figure 4: The estimated mean impulse responses to a risk premium shock: money financing (solid line) *versus* debt-financing (dashed line)

Inflationary shock - Figure 5 displays the impulse responses to a price mark-up shock. Following a price mark-up shock, output declines in a MF regime. Consumption moves accordingly. The effect of an increase in prices is exerted through the labour market as real wages and then labour decline leading to a decrease in production and output. As a consequence, money demand decline as well as the nominal interest rate Overall the real interest rate decreases. On the contrary, in the DF regime, the central bank intervenes increasing the nominal rate to curb inflation. However, the increase in inflation is much stronger than the increase in the nominal rate and therefore, in the first periods, the real rate declines. Production and consumption are sustained in the first periods by an increase in labour and by the decline in the real rate. This effect is transitory as the impulse responses of these three variables start declining after few periods and soon become negative when the real rate increases.

The effects of the inflationary shock on the consumption of borrowers and savers are different in the two regimes. In the MF regime the consumption of both agents decline but the effect is more detrimental for borrowers since for them the wage is the only source of income while savers are firms' owners. On the other hand, in the DF regime, there is a very strong and persistent decline in the consumption of borrowers and an initial increase in the consumption of savers. This is due to a wealth effect, positive in the case of the saver and negative in the case of the borrower, generated by the increase in the interest rate.

Overall, output declines much strongly in the DF regime than in the MF regime and these results show that the MF regime is effective in limiting the negative effects on the economy following an increase in inflation. We are the first, to the extent of our knowledge, to show the difference in the impact of an inflationary shock between an economy financed with public debt and economy financed with liquidity.

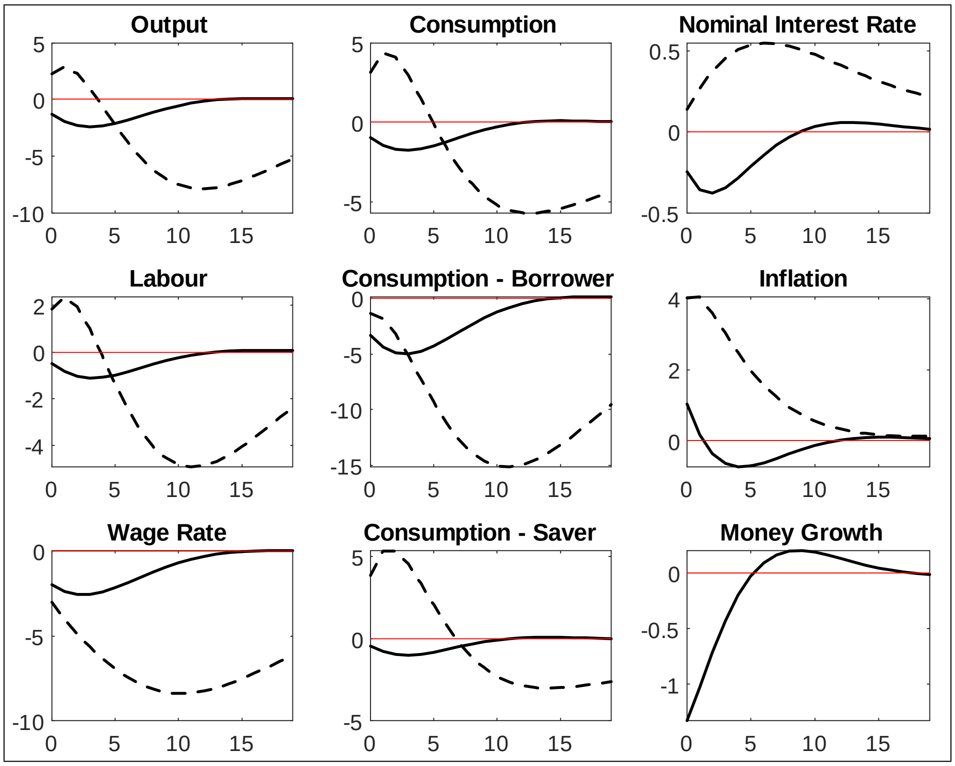

Figure 5: The estimated mean impulse responses to an inflationary shock: money financing (solid line) *versus* debt-financing (dashed line)

5 Business Cycle Movements

In this section, we address the questions we raised at the beginning of this paper. First, are the main driving forces of fluctuations the same in a MF and DF regime? Second, are the forces driving the redistribution the same in the two regimes?

Table **5** presents results from the variance decomposition. The fiscal shock explains 60% of the variance in output in a MF regime while it explains only 30% in a DF regime. The same is true for borrower consumption. The fiscal shock is capable of explaining more than 40% of the borrower's variance in consumption in a MF regime, but only 0.5% in a DF regime. The variance of the saver's consumption, on the other hand, remains mainly linked to the shock to the risk premium in both regimes - the substitution effect well argued in both the empirical and theoretical literature.

A related and very relevant question is how the shocks can contribute to growth and redistribution in the two different regimes. Figures 6-11 provide a visual representation. The solid black line displays the detrended historical data, obtained by subtracting from the raw series the estimated deterministic trend. The columns show the historical contribution of the eight factors, given our estimated parameters. The narrative that comes from the estimated DSGE model is different in the two regimes. As Figure 6 shows, in a MF regime, the dynamics of the output gap is mainly driven by the fiscal shock which has a substantial effect on the economy. On the contrary, as Figure 7 shows, in a DF regime, with the exception of the monetary shock and the productivity shock, all shocks contribute in explaining growth. A similar analysis can be made for borrower's consumption. As Figure 8 shows, in a MF regime, the dynamics of the borrower consumption is mainly driven by the fiscal shock. In contrast, as Figure 9 shows, in a DF regime, the wage mark-up shock plays the major role. As regards the consumption of savers, the results show that its main determinant is the risk-premium shock in both regimes. However, the contribution

	Δy	π	Δw	r	Δc_b	Δc_s
MFFS						
ε^a	2.65	1.36	0.83	0.45	11.56	0.89
ε^b	20.15	16.65	67.71	70.44	18.79	51.51
ε^g	60.34	25.23	14.76	15.64	41.78	28.19
ε^i	9.38	3.81	11.53	9.03	6.61	12.19
ε^m	0.28	0.31	0.70	2.30	0.30	0.52
ε^p	2.51	7.27	2.72	1.11	4.36	2.31
ε^w	4.69	45.37	1.75	1.03	16.61	4.40
DFFS						
ε^a	1.47	0.10	0.18	0.71	12.38	0.81
ε^b	21.91	0.27	0.05	0.36	6.32	60.13
ε^g	28.66	0.06	0.06	0.70	6.88	0.55
ε^i	14.61	0.18	0.28	0.70	4.04	0.40
ε^m	2.30	0.25	0.59	2.41	1.03	2.30
ε^p	18.91	10.87	84.99	55.01	9.54	32.06
ε^w	12.14	88.27	13.86	40.10	59.81	3.75

Table 5: Variance decomposition (MFFS vs DFFS)

of the fiscal shock is relevant in the MF regime in the first half of the sample while its role is very limited in the DF regime. Furthermore, the price markup shock is relevant in the DF regime while its contribution is almost zero in the MF regime.

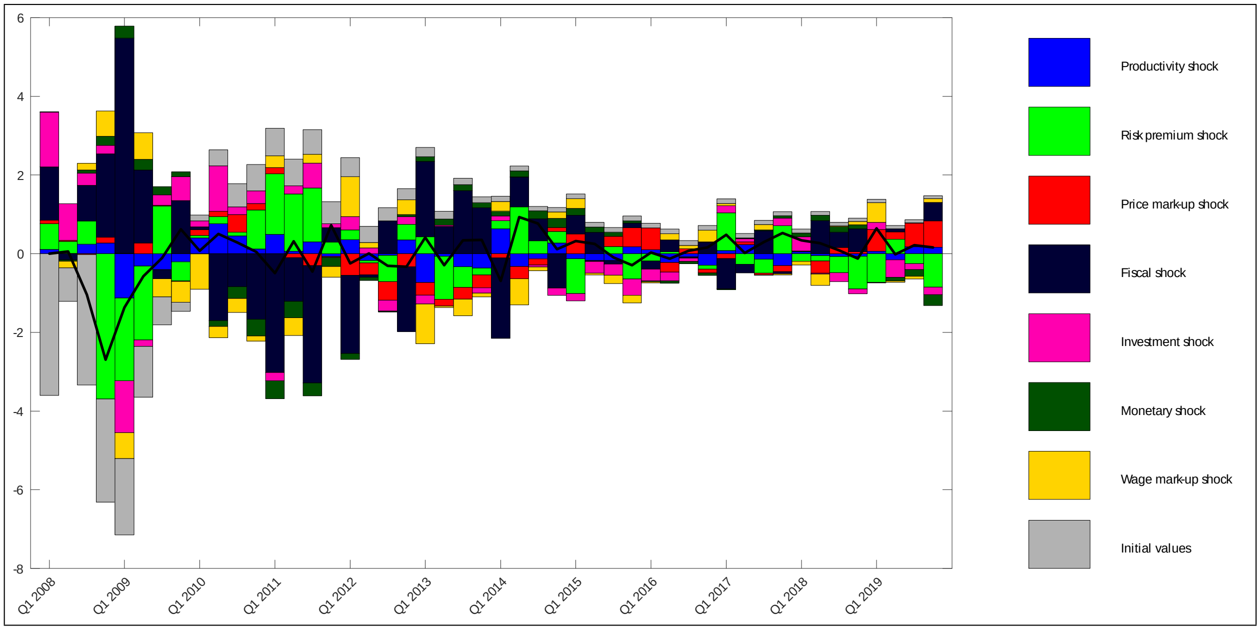

Figure 6: Historical decomposition of output in a MF regime

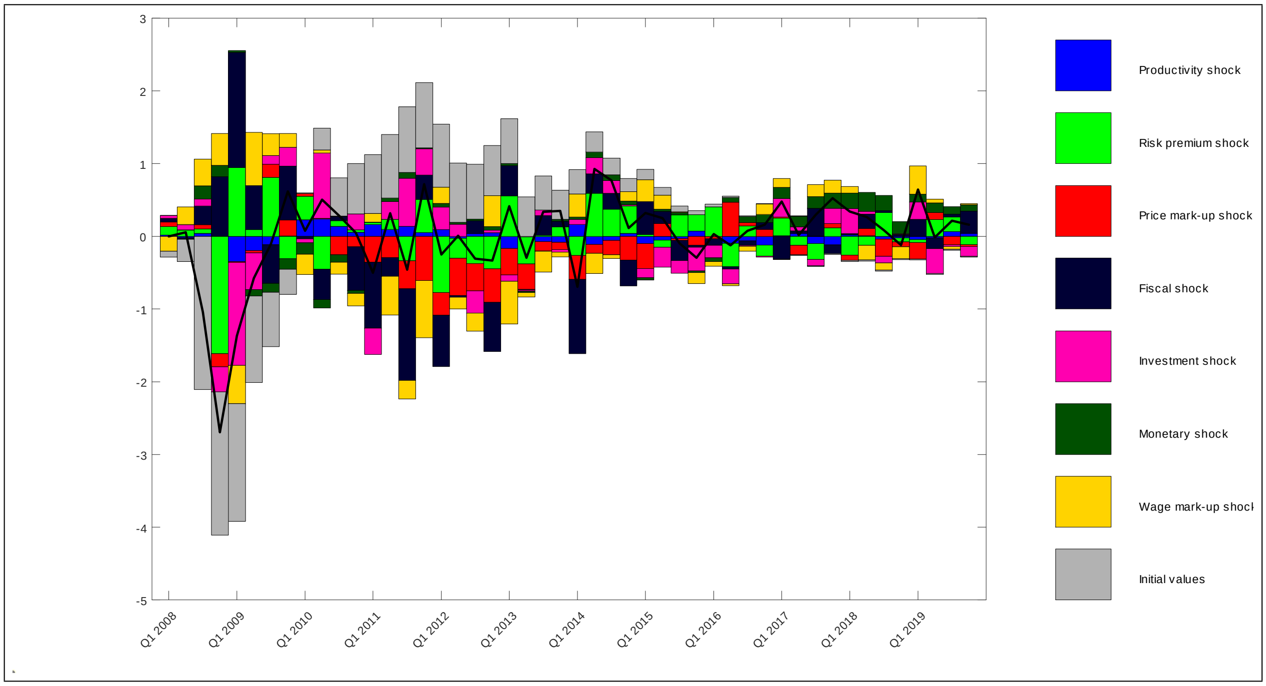

Figure 7: Historical decomposition of output in a DF regime

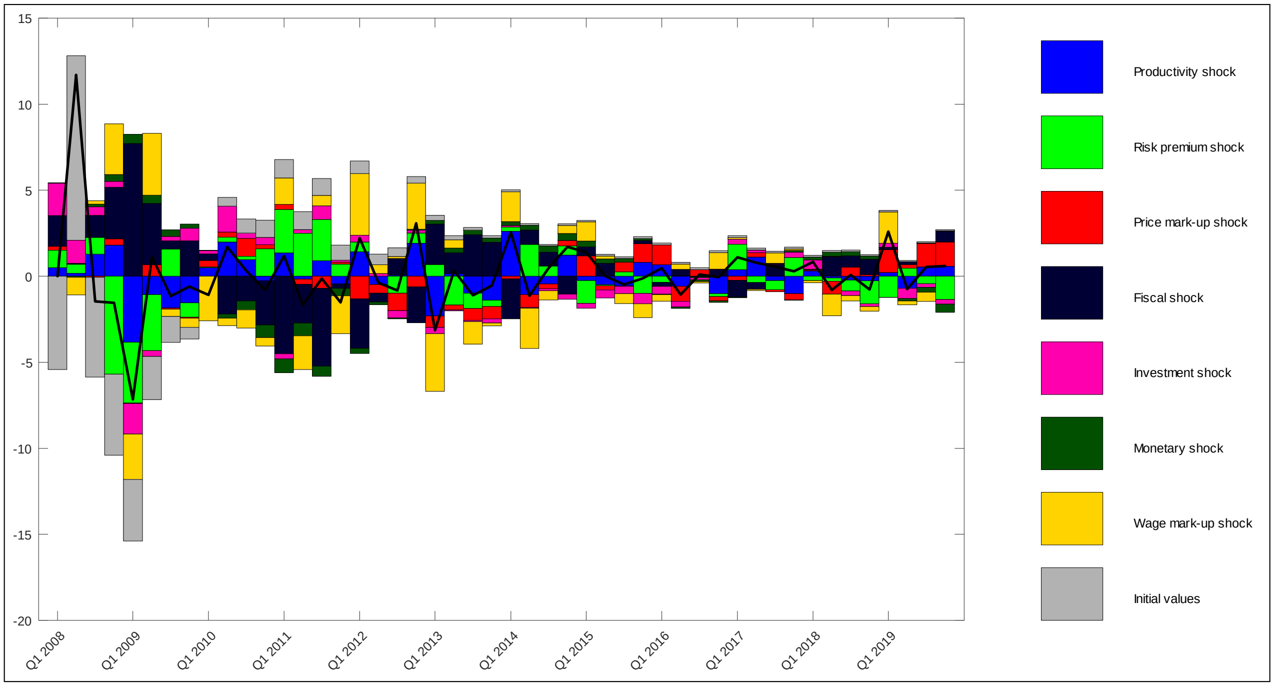

Figure 8: Historical decomposition of borrower consumption in a MF regime

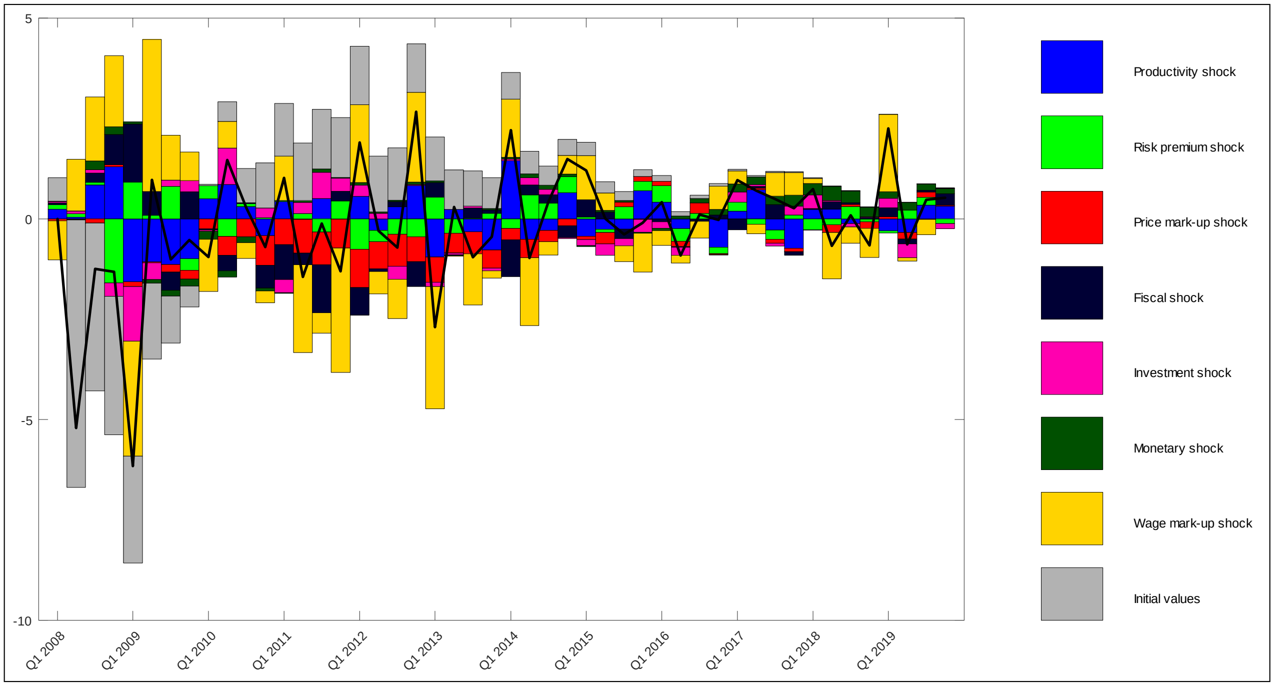

Figure 9: Historical decomposition of borrower consumption in a DF regime

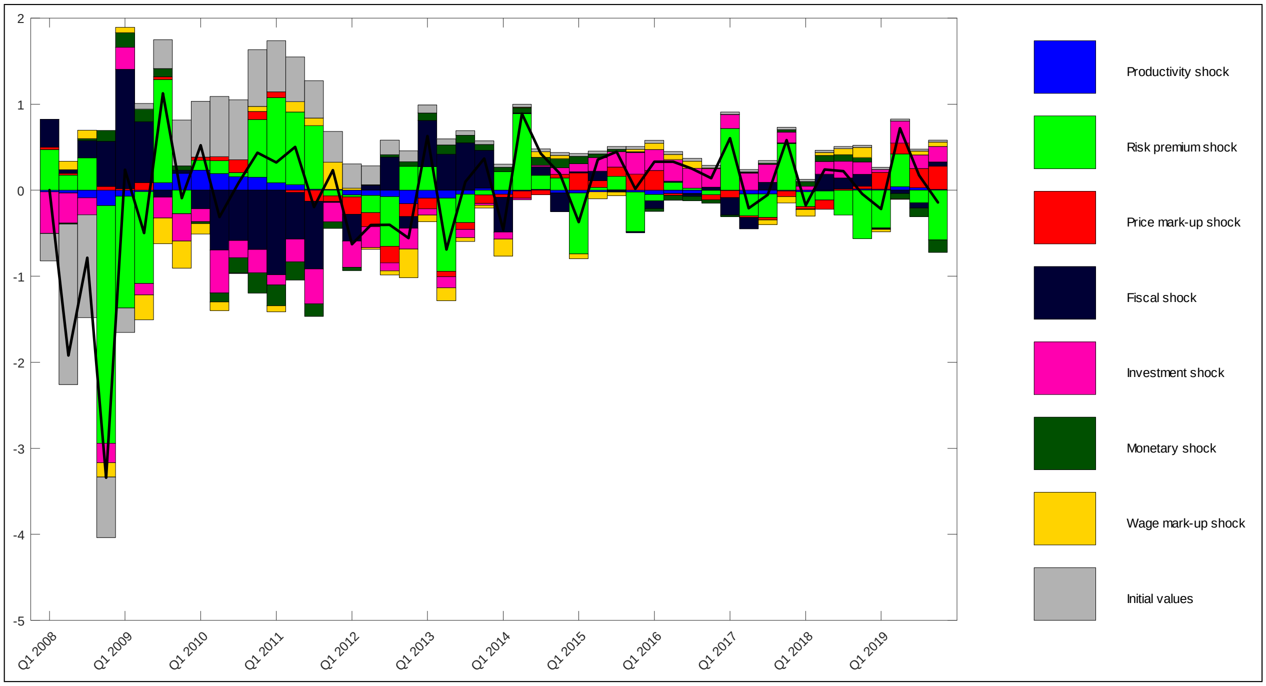

Figure 10: Historical decomposition of saver consumption in a MF regime

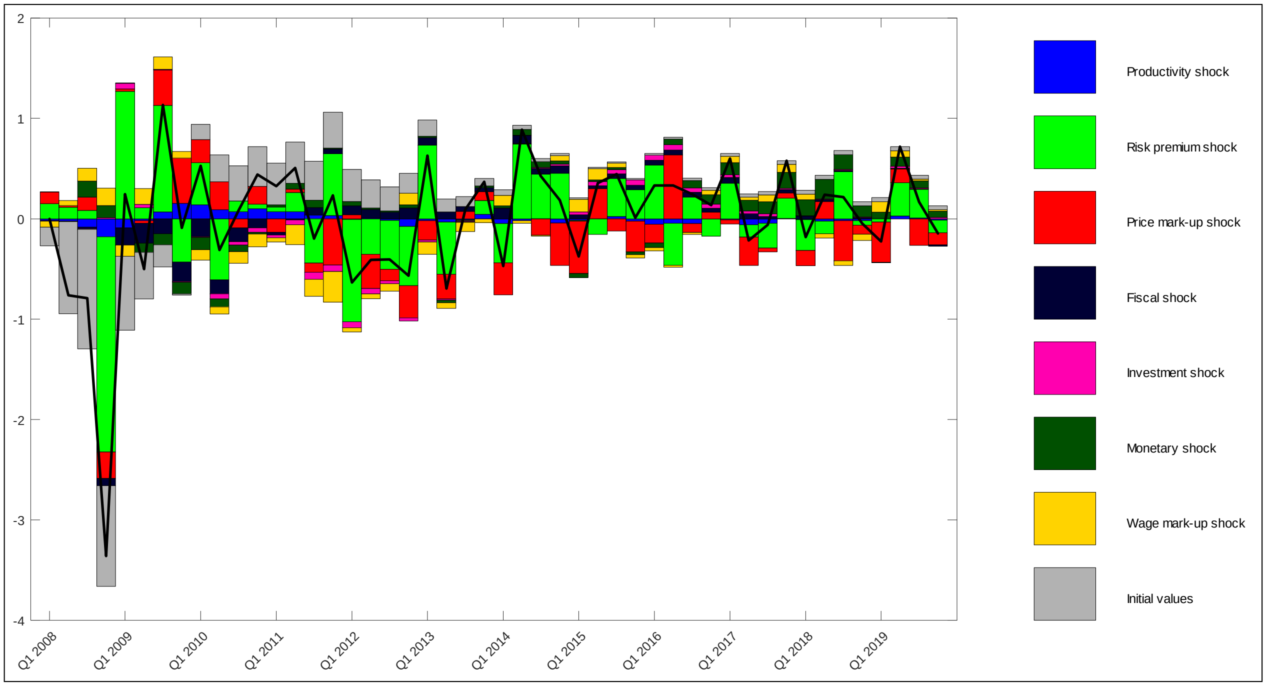

Figure 11: Historical decomposition of saver consumption in a DF regime

6 Concluding remarks

On March 17, 2020 Gali wrote "The time is now" about money-financed fiscal stimuli. We wanted to carry out a conterfactual analysis of US data over the period in which QE policies were conducted, assuming that money creation was accompanied by unchanged real public debt (MF regime).

We found that the share of borrower in a MF regime is lower than the one in a DF regime - where monetary policy is described by the Taylor rule and public debt increases endogenously and unconditionally - meaning that the MF regime is more effective in limiting inequalities. A result to be read complementary to the result of Punzo and Rossi (2022) which demonstrate that the redistribution channel in an MF regime is wider than that of a DF regime, when analyzing a fiscal shock.

The MF regime enhances the positive effects of fiscal and risk premium shocks with respect to the DF regime. The inflationary shock has recessionary effects in the

MF regime and expansionary effects in the DF regime. However, in the DF regime, output and consumption growth are temporary as after few periods the real rate start increasing leading to a sharp fall of both variables leading to a recession that is more severe than the one occurring in the MF regime. This is due to the fact that the DF regime has very detrimental effects on the consumption of borrowers leading to an increase in consumption inequality between borrowers and savers.

Finally, the fiscal shock mainly explains the variance in output and borrower consumption in a MF regime. The variance of the saver's consumption, on the other hand, remains mainly linked to the risk premium shocks in both regimes. In a DF regime, the wage mark-up shock plays the major role.

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A Measurement equations

This section discusses the sources and the transformations applied to the four variables employed in the estimation.

We consider quarterly data from 2008 to 2019. Our database consists of 9 variables: real GDP, the GDP deflator, private consumption, fixed private investment, wages, hours worked, the federal funds rate, employment and population. Wages are measured with an index of hourly compensation (PRS85006103) computed by the Bureau of Labor Statistics. Hours worked are the average weekly hours from the nonfarm business sector (PRS85006023) computed by the Bureau of Labor Statistics. Employment is total civilian employment as computed by the Bureau of Labor Statistics. Population is the civilian noninstitutional population from 16 years. All the variables except for wages and hours worked are taken from Datastream.

These variables are combined to obtain the seven observables we use in the estimation as in Smets and Wouters (2007). In particular, we derive a population index by dividing the series of civilian population by its value in 2012Q4. Real consumption and investments are obtained dividing their nominal value by the GDP deflator. Then, real GDP, consumption, investment and hours are transformed in per-capita terms by dividing their values by the civilian population. Real wages are computed by dividing compensation per hour by the GDP deflator. The nominal interest rate is transformed in quarterly terms. More formally:

- real GDP: $\ln\left(\frac{GDP_{\text{real}}}{Pop_I}\right)\cdot 100$;
- real consumption: $\ln\left(Cons/GDPdefl_t/PopI_t\right)\cdot 100$;
- real investment: $\ln\left(Inv/GDPdefl_t/PopI_t\right)\cdot 100$;
- real wage: $\ln\left(\frac{wages}{GDP_{deflt}}\right)\cdot 100$;
- hours: $\left(\left(\frac{Hours_t \cdot EmpI_t}{100}\right)/PopI_t\right)\cdot 100$;
- inflation: $\left(\ln GDPdefl_t - \ln GDPdefl_{t-1}\right)\cdot 100$;
- nominal interest rate: $FFR_t/\left(4\cdot 100\right)$;

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