Dissecting The Sources Of The Great Recession And Beyond: Some Useful Lessons*

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Abstract

Many countries face highly depressed economic activity due to the pandemics with several central banks once more constrained by the zero lower bound (ZLB) on the nominal interest rate. We argue there are useful lessons to learn from the Great Recession and 2008-2019 period more generally. We estimate a medium-scale New Keynesian model with Bayesian techniques for a sample of data ranging from 1983 to 2019. Based on our estimated model, we dissect the data on key macroeconomic variables to identify the factors that drove the recession and slowed the recovery, and those that prevented even more economic distress. We address concerns that the Fed raised the interest rate too early around 2015, which slowed the recovery. We provide empirical evidence supporting this claim. We conclude that faced with exceptional events like the Great Recession and the pandemics, the fiscal and monetary authorities should join their efforts to provide stronger economic stimulus and this over a longer period of time.

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1 Introduction

More than a decade after the Great Recession (GR) Crisis, many countries are still facing highly depressed economic activity due to the COVID 19 pandemics, with several central banks constrained once more by the zero lower bound (ZLB) on nominal interest rates. While we currently do not have enough data to fully explore the macroeconomic consequences of the pandemics, we argue there are useful lessons to learn from the GR and from the period 2008-2019 more generally.

We dissect the data on output, consumption, investment, hours worked, and inflation between 2008 and 2019 to identify the factors that drove the GR and slowed the recovery, and those that helped preventing even more economic distress. Furthermore, in light of the dilemma policymakers are facing, we examine whether fiscal and monetary policies have been effective at mitigating the severity of the recession and speeding up the recovery. While doing so, we address concerns that, as the economic recovery gained speed in 2015, the Fed tightened its policy too early by raising the nominal interest rate above the ZLB in fear that inflation would accelerate, a move many observers deemed too early and said rattled financial markets and slowed the economic recovery.[1]

Some of these concerns have been expressed by members of the FOMC at the December 2015 Meeting. For instance Lael Brainard argued that:

"Im also mindful of the fact that there are important risks on the other side—in particular, the risk that inflationary pressures may emerge with greater force than is expected today. As I take into account the risks on both sides, the combination of asymmetrically greater room to tighten than to ease through conventional means; core inflation stubbornly below its target, with the deterioration we've seen in inflation expectations; and downside risks arising from abroad leads me to place somewhat greater weight on the possible regret associated with tightening too early than on the possible regret associated with waiting a little longer to see some of these risks play out before moving."

William Dudley who was Vice-Chairman of the FOMC at the time was also reluctant to tighten monetary policy by raising interest rates:

[1]See other similar concerns in the Transcript of the December 2015 FOMC Meeting which are available at https://www.federalreserve.gov/monetarypolicy/fomc_historical_year.htm.

"When I put all of this together—no significant change in the growth outlook, considerable risk from abroad, and inflation expectations in some danger of becoming unhinged to the downside—that suggests to me that there's not a slam-dunk case for tightening at this meeting or, for that matter, concluding that not tightening in September was a mistake."

We provide empirical evidence prior to the pandemics validating these concerns and argue that, facing exceptional events like the GR and pandemics, fiscal and monetary authorities should be prepared to provide strong stimulus over a longer period of time. In particular, we argue that the sharp decline in the unemployment rate between 2009 and 2019 hides another reality, namely that per capita working hours had not yet returned to their pre-2008 level at the end of 2019.

Several studies in the literature have looked at related issues.[2] Some have identified the sources of the GR *per se* (Ireland (2011); Christiano et al. (2014); Del Negro et al. (2015); Christiano et al. (2015)). Others have explored why deflation has not been stronger and longer faced with highly depressed economic activity (Coibion and Gorodnichenko (2015); Del Negro et al. (2015)). Some have investigated whether fiscal and unconventional monetary policies have some stabilizing power at the ZLB and whether they were effective during the GR and the post GR-years (Sims and Wolff (2018); Campbell et al. (2019); Sims and Wu (2019, 2020)). Others have explored whether a binding ZLB constraint matters for macroeconomic volatility and for the economy's response to shocks (Garín et al. (2019); Debortoli et al. (2019)).

The framework used for our empirical investigation belongs to the class of medium-scale New Keynesian (NK) models.[3] Examples of such models include those of Christiano et al. (2005), Smets and Wouters (2007), Justiniano and Primiceri (2008), Justiniano et al. (2010, 2011), Khan and Tsoukalas (2011), and more recently Del Negro et al. (2015), and Christiano et al. (2015).

The paper closest to ours is Mouabbi and Sahuc (2019). They use the Smets and Wouters (2007) model to assess the macroeconomic consequences of implementing unconventional monetary policies for the euro area. They summarize unconventional policy tools via the shadow policy rate representing the shortest maturity rate extracted from a term structure model that

[2] Useful surveys can be found in Kuttner (2018) and Sims and Wu (2020).

[3] Medium-scale DSGE NK models as opposed to small-scale DSGE NK models include rigidities both on nominal wages and prices, capital accumulation, and different real adjustment frictions.

would generate the observed yield curve had the ZLB not been binding. They show that unconventional monetary policy prevented greater output losses during the GR and recovery. They also offer parsimonious US evidence for inflation and output.

Our model differs from theirs in some significant ways. First, we include two structural ingredients identified as key features of the new generation of Monetary DSGE models by Christiano et al. (2010). One is the use by firms of intermediate goods in an input-output production structure. This is a feature of U.S. production which is well documented empirically (Basu, 1995; Huang et al., 2004). This is often referred to as a "roundabout production structure." Roundabout production introduces strategic complementarities in firms' pricing decisions, making marginal cost less sensitive to input factor prices and contributing to inflation persistence.

A second ingredient is working capital which firms use in our model to finance a fraction of all of their factor payments (Phaneuf et al., 2018). This generates a cost channel whereby interest rates can have a direct impact on firms' real marginal costs as supported by evidence in Ravenna and Walsh (2006), Chowdhury et al. (2006) and Tillman (2008), among others. Because we are interested in the macroeconomic policies which possibly affect interest rates and hence can have both supply-side as well as demand-side effects through a cost channel.

Yet, another significant difference with their approach is that we distinguish between investment-specific (IS) shocks identified by changes in the relative price of investment goods to consumption goods, and shocks affecting the marginal efficiency of investment (MEI) that are orthogonal to this relative price. Mouabbi and Sahuc consider only the first type of investment shock. However, Schmitt-Grohé and Uribe (2012) have shown that, when considering measurement and identification issues, investment-specific shocks explain little of business cycle fluctuations. Justiniano et al. (2011) provide evidence corroborating that investment-specific shocks contribute nothing to aggregate fluctuations, while MEI shocks account for the bulk of business cycle fluctuations. Therefore, omitting this key source of business cycle fluctuations may bias estimates and the quantitative assessment of shocks driving the GR and recovery.

We estimate the model using a shadow policy rate for the US (Wu and Xia (2016)). Our paper makes four main contributions to this burgeoning literature. First, based on an estimated multi-shock DSGE model, we dissect the US data to identify the adverse shocks that drove the GR in

2008-2009. We find they were different across key macro variables. Unlike Mouabbi and Sahuc (2019), we find that IS shocks played almost no role driving movements in nominal and real variables during the GR and recovery, even in the case of investment.

In the early stage of the GR, we find that the adverse shocks affecting output growth were mainly those to TFP, MEI and government spending (GS). Three shocks in particular contributed to the severity of the recession: those to MEI, price markup (PM) and preference shocks (PR). Following Justiniano et al. (2011), MEI shocks can be seen as an indirect way of modeling financial frictions in a NK context. In this sense, our findings are not inconsistent with studies emphasizing financial frictions (Christiano et al., 2014, 2015). We find that in our estimated model, PM shocks move output and inflation in opposite directions acting as supply-side disturbances.

While the adverse shocks affecting hours growth were broadly the same as for output growth, we find that those affecting consumption growth and investment growth were quite different. In the case of consumption growth, PR and PM shocks were the most significant, while for investment growth, MEI shocks were most important followed by PM shocks.

Second, we identify the shocks that helped avoiding even more distress during the GR. Monetary policy (MP) shocks had their strongest stimulating impact on output growth during the first year of the GR. GS shocks also had a positive impact on output growth from 2008:Q4 to 2009:Q3, preventing output from dropping even more during the GR. However, we find that the most favorable shock starting 2008:Q4, and this for 8 consecutive quarters, was the TFP shock that contributed positively to output growth.

Third, we look at the behavior of inflation during the Great Recession. Hall (2011) argues that deflation should have been stronger and should have lasted longer than it did after 2008:Q1. We find that the main shocks driving inflation during the GR were mainly those to MEI, PR and TFP. MEI and PR shocks played the role of unfavorable demand-side disturbances moving output and inflation in the same direction. We identify the counter influences to deflation as the MP shocks since the start of the GR, and the PM shocks after 2008:Q4. Therefore, while PM shocks acted as unfavorable supply-side disturbances moving output in opposite directions during the GR, TFP shocks by contrast played the role of favorable supply-side disturbances. Our evidence that unconventional monetary policy prevented deflation from being stronger and longer during the GR and ensuing years is consistent with the fact that it also had a positive effect on output growth between 2008:Q1 and 2012:Q2.

Our explanation of the behavior of inflation during the GR hence differs from those of Del Negro et al. (2015) and Christiano et al. (2015). Del Negro et al. argue that adding financial frictions and a time-varying inflation target to an otherwise standard medium-scale DSGE model help predict a strong contraction in economic activity and a protracted but relatively modest decline in inflation during the GR. The evidence in Christiano et al. point instead to a fall in TFP relative to trend and a rise in the cost of working capital in a DSGE model with perfectly flexible nominal wages, sticky prices, a binding ZLB constraint and financial frictions.[4]

Fourth, we assess the effectiveness of fiscal and unconventional monetary policies between 2008 and 2020. According to the data, there was a large drop of 4.5% in output during the GR. Meanwhile, consumption dropped by 2.3%, investment by 25.6%, and hours worked by 11.5%. Furthermore, the recovery was weak and slow. While output and consumption got back to their pre-recession level in 2014:Q3, investment returned to its pre-recession level only in 2018:Q1 and working hours have not returned yet to their 2008 level.

We show that both consumption and output benefited from trend output growth during the GR and recovery years. In fact, conditioned on trend growth we show that both consumption and output did not fall below the pre-recession levels except for a weak decline in output early during the GR. This was not the case for investment and working hours that generally stayed below their pre-2008 levels until 2020 conditioned on trend output growth.

We find that fiscal policy had a positive impact during the GR by contributing to a lesser drop in output from 2008:Q4 to 2009:Q3, and this mainly by slowing down the decline in working hours during that short period of time. However, we find that fiscal policy somewhat slowed the recovery because it had a fairly weak positive impact on consumption and a negative effect on working hours.

Unconventional monetary policy had a much stronger impact on the GR and recovery than fiscal policy. Based on our estimated model, we find that MP shocks were negative almost all

[4] Direct comparison between alternative models of the GR is difficult because their structure is different: flexible vs sticky nominal wages, estimation method (IRFs VAR vs Model matching), number and types of shocks included in the estimation, direct or indirect modeling of financial frictions, Taylor rule specification, etc.

the time between 2008:Q1 and 2014:Q2. Based on counterfactual experiments conditioned on a shock to the shadow policy rate, we find that the effects of the Fed's unconventional policy on output growth were generally expansionary between 2008 and 2012:Q2, and then between 2013:Q4 and 2014:Q3. Our counterfactual conditioned on MP shocks only implies that output rose constantly between 2008:Q1 and 2015:Q4. While the actual increase in output was 1.7% by the end of 2015 relative its pre-recession level, the counterfactual says the increase was 12%. We find a similar pattern for consumption.

There have been criticisms that the Fed raised interest rates too rapidly and that this was an impediment to a faster economic recovery. In fact, the shadow rate began an ascension in 2014:Q3, reaching zero in 2016:Q1. It then continued rising to 2.38% in 2019:Q1. Evidence from our estimated model confirms that between 2015 and 2020, MP shocks were either positive or slightly negative compared to those between 2008 and 2015. We find that during that time MP shocks contributed negatively to output growth. Also, based on a counterfactual conditioned on MP shocks only, we find that the level of output even dropped between 2015 and 2016:Q3. We find similar declines in the levels of consumption, investment and hours around the same date.

We believe our empirical findings lend credence to the view that the Fed raised interest rates too prematurely, which resulted in slowing down the recovery. Therefore, the important lesson to learn from our findings is that when confronted with exceptional events like the GR with the Fed facing near-zero lower bound, policymakers should consider implementing unconventional monetary policy for a much longer period of time than it did to sustain the recovery.

The rest of the paper is organized as follows. Section 2 describes our DSGE model, including the shadow policy rule. Section 3 lists the observables used in the estimation and broadly describes the Bayesian estimation procedure. Section 4 presents some estimation results, including model's fit and variance decomposition of observables based on our estimated model. Section 5 identifies what were the adverse shocks during the Great Recession and recovery years, and assesses their macroeconomic consequences. Section 6 focuses on whether unconventional monetary policy has been stabilizing, that is, whether it helped mitigating the recessionary effects of adverse shocks and amplifying the expansionary effects of favorable shocks. Section 7 assesses how our estimated model can cope with the behavior of inflation during the Great Recession and the recovery years. Section 8 contains concluding remarks.

2 Model

The model laid out in this section assumes imperfectly competitive labor and goods markets, sticky wages and sticky prices. It also features real adjustment frictions like consumer habit formation, investment adjustment costs and variable capital utilization. Economic growth stems from trend growth in neutral and investment-specific technology (Justiniano and Primiceri, 2008). Firms' production and pricing decisions are related through input-output linkages. Firms borrow working capital to finance a fraction of their variable input costs. Business cycle fluctuations are driven by eight different types of disturbances.

2.1 Gross Output

Given the input-output production structure, we distinguish between gross total output, X_t, and final output, Y_t. Gross output, X_t, is produced by a perfectly competitive firm using a continuum of intermediate goods, X_{jt}, $j \in (0,1)$ and the CES production technology:

$$X_t = \left(\int_0^1 X_{jt}^{\frac{1}{1+\lambda_{p,t}}} dj \right)^{1+\lambda_{p,t}}, \tag{1}$$

with $\lambda_{p,t}$ following the exogenous stochastic process:

$$\lambda_{p,t} = (1-\rho_p)\,\lambda_p + \rho_p \lambda_{p,t-1} + \varepsilon_{p,t} - \theta_p \varepsilon_{p,t-1}. \tag{2}$$

$\varepsilon_{p,t}$ is *i.i.d.* $N\left(0, \sigma_p^2\right)$ and denotes a price-markup shock, $\lambda_{p,t}$ being the desired markup of price over marginal cost for intermediate firms.

Profit maximization and a zero-profit condition for gross output leads to the following downward sloping demand curve for the j^{th} intermediate good:

$$X_{jt} = \left(\frac{P_{jt}}{P_t} \right)^{-\frac{\left(1+\lambda_{p,t}\right)}{\lambda_{p,t}}} X_t, \tag{3}$$

where P_{jt} is the price of good j, and P_t is the aggregate price index:

$$P_t = \left(\int_0^1 P_{jt}^{-\frac{1}{\lambda_{p,t}}} dj \right)^{-\lambda_{p,t}}. \tag{4}$$

2.2 Intermediate Goods Producers and Price Setting

A monopolist produces intermediate good j according to the following production function:

$$X_{jt} = \max \left\{ A_t \Gamma_{jt}^{\phi} \left(K_{jt}^{\alpha} L_{jt}^{1-\alpha} \right)^{1-\phi} - \Omega_t F, 0 \right\}, \tag{5}$$

where A_t is an exogenous neutral technological progress, whose growth rate $z_t \equiv \ln \left(\frac{A_t}{A_{t-1}} \right)$ follows a stationary AR(1) process:

$$z_t = (1 - \rho_z) g_z + \rho_z z_{t-1} + \varepsilon_{z,t}, \tag{6}$$

where g_z is the steady-state growth rate of neutral technology, and $\varepsilon_{z,t}$ is a TFP or neutral technology shock which is i.i.d. $N(0, \sigma_z^2)$. Γ_{jt} denotes the intermediate inputs, $\widehat{K}_{jt}$ the capital services, and L_{jt} the labor input used by the j^{th} producer. Ω_t is a growth factor which is composed of trend growth in neutral and investment-specific technologies. F is a fixed cost implying zero steady-state profits and ensuring the existence of balanced growth path.

The stochastic growth factor Ω_t is given by the composite technological process:

$$\Omega_t = A_t^{\frac{1}{(1-\phi)(1-\alpha)}} V_t^{I \frac{\alpha}{1-\alpha}}, \tag{7}$$

where V_t^I denotes the investment-specific technological progress (hereafter IST). IST progress is non-stationary and its growth rate $v_t^I \equiv \ln \left(\frac{V_t^I}{V_{t-1}^I} \right)$ follows a stationary AR(1) process:

$$v_t^I = (1 - \rho_v) g_v + \rho_v v_{t-1}^I + \epsilon_t^I,$$

where g_v is the steady-state growth rate of the IST process and ϵ_t^I is an IST shock which is i.i.d. $N \left(0, \sigma_{\epsilon^I}^2 \right)$.

The cost-minimization problem of a typical j firm is:

$$\min_{\Gamma_t,\widehat{K}_t,L_t} (1-\psi+\psi S_t)(P_t\Gamma_{jt}+R_t^k\widehat{K}_{jt}+W_tL_{jt}),$$

subject to:

$$A_t\Gamma_{jt}^{\phi}\left(\widehat{K}_{jt}^{\alpha}L_{jt}^{1-\alpha}\right)^{1-\phi}-\Omega_tF\geq\left(\frac{P_{jt}}{P_t}\right)^{-\theta}X_t. \tag{8}$$

R_t^k is the nominal rental price of capital services, and W_t is the nominal wage index. The parameter ψ is the percentage of input costs financed through working capital. If $\psi=0$, firms do not use working capital at all to finance their input costs. If instead $\psi=1$, then firms finance all of their input costs through working capital, reimbursing their short-term loan at the shadow interest rate S_t.

If we define $\Psi_t\equiv(1-\psi+\psi S_t)$, and solve the cost-minimization problem, then real marginal cost is:

$$mc_t=\overline{\phi}A_t^{(1-\alpha)(\phi-1)}\Psi_t\left[\left(r_t^k\right)^{\alpha}(w_t)^{(1-\alpha)}\right]^{1-\phi}, \tag{9}$$

and the demand functions for the intermediate and primary factor inputs are,

$$\Gamma_{jt}=\phi\frac{mc_t}{\Psi_t}\left(X_{jt}+\Omega_tF\right), \tag{10}$$

$$K_{jt}=\alpha\left(1-\phi\right)\frac{mc_t}{\Psi_tr_t^k}\left(X_{jt}+\Omega_tF\right), \tag{11}$$

$$L_{jt}=(1-\alpha)(1-\phi)\frac{mc_t}{\Psi_tw_t}\left(X_{jt}+\Omega_tF\right), \tag{12}$$

where $\overline{\phi}\equiv\phi^{-\phi}\left(1-\phi\right)^{\phi-1}\left(\alpha^{-\alpha}\left(1-\alpha\right)^{\alpha-1}\right)^{1-\phi}$, $mc_t=\frac{MC_t}{P_t}$, is the real marginal cost which is common to all firms, r_t^k is the real rental price on capital services, and w_t is the real wage.

Intermediate firms allowed to reoptimize their price with probability $1-\xi_p$ all choose the same price P_t^*. Firms not allowed to reoptimize their price index $P_{j,t-1}$ to lagged inflation, π_{t-1}, and steady-state inflation, π. The price-setting rule is given by

$$P_{jt}\begin{cases}=P_{jt}^{*} & \text{with probability } 1-\xi_p\\ =P_{j,t-1}\pi_{t-1}^{\iota_p}\pi^{1-\iota_p} & \text{with probability } \xi_p\end{cases}, \tag{13}$$

where ι_p and $1-\iota_p$ denote the degree of price indexation to past inflation and steady-state inflation, respectively. When given the opportunity to reoptimize its price, a firm j chooses a price that maximizes the present discounted value of future profits, subject to (3) and to cost minimization:

$$\max_{P_{jt}} \quad E_t \sum_{s=0}^{\infty} \xi_p^s \beta^s \frac{\Lambda_{t+s}}{\Lambda_t} \left[P_{jt} X_{j,t+s} \Pi_{t,t+s}^p - MC_{t+s} X_{j,t+s} \right], \tag{14}$$

where β is the discount factor, Λ_t is the marginal utility of nominal income to the representative household that owns the firm, ξ_P^s is the probability that a price chosen in period t will still be effective in period $t+s$, $\Pi_{t,t+s}^p = \Pi_{k=1}^s \pi_{t+k-1}^{\iota_p} \pi^{1-\iota_p}$ is the cumulative price indexation between t and $t+s-1$, and MC_{t+s} is the nominal marginal cost.

Solving the problem yields the following optimal price:

$$E_t \sum_{s=0}^{\infty} \xi_p^s \beta^s \lambda_{t+s}^r X_{jt+s} \frac{1}{\lambda_{p,t+s}} \left(p_t^* \frac{\Pi_{t,t+s}^p}{\pi_{t+1,t+s}} - (1+\lambda_{p,t+s})\, mc_{t+s} \right) = 0, \tag{15}$$

where λ_t^r is the marginal utility of an additional unit of real income received by the household, $p_t^* = \frac{P_{jt}}{P_t}$ is the real optimal reset price and $\pi_{t+1,t+s} = \frac{P_{t+s}}{P_t}$ is cumulative inflation between $t+1$ and $t+s$.

2.3 Households and Wage Setting

There is a continuum of households, indexed by $i \in [0,1]$, who are monopoly suppliers of labor. They face a downward-sloping demand curve for their particular type of labor given in (23). Each period, households face a probability $(1-\xi_w)$ giving them the opportunity to reset their nominal wage. As in Erceg et al. (2000), utility is separable in consumption and labor. State-contingent securities insure households against idiosyncratic wage risk arising from staggered wage-setting. Under these circumstances, households are then identical along all dimensions other than labor supply and wages.

The problem of a typical household, omitting dependence on i except for these two dimensions, is:

$$\max_{C_t, L_{it}, K_{t+1}, B_{t+1}, I_t, Z_t} \quad E_0 \sum_{t=0}^{\infty} \beta^t b_t \left(\ln\left(C_t - hC_{t-1}\right) - \eta \frac{L_{it}^{1+\chi}}{1+\chi} \right), \tag{16}$$

subject to the following budget constraint,

$$P_t \left(C_t + I_t + \frac{a(Z_t) K_t}{V_t^I} \right) + \frac{B_{t+1}}{S_t} \leq W_{it} L_{it} + R_t^k Z_t K_t + B_t + \Pi_t + T_t, \tag{17}$$

and the physical capital accumulation process,

$$K_{t+1} = \vartheta_t V_t^I \left(1 - AC\left(\frac{I_t}{I_{t-1}}\right)\right) I_t + (1-\delta)K_t. \tag{18}$$

b_t in the utility function is an exogenous risk premium shock. C_t is real consumption and h, a parameter determining internal habit. L_{it} denotes hours and χ is the inverse Frisch labor supply elasticity. I_t is investment, and $a(Z_t)$ is a resource cost of utilization, which satisfies $a(1) = 0$, $a'(1) = 0$, and $a''(1) > 0$. This resource cost is measured in units of physical capital. W_{it} is the nominal wage paid to labor of type i, B_t is the stock of nominal bonds the household enters with in period t. Π_t denotes the distributed dividends from firms. T_t is a lump-sum transfer from the government. $AC\left(\frac{I_t}{I_{t-1}}\right)$ is an investment adjustment cost, which satisfies $AC\left(.\right) = 0$, $AC'(.) = 0$, and $AC''\left(.\right) > 0$, δ is the rate of depreciation of physical capital, and ϑ_t is a stochastic shock to the marginal efficiency of investment (MEI).

The risk premium shock, b_t, follows the AR(1) process:

$$\ln b_t = \rho_b \ln b_{t-1} + \varepsilon_t^b, \tag{19}$$

where ε_t^b is i.i.d. $N\left(0, \sigma_b^2\right)$.

The functional forms for the resource cost of capital utilization and the investment adjustment cost are:

$$a(Z_t) = \gamma_1(Z_t - 1) + \frac{\gamma_2}{2}(Z_t - 1)^2,$$

$$AC\left(\frac{I_t}{I_{t-1}}\right) = \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - g_v\right)^2.$$

The MEI shock, ϑ_t, follows the AR(1) process:

$$\ln \vartheta_t = \rho_I \ln \vartheta_{t-1} + \eta_t^I, \quad 0 \leq \rho_I < 1, \tag{20}$$

where η_t^I is i.i.d. $N\left(0, \sigma_{\eta^I}^2\right)$.

2.4 Employment Agencies

A large number of competitive employment agencies combine differentiated labor skills into a homogeneous labor input sold to intermediate firms, and this according to:

$$L_t = \left(\int_0^1 L_{it}^{\frac{1}{1+\lambda_{w,t}}} di\right)^{1+\lambda_{w,t}}, \tag{21}$$

where $\lambda_{w,t}$ is the stochastic desired markup of wage over the household's marginal rate of substitution. The desired wage markup follows an ARMA(1,1) process:

$$\lambda_{w,t} = (1 - \rho_w)\,\lambda_w + \rho_w \lambda_{w,t-1} + \varepsilon_w - \theta_w \varepsilon_{w,t-1}, \tag{22}$$

where λ_w is the steady-state wage markup and ε_w is a *i.i.d.* $N\left(0, \sigma_w^2\right)$ wage-markup shock.

Profit maximization by the perfectly competitive employment agences implies the following labor demand function:

$$L_{it} = \left(\frac{W_{it}}{W_t}\right)^{-\frac{1+\lambda_{w,t}}{\lambda_{w,t}}} L_t, \tag{23}$$

where W_{it} is the wage paid to labor of type i and W_t is the aggregate wage index:

$$W_t = \left(\int_0^1 W_{it}^{-\frac{1}{\lambda_{w,t}}}\, di\right)^{-\lambda_{w,t}}. \tag{24}$$

2.5 Wage setting

Each period, a household reoptimizes its nominal wage with probability $1 - \xi_w$. Households given the opportunity to reset their nominal wage all choose the same wage rate W_t^*. Those not allowed to reset their wage index $W_{i,t-1}$ to lagged inflation, π_{t-1}, and steady-state inflation, π. The wage-setting rule is then given by:

$$W_{it} = \begin{cases} W_{it}^* & \text{with probability } 1 - \xi_w \\ W_{i,t-1}\left(\pi_{t-1} e^{\frac{1}{(1-\alpha)(1-\phi)} z_{t-1} + \frac{\alpha}{(1-\alpha)} v_{t-1}^I}\right)^{\iota_w} \left(\pi e^{\frac{1}{(1-\alpha)(1-\phi)} g_z + \frac{\alpha}{(1-\alpha)} g_v}\right)^{1-\iota_w} & \text{with probability } \xi_w, \end{cases} \tag{25}$$

where W_{it}^* is the reset wage. When allowed to reoptimize its wage, the household chooses the nominal wage that maximizes the present discounted value of flow utility flow (16) subject to demand schedule (23). From the first-order condition, the optimal wage rule is:

$$E_t \sum_{s=0}^{\infty} (\beta \xi_w)^s \frac{\lambda_{t+s}^r L_{it+s}}{\lambda_{w,t+s}} \left[w_t^* \frac{\Pi_{t,t+s}^w}{\pi_{t+1,t+s}} - (1 + \lambda_{w,t+s}) \frac{\eta \varepsilon_{t+s}^h L_{it+s}^{\chi}}{\lambda_{t+s}^r}\right] = 0, \tag{26}$$

where ξ_w^s is the probability that a wage chosen in period t will still be effective in period $t+s$, $\Pi_{t,t+s}^w = \Pi_{k=1}^s \left(\pi e^{\frac{1}{(1-\alpha)(1-\phi)}g_z + \frac{\alpha}{(1-\alpha)}g_v}\right)^{1-\iota_w} \left(\pi_{t+k-1} e^{\frac{1}{(1-\alpha)(1-\phi)}z_{t-k+1} + \frac{\alpha}{(1-\alpha)}v_{t-k+1}^I}\right)^{\iota_w}$ is the cumulative wage indexation between t and $t+s-1$, and ι_w and $1-\iota_w$ denote the degree of wage indexing to past and steady-state inflation, respectively. Given our assumption on preferences and wage-setting, all updating households choose the same optimal reset wage, denoted in real terms by $w_t^* = \frac{W_{it}}{P_t}$.

2.6 Monetary and Fiscal Policy

Following Wu and Xia (2016) and Wu and Zhang (2019), the shadow rate federal funds rate S_t intends to summarize both rule-based monetary policy and the use of unconventional monetary policy tools. With rule-based policy, the shadow rate equals the effective federal funds rate. With unconventional policy tools, $S_t < 0$.

The shadow rate complies with a rule stating that the Fed smooths its short-term movements and reacts to deviations of inflation from target, and to deviations of the growth rate of real GDP $(\widehat{Y}_t/\widehat{Y}_{t-1})$ from trend output growth:

$$\frac{S_t}{S} = \left(\frac{S_{t-1}}{S}\right)^{\rho_R} \left[\left(\frac{\pi_t}{\overline{\pi}}\right)^{\alpha_\pi} \left(\frac{\widehat{Y}_t}{\widehat{Y}_{t-1}} g_{\widehat{Y}}^{-1}\right)^{\alpha_{\Delta y}}\right]^{1-\rho_R} \varepsilon_t^r, \tag{27}$$

where ρ_R is a smoothing parameter, α_π, and $\alpha_{\Delta y}$ are control parameters, and ε_t^r is monetary policy shock which is i.i.d. $N\left(0, \sigma_r^2\right)$.

Fiscal policy is fully Ricardian. The government finances budget deficit by issuing short-term bonds. Public spending is a time-varying fraction of final output, Y_t, that is

$$G_t = \left(1 - \frac{1}{g_t}\right) Y_t, \tag{28}$$

where g_t is a government spending shock that follows the AR(1) process:

$$\ln g_t = \left(1-\rho_g\right) \ln g + \rho_g \ln g_{t-1} + \varepsilon_{g,t}. \tag{29}$$

where g is the steady-state level of government spending and $\varepsilon_{g,t}$ is an i.i.d. $N\left(0, \sigma_g^2\right)$ government spending shock.

2.7 Market-Clearing and Equilibrium

Market-clearing for capital services, labor, and intermediate inputs requires that $\int_0^1 \widehat{K}_{jt}dj = \widehat{K}_t$, $\int_0^1 L_{jt}dj = L_t$, and $\int_0^1 \Gamma_{jt}dj = \Gamma_t$.

Gross output can be written as:

$$X_t = A_t\Gamma_t^{\phi}\left(K_t^{\alpha}L_t^{1-\alpha}\right)^{1-\phi} - \Omega_t F. \tag{30}$$

Value added, Y_t, is related to gross output, X_t, by

$$Y_t = X_t - \Gamma_t, \tag{31}$$

where Γ_t denotes total intermediates. Real GDP is given by

$$\widehat{Y}_t = C_t + I_t + G_t. \tag{32}$$

The resource constraint of the economy is:

$$\frac{1}{g_t}Y_t = C_t + I_t + \frac{a(Z_t)K_t}{V_t^I}. \tag{33}$$

2.8 Log-Linearization

Economic growth stems from neutral and investment-specific technological progress. Therefore, output, consumption, intermediates and the real wage all inherit trend growth $g_{\Omega,t} \equiv \frac{\Omega_t}{\Omega_{t-1}}$. In turn, the capital stock and investment grow at the rate $g_I = g_K = g_{\Omega,t}g_{v,t}$. Solving the model requires detrending variables, which is done by removing the joint stochastic trend, $\Omega_t = A_t^{\frac{1}{(1-\phi)(1-\alpha)}} V_t^{I\,\frac{\alpha}{1-\alpha}}$, and taking a log-linear approximation of the stationnary model around the non-stochastic steady state. The full set of equilibrium conditions can be found in Appendix A.

3 Data and Estimation Methodology

This section describes the data and Bayesian estimation methodology used in our empirical analysis.

3.1 Data

The model of Section 2 is estimated with US quarterly data on output, consumption, investment, real wages, hours worked, inflation, the shadow rate, and the relative price of investment goods to consumption goods.

All nominal series are converted in real terms by dividing with the price deflator corresponding to our measure of output. Furthermore, output, consumption, investment and hours worked are expressed in per capita terms by dividing with the civilian non-institutional population between 16 and 65. The shadow rate equals the effective federal funds rate during years of conventional monetary policy, whereas for years during which the Fed used unconventional policy tools, it corresponds to the shadow rate of Wu and Xia (2016). All data except the shadow rate are in logs and seasonally adjusted.

3.2 Bayesian Methodology

We a subset of the model's structural parameters with a Bayesian procedure. This procedure is now widely used when estimating DSGE models, and recent overviews of it can be found in An and Schorfheide (2007) and Fernández-Villaverde (2010). The key steps in this methodology are as follows. The model presented in the previous sections is solved using standard numerical techniques and the solution is expressed in state-space form as follows:

$$v_t = Av_{t-1} + B\varepsilon_t$$

$$\mathbf{Y}_t = \begin{bmatrix} \widehat{gdp}_t - \widehat{gdp}_{t-1} + \widehat{g}_{\Omega,t} \\ \widehat{c}_t - \widehat{c}_{t-1} + \widehat{g}_{\Omega,t} \\ \widehat{i}_t - \widehat{i}_{t-1} + \widehat{g}_{\Omega,t} \\ \widehat{w}_t - \widehat{w}_{t-1} + \widehat{g}_{\Omega,t} \\ \widehat{L}_t \\ \widehat{\pi}_t \\ \widehat{S}_t \\ -\widehat{v}_t^I \end{bmatrix} + \begin{bmatrix} \overline{g}_\Omega \\ \overline{g}_\Omega \\ \overline{g}_\Omega \\ \overline{g}_\Omega \\ \overline{L} \\ \overline{\pi} \\ \overline{S} \\ \overline{g}_v \end{bmatrix}$$

where A and B denote matrices of reduced form coefficients that are non-linear functions of the structural parameters. v_t denotes the vector of model variables, ε_t the vector of exogenous disturbances, $gdp_t = \frac{GDP_t}{\Omega_t}$, $c_t = \frac{C_t}{\Omega_t}$, $i_t = \frac{I_t}{\Omega_t}$ and $w_t = \frac{W_t}{\Omega_t}$. The parameters $\overline{g}_\Omega$, $\overline{L}$, $\overline{\pi}$, $\overline{R}$ and $\overline{g}_v$ are related to the model's steady state as follow: $\overline{g}_\Omega = 100 \log g_\Omega$, $\overline{L} = 100 \log L$, $\overline{\pi} = 100 \log \pi$, $\overline{S} = 100 \log S$ and $\overline{g}_v = 100 \log g_v$. The symbol ˆ denotes a variable which is measured as a log-deviation from steady state.

The vector of observable variables at time t to be used in the estimation is

$$\mathbf{Y}_t = \left[\Delta \log Y_t, \Delta \log C_t, \Delta \log I_t, \Delta \log \frac{W_t}{P_t}, \log L_t, \pi_t, S_t, v_t^I \right],$$

where Δ denotes the first-difference operator.

Let Θ denote the vector that contains all the structural parameters of the model. The non-sample information is summarized with a prior distribution with density $p(\Theta)$. The sample information (conditional on version M_i of the DSGE model) is contained in the likelihood function, $p(\mathbf{Y}_T \Theta, M_i)$, where $\mathbf{Y}_T = [Y_{1,...,} Y_T]^{'}$ contains the data. The likelihood function allows one to update the prior distribution of Θ, $p(\Theta)$. Then, using Bayes' theorem, we can express the posterior distribution of the parameters as

$$p(\Theta \mid \mathbf{Y}_T, M_i) = \frac{p(\mathbf{Y}_T \mid \Theta, M_i) p(\Theta)}{p(\mathbf{Y}_T, M_i)}$$

where the denominator, $p(\mathbf{Y}_T, M_i) = \int p(\Theta) p(\mathbf{Y}_T \mid M_i) d\Theta$ is the marginal data density conditional on model M_i. In Bayesian analysis the marginal data density constitutes a measure of model fit with two dimensions: goodness of in-sample fit and a penalty for model complexity. The posterior distribution of parameters is evaluated numerically using the random walk Metropolis–Hastings algorithm. We simulate the posterior using a sample of two million draws and use this (after dropping the first 20% of the draws) to report $i)$ the posterior mean of the structural parameters and shock processes, and the 10 and 90 percentiles of their posterior distributions, and the $ii)$ parameter estimates conditioned on the posterior mode. All estimations are done using Dynare (Adjemian et al. (2011)).

3.3 Prior Distribution

Some parameters are held fixed prior to estimation. We assign them values commonly found in the literature. The quarterly rate of depreciation of physical capital δ is set at 0.025, implying an annual rate of depreciation of 10%. The steady-state ratio of government spending to GDP is 0.19, corresponding to the average value of G_t/Y_t in our sample. The elasticity of substitution between differentiated goods and that between differentiated labor skills are each set at 10.

Table 1 lists the choice of priors for the parameters we estimate. We use prior distributions which are broadly consistent with those found in the literature, for example by Smets and Wouters (2007) and Justiniano et al. (2011). For the share of intermediates into gross output, ϕ, we use a Beta prior with mean 0.5 and standard deviation 0.1. For the percentage of firms' input costs financed by working capital, ψ, we also use a Beta prior, with mean 0.3 and standard deviation 0.1.

4 Estimation Results

4.1 Parameter Estimates

Table 1 reports posterior modes of the structural parameters and shock processes and their associated standard deviations. These estimates are for the sample 1983:Q1-2019:Q4.

The shadow rate response to deviations of inflation from target is about 1.63, while that of the response to output growth from trend growth is 0.226. The degree of interest rate smoothing is 0.91. Brault et al. (2021) report the following estimates for a broadly similar model estimated for the sample 1984:Q1- 2007:Q3, which thus excludes 2008-2019: $\alpha_\pi = 2.27$, $\alpha_{\Delta y} = 0.183$ and $\rho_R = 0.823$. Therefore, when unconventional monetary policies translate into an estimated Taylor-type of rule, we find evidence of a somewhat more accommodative monetary policy stance to inflation when also taking into account the period 2008-2019 in the post-1983 sample.

Two parameters about which little is known based on the previous literature are ψ and ϕ. We report an estimate of ψ of 0.243. This estimate suggests that firms borrow working capital to finance a modest fraction of their variable input costs. The share of intermediate goods is estimated at 0.43. While this estimate suggests there is roundaboutness in the US production structure, it is somewhat lower than the value typically assigned by calibration to this parameter which is 0.5. A possible reason for this difference is that studies which calibrate ϕ tend to rely on evidence for the US manufacturing sector, while our estimate is for the US economy.

To assess the sources of business cycle fluctuations over our full sample, we compute the variance decomposition of our observables at the business cycle frequency of 6-32 quarters based on our estimated model. The results are reported in Table 2. The MEI shock with a contribution of about 33% is the main driving disturbance of the cyclical variance of output growth, followed by the TFP shock at 20%. Now, Justiniano et al. (2011) have found that MEI shocks contributed nearly 60% of the cyclical variance of output growth for a sample 1954:Q3-2009:Q1. But Brault et al. (2021) report a significant drop in the contribution of MEI shocks, to only 20%, for a sample 1984:Q1-2007:Q3 omitting the pre-1980s. Therefore, the increase from 20% to 34% seems to suggest MEI shocks had a greater cyclical role to play between 2008 and 2019, something our analysis will later confirm. Also, we find that IST shocks contribute almost nothing to the cyclical variance of our observables, except to the relative price of investment to consumption goods. This confirms that distinguishing between the two types of investment shocks may significantly affect the estimation results and identification of the sources of business cycle fluctuations.

The PM shock is also a significant a significant source of fluctuations over our sample, explaining a non-negligible 16% of the cyclical variance of output growth, 12% of that of investment growth, 18% of that of real wage growth, 18% of that in hours, 39% of that of inflation and 13% of that of the nominal interest rate. Justiniano et al. (2011) found for a pre-2008 postwar sample that the PM shock contributed nearly 0% of the cyclical variance of observables, except for the real wage (23%) and inflation (39%).

The PR shock explains a high 71% of the cyclical variance of consumption growth, 19% of that in output growth and inflation, and 18% in hours. Finally, monetary policy shocks explain nearly 41% of the variance of the shadow rate.

5 The Great Recession and Beyond

This Section investigates the sources of the Great Recession and slow recovery. First, we look at the behavior of shocks between 2008 and 2019. Second, we provide an impulse-response analysis of output and inflation conditioned on each of the eight shocks to identify which shocks behave more like demand-side disturbances moving output and inflation in the same direction, and which are more like supply-side disturbances moving output and inflation in opposite directions. Third, we compute the contribution, either negative or positive in percentage, to output growth, consumption growth, investment growth, hours growth and nominal interest rate of each of the eight shocks, and this quarter-per-quarter between 2008 and 2019.

5.1 Shocks Between 2008 and 2019

To analyze the behavior of shocks between 2008:Q1 and 2019:Q4, we compute Kalman smoothed shocks conditioned on information from our estimated model for the sample period 1983:Q1 to 2019:Q4. They are displayed in *Figure 1* for the eight shocks of the model.

The GR witnessed several contractionary shocks. The first quarter of 2008 saw a combination of negative shocks to TFP, GS and MEI. In the second and third quarter of 2008, the main contractionary shocks were those to MEI, PR, PM and TFP. However, the largest contractionary shock occured in the fourth quarter of 2008 and was a negative shock to MEI. This shock was 2.6 times larger than its highest previous negative value recorded in 1988:Q1. The PR shock was often negative during the 2008-2019 period, with the largest negative value also in 2008:Q4. The PM shock was generally positive during the GR, except in 2008:Q4 where it was strongly negative. The TFP shock was significantly positive during the GR, except at the early stage of the recession.

As for policy shocks, we see that the MP shocks were mainly negative between 2008 and 2014:Q4, and often positive between 2015 and 2019. Moreover, when negative the MP shocks between 2015 and 2019 were much smaller on average than they were between 2008 and 2014. The government spending shock negative at the start of the GR. It was positive in 2008:Q4, reaching its highest positive value in 2009:Q1. However, between 2009:Q3 and 2019:Q4, these shocks were mainly negative.

Figure 2 summarizes movements in the shadow rate between 2008 and 2019. The Fed gradually raised the shadow rate as of 2014:Q2, and then set the Fed funds rate above the ZLB in 2015:Q3. The Fed funds rate eventually reached 2.4% by 2018:Q1. Thus, the higher shadow rates coincided with periods where MP shocks were less negative, and became eventually positive.

Figure 3 presents the impulse-response functions (IRFs) for level of output and inflation (in annualized % points) conditioned on each of the eight shocks of our model. They are IRFs to a one standard deviation positive shock based on posterior modes. Of the eight shocks, four behave like demand-side disturbances pushing output and inflation in the same direction: MP, GS, PR and MEI. Two behave more like supply-side disturbances moving output and inflation in opposite directions: TFP and PM.

5.2 Dissecting the Sources of the Great Recession and Beyond

We dissect the sources of the GR and recovery by using Kalman smoothed shocks from our estimated model. We compute their quarter-by-quarter percentage contribution (positive or negative) to output growth, consumption growth, investment growth, hours growth, and inflation. They are reported in Figures 4 to 7, where the contribution of each type of shock is identified by a different colour.

Figure 4 suggests that the factors contributing negatively to output growth during the GR were shocks to MEI, PM, PR, TFP (in the early stage of the GR) and GS (later in the GR). Meanwhile, the factors which had a positive impact on output growth were those to TFP (later in the GR), MP and GS (from 2008:Q4 to 2009:Q2). The factors that slowed the recovery were somewhat different than those that drove the GR. They were mainly PM shocks (early in the recovery), and TFP shocks (later in the recovery). PM shocks (later in the recovery) and MP shocks were factors contributing positively to the recovery.

Between 2010:Q1 and 2014:Q4, MP shocks generally had a modest stimulative impact on output growth compared to their stronger expansionary effects during the GR. GS shocks had both contractionary and expansionary on output growth, and were not a factor speeding up the recovery as we later show.

However, between 2015 and 2019, MP shocks clearly had contractionary effects on output growth. These contractionary effects were larger than the expansionary effects they had previously had during the recovery. Therefore, by returning to interest rates above the ZLB and relatively strong positive MP shocks in 2015 and 2016, the Fed contributed to some extent to undo the positive effects of unconventional monetary policy on output growth recorded between 2010 and 2014. This was also the case, but to a lesser extent between 2017 and 2019.

Figure 5 looks at consumption growth. The main factors contributing to depress consumption during the GR have been shocks to preferences, price markup, TFP (in the early stage of the recession) and government spending. Unlike output growth, MEI shocks did not have a negative impact on consumption growth. As for output growth, MP and TFP shocks (after 2008:Q3) contributed positively to consumption growth during the GR. Again, the factors that slowed the consumption recovery were shocks to PR, TFP (early in the recovery), and PM (later in the recovery). MEI shocks had some negative impact on consumption growth during the fiscal shocks had a moderate expansionary impact on the consumption recovery.

As for output growth, the effects of monetary policy shocks on consumption growth were contractionary between 2015 and 2019. Other factors that contributed negatively to consumption growth during that time were TFP and MEI shocks.

Figure 6 summarizes the factors contributing to investment growth between 2008 and 2019. What is striking is the strong negative effects adverse factors had on investment growth. Unsurprisingly, MEI shocks were those contributing most negatively on investment growth during the GR. They were followed by adverse PM shocks, and to a lesser extent by TFP shocks. The 2010-2014 period saw adverse TFP and MEI shocks slowing the recovery. Meanwhile, PM and PR shocks had positive effects on investment growth. MP shocks had some positive and negative effects on investment growth. Fiscal shocks had no effect.

Again, as for output growth and consumption growth, in 2015 and 2016, MP shocks had quite a significant negative impact on investment growth. It was also the case between 2017 and 2019. Menawhile, MEI and PM shocks had some positive impact on investment growth. Fiscal shocks essentially had no impact on investment growth throughout the 2008-2019 period.

Figure 7 shows how different factors affected hours growth between 2008-2019. The shocks contributing negatively to hours growth during the GR were about the same as for output growth: MEI, PM, PR, TFP (early in the GR), and GS (later in the GR). Those that had a positive impact on change in hours were shocks to TFP (later in the GR), MP and GS (from 2008:Q4 to 2009:Q2).

MP and GS shocks did not have much of an impact on change in hours during the recovery, that saw mostly PM shocks having a positive effect and TFP shocks having a negative effect on change in hours.

Once more, MP shocks contributed negatively to change in hours between 2015:Q1 and 2017:Q3, and in a few periods after. Fiscal shocks contributed both negatively and positively, but their effects are relatively small.

Figure 8 dissects the contribution of shocks to period-by-period inflation. During the GR, the main factors which had a negative impact on inflation were by order of importance RP shocks, MEI shocks, TFP shocks and PM shocks (in 2008:Q4). Meanwhile, those contributing positively to inflation were by far PM and MP shocks. Whereas the shocks that affected inflation negatively were quantitatively more important than those having a positive impact, the positive effects of PM and MP shocks were nonetheless sufficiently important to weaken deflation during the GR. Note that MP shocks continued to have a significant positive impact on inflation from 2010:Q1 to 2015:Q1, but that after their influence on inflation declined quite rapidly until the end of 2019:Q4.

6 Macro Policies and Inflation Between 2008 and 2019

The present Section studies the effectiveness of fiscal and monetary policies between 2008 and 2019. It also looks at the behavior of inflation during the same period. For output, consumption, investment and hours, each figure sets the level of a variable to 100 in 2008:Q1.

6.1 Fiscal and Monetary Policies

Figure 9 compares the baseline (actual) paths of output and inflation and their counterfactual paths without government spending shocks. Without the strong positive government spending shocks occuring in 2008:Q4, and 2009:Q1-2009:Q2, the recession would have been somewhat more severe. However, after the GR fiscal shocks were not only much smaller but they were often negative. As a result, they did not have a stimulative impact on output. If anything, based on our counterfactual they contributed to lower the level of output relative to the actual path. Government spending shocks had no effect on inflation.

Figure 10 makes a similar comparison, this time between the baseline paths of output, consumption, investment, hours and inflation and their counterfactuals without monetary policy shocks. As the Fed after the start of the recession took some time before adopting unconventional monetary policy tools, MP shocks had a relatively small impact on real variables during the first three quarters of the GR. However, they had a sizable impact on the troughs of real variables.

MP shocks also helped output, consumption and investment to return to their pre-recession levels more rapidly. Since it was significantly more affected by the GR, it took more time for investment to return to its pre-recession level than output and consumption. Working hours, however, have not returned yet to their pre-recession level by 2019:Q4. Our evidence hence suggests that unconventional monetary policies contributed to mitigate the severity of the recession and to somewhat speed up the recovery.

However, despite unconventional monetary policy tools had a stimulative impact between 2008 and 2014, there were concerns among policymakers that the Fed started to raise the shadow rate too early in 2014:Q2. This eventually led the Fed to set the nominal interest rate above the ZLB from 2015:Q3 until 2019:Q4 (see *Figure 2*). The concerns were that by raising interest rates too rapidly, the Fed would prevent real variables from returning to their pre-recession levels more rapidly. Such concerns have been expressed by economists like Lael Brainard, William Dudley and Daniel Tarullo in 2015, as witnessed by the Transcript of the FOMC Meeting.

Our evidence tends to support these concerns. *Figure 1* shows that when the Fed started to raise the nominal interest rate in 2014:Q2, MP shocks became less negative and often positive between 2015:Q1 to 2019:Q4. *Figures 4-7* clearly show that MP shocks generally had a negative impact on the growth rates of output, consumption, investment and hours growth between 2015 and 2019. *Figure 10* shows that investment by 2015:Q1 almost reached its pre-recession level, but then dropped quite significantly until 2016:Q4. Recall that this corresponds to a period where MP shocks had been significantly positive and weakly negative. Furthermore, MP shocks stopped having a stimulative impact on investment after 2017:Q3. This slowed the output recovery.

A different way to assess whether the Fed raised interest rates too rapidly is by evaluating the annualized percentage contributions of MP shocks to the average growth rates of output, consumption, investment and change in hours relative to the counterfactuals without MP shocks.

We do this for the following periods: 2008-2012, 2008-2014 and 2015-2019. The results are reported in *Table 3*.

With MP shocks, output growth is found to be 1.03% higher on average than without them for the period 2008-2012, and 0.86% higher for the period 2008-2014. By contrast, output growth was on average 1.02% lower with MP shocks for the period 2015-2019. Consumption growth was 0.6% higher on average for the period 2008-2012 and 0.55% higher for the period 2008-2014. But without MP shocks it would have been 0.45% higher for the period 2015-2019.

Investment growth was most affected by the raise in interest rates between 2015 and 2019. For the 2008-2012 period, investment growth was 3% higher on average with MP shocks, while it was 2.26% higher for the period 2008-2014. However, it would have 3.56% higher without MP shocks for the period 2015-2019.

As for hours growth, it was 0.84% higher on average for the period 2008-2012, and 0.67% higher for the period 2008-2014. Then, for the period 2015-2019, it was 0.91% lower on average with MP shocks.

Now, where there compelling reasons to fear that inflation was about to accelerate in the year 2015 and after? While it is true that the unemployment rate has dropped from 10% in 2009 to 5% in 2015, working hours were still significantly below their pre-recession level in 2014-2015. Furthermore, by the time the Fed began to raise the shadow rate in 2014:Q2, inflation had declined from 4.3% in 2011:Q2 to slightly above 2% in 2014:Q2 and could hardly be viewed as accelerating at the time.

Therefore, our evidence lends credence to the view that the Fed had returned to positive interest rates too rapidly. In retrospect, these concerns are even more acute that, as of 2020, the world economy had suffered from another exceptional event in the form of the COVID 19 pandemics.

7 Inflation During the Great Recession

Del Negro et al. (2015), and Christiano et al. (2015) have taken a closer look at the behavior of inflation during the Great Recession and ensuing years of recovery following Hall (2011)'s argument that inflation according to the New Keynesian credo should have been more responsive to depressed economic activity during the GR, and therefore should have declined by more than it did. Del Negro et al. suggest that adding financial frictions and a time-varying inflation target to the NK model helps predict a strong contraction in economic activity and a protracted but relatively modest decline in inflation during the GR and recovery years. Using a DSGE model with perfect nominal wage flexibility, sticky prices, a binding ZLB constraint and financial frictions, Christiano et al. (2015) show that a fall in TFP relative to trend and a rise in the cost of working capital might explain the behavior of inflation during the Great Recession.

Figure 8 assesses the factors that contributed to inflation between 2008 and 2019. The factors that had a negative impact on inflation during the GR are shocks to preferences, MEI, TFP and PM (in 2008:Q4). Those that contributed positively, and hence prevented a stronger deflation during the GR are shocks to MP and PM.

The key role of PM shocks in explaining the behavior of inflation during the GR could appear to some as "disturbing to the extent that such markup shocks are difficult to interpret and have small effects on variables other than inflation" (Del Negro et al., 2015). However, we have found that PM shocks for the sample 1983-2019 explain much more than just the cyclical variance of inflation, contributing quite significantly to cyclical variance of output growth, investment growth, real wage growth and change in working hours. Furthermore, de Walque et al. (2006) did propose an explanation that the estimated price mark-up shocks represent relative price (e.g. productivity) shocks in a flexible-price sector.

8 Conclusion

What have we learned from dissecting key macroeconomic data over the period 2008-2019? After identifying the factors that drove the GR, we turned our attention to the role played by macroeconomic policies in mitigating the severity of the recession, speeding the recovery and stimulating economic activity more generally during that decade.

We have shown that fiscal policy through significant positive government spending shocks had some effect at reducing the severity of the GR, especially early in the recession, but not after. Unconventional monetary policy had a stimulative impact on the economy between 2008:Q3 and 2014:Q2. But after that, our evidence suggests that monetary policy slowed the recovery, our counterfactual experiments revealing that between 2015 and 2019, output growth, consumption growth, investment growth and change in working hours would have been higher on average without monetary policy shocks.

We have also argued that while the unemployment rate has dropped from 10% in 2019 to 5% in 2015, this was hidding another reality, namely that per capita total working hours were not back to their pre-recession level even by 2019. Moreover, we have shown there was no indication that inflation was about to accelerate when the Fed decided to raise the shadow rate in 2014:Q3, to eventually lift it above the ZLB until 2019.

We conclude that extraordinary events like the GR and the COVID 19 pandemics wiill necessitate in the future a coordination of expansionary fiscal and unconventional monetary policies, and this for much longer period of time than experienced during the 2008-2019 historical episode.

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Table 1: Results from posterior maximization (parameters)

	Prior			Posterior	
	Dist.	Mean	Stdev	Mode	Stdev
α	norm	0.300	0.0500	0.1524	0.0099
ι_p	beta	0.500	0.1500	0.1076	0.0484
ι_w	beta	0.500	0.1500	0.4120	0.0825
g_Y	norm	0.400	0.0250	0.3752	0.0241
g_I	norm	0.200	0.0250	0.2442	0.0250
h	beta	0.500	0.1000	0.8526	0.0232
$\bar{l}$	norm	0.000	0.5000	-0.1050	0.4903
$\pi^\star$	norm	0.500	0.1000	0.6009	0.0857
$100(\beta^{-1}-1)$	gamm	0.250	0.1000	0.1044	0.0431
χ	gamm	2.000	0.7500	2.9976	0.7740
ξ_p	beta	0.660	0.1000	0.7398	0.0323
ξ_w	beta	0.660	0.1000	0.7027	0.0364
σ_a	gamm	5.000	1.0000	5.2776	0.9963
κ	gamm	4.000	1.0000	5.6117	0.9371
ψ	beta	0.300	0.1000	0.2433	0.0964
ϕ	beta	0.500	0.1000	0.4290	0.0722
α_π	norm	1.500	0.3000	1.6259	0.1957
$\alpha_{\Delta y}$	norm	0.125	0.0500	0.2255	0.0499
ρ_R	beta	0.600	0.2000	0.9105	0.0108
ρ_z	beta	0.400	0.2000	0.3169	0.0674
ρ_g	beta	0.600	0.2000	0.9939	0.0046
ρ_v	beta	0.200	0.1000	0.3218	0.0748
ρ_p	beta	0.600	0.2000	0.9883	0.0087
ρ_w	beta	0.600	0.2000	0.9531	0.0210
ρ_b	beta	0.600	0.2000	0.9017	0.0325
ρ_I	beta	0.600	0.2000	0.9422	0.0264
θ_p	beta	0.500	0.2000	0.7983	0.0693
θ_w	beta	0.500	0.2000	0.9775	0.0152
σ_r	invg	0.100	1.0000	0.1268	0.0081
σ_z	invg	0.500	1.0000	0.3989	0.0401
σ_v	invg	0.500	1.0000	0.3080	0.0180
σ_{η^I}	invg	0.500	1.0000	0.5640	0.0330
σ_p	invg	0.100	1.0000	0.2355	0.0240

(Continued on next page)

Table 1: (continued)

	Prior			Posterior	
	Dist.	Mean	Stdev	Mode	Stdev
σ_w	invg	0.100	1.0000	0.4320	0.0279
σ_b	invg	0.100	1.0000	0.0715	0.0092
σ_{ϵ^I}	invg	0.500	1.0000	3.9460	0.4962

Table 2: VARIANCE DECOMPOSITION (IN PERCENT)

	MP	N. Tech.	Govt.	IST	P-Markup	W-Markup	Pref.	MEI
Output	7.63	19.78	4.49	0.59	15.54	0.69	18.52	32.76
Consumption	3.25	19.30	1.04	0.06	4.92	0.99	69.56	0.88
Investment	5.22	6.20	0.00	1.25	12.47	0.46	3.54	70.85
Wage	0.28	39.18	0.00	0.14	18.17	40.96	0.41	0.86
Log Hours	8.45	14.02	2.53	0.27	18.00	2.27	18.22	36.24
Inflation	5.53	11.70	0.19	0.38	38.83	7.18	18.67	17.52
RPI	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00
Nom. Interest Rate	41.20	3.14	0.25	0.37	12.85	3.63	16.81	21.75

Notes: The variance decomposition is reported at the business cycle frequency of 6-32 quarters. Output, consumption, investment, and wages are in growth rates.

Table 3: Average growth rates without MP shocks

	2008Q1-2012Q4	**2008Q1-2014Q4**	**2015Q1-2019Q4**
Output growth	1.03	0.86	-1.02
Consumption growth	0.60	0.55	-0.45
Investment growth	3.00	2.26	-3.56
Hours growth	0.84	0.67	-0.91

Notes: Numbers report the average difference in growth rates for variable with and without monetary policy shocks across the three periods.

Figure 1: KALMAN SMOOTHED SHOCKS OVER THE GREAT RECESSION AND RECOVERY YEARS

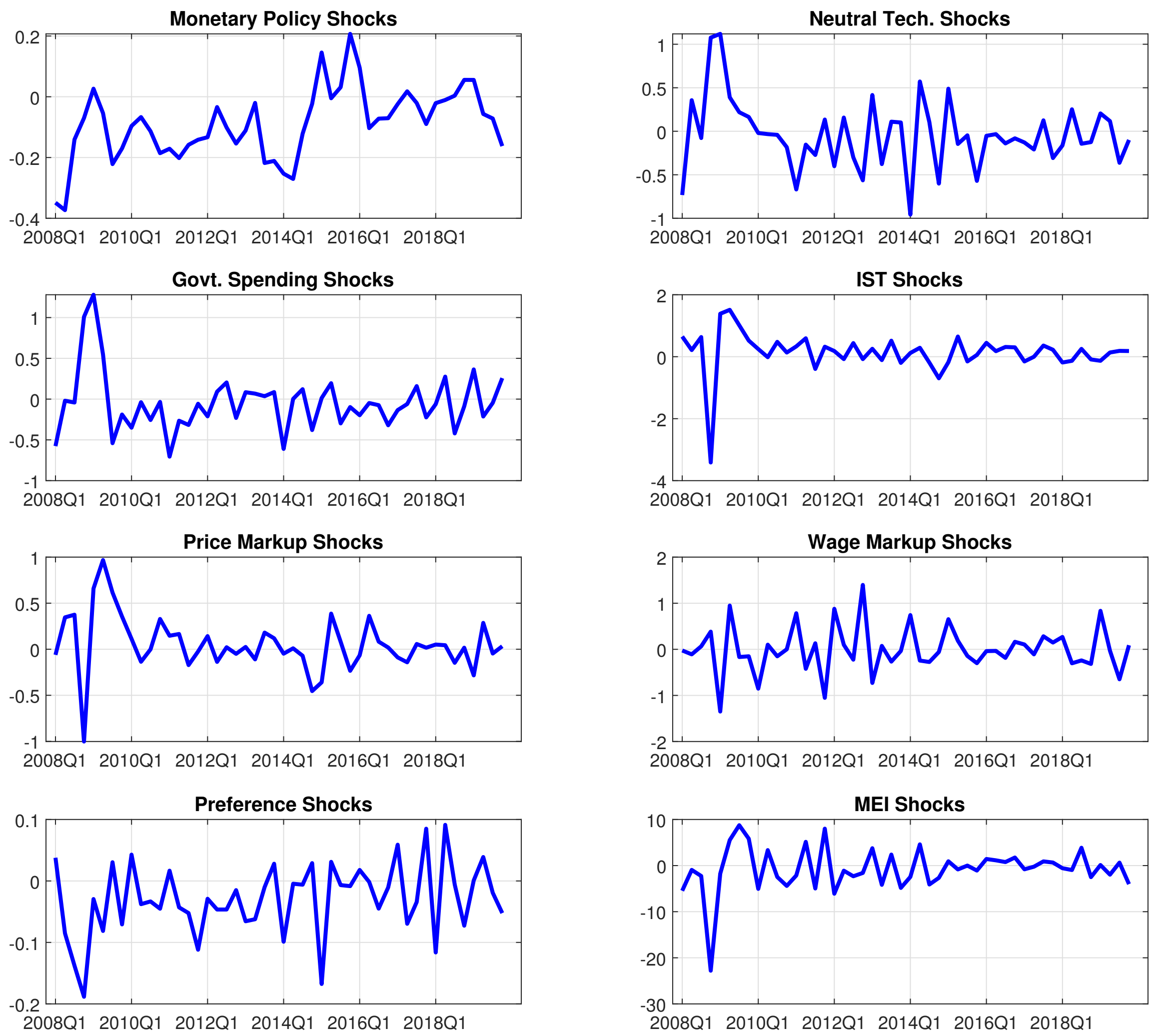

Figure 2: SHADOW RATE

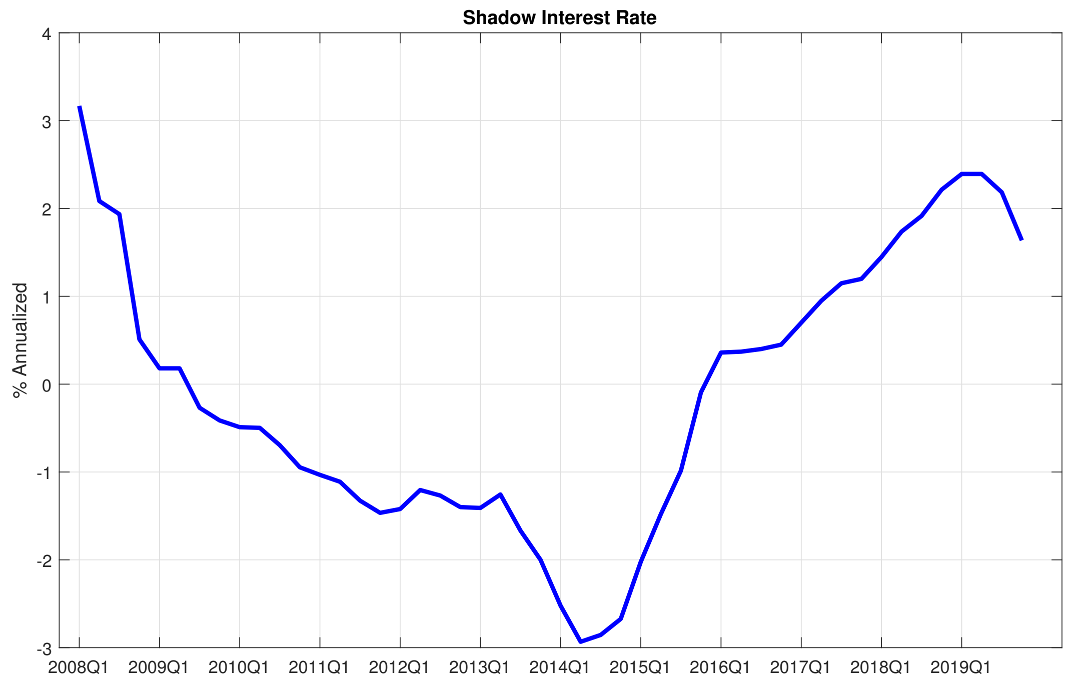

Figure 3: IMPULSE RESPONSE FUNCTIONS FOR OUTPUT (LEVEL) AND INFLATION

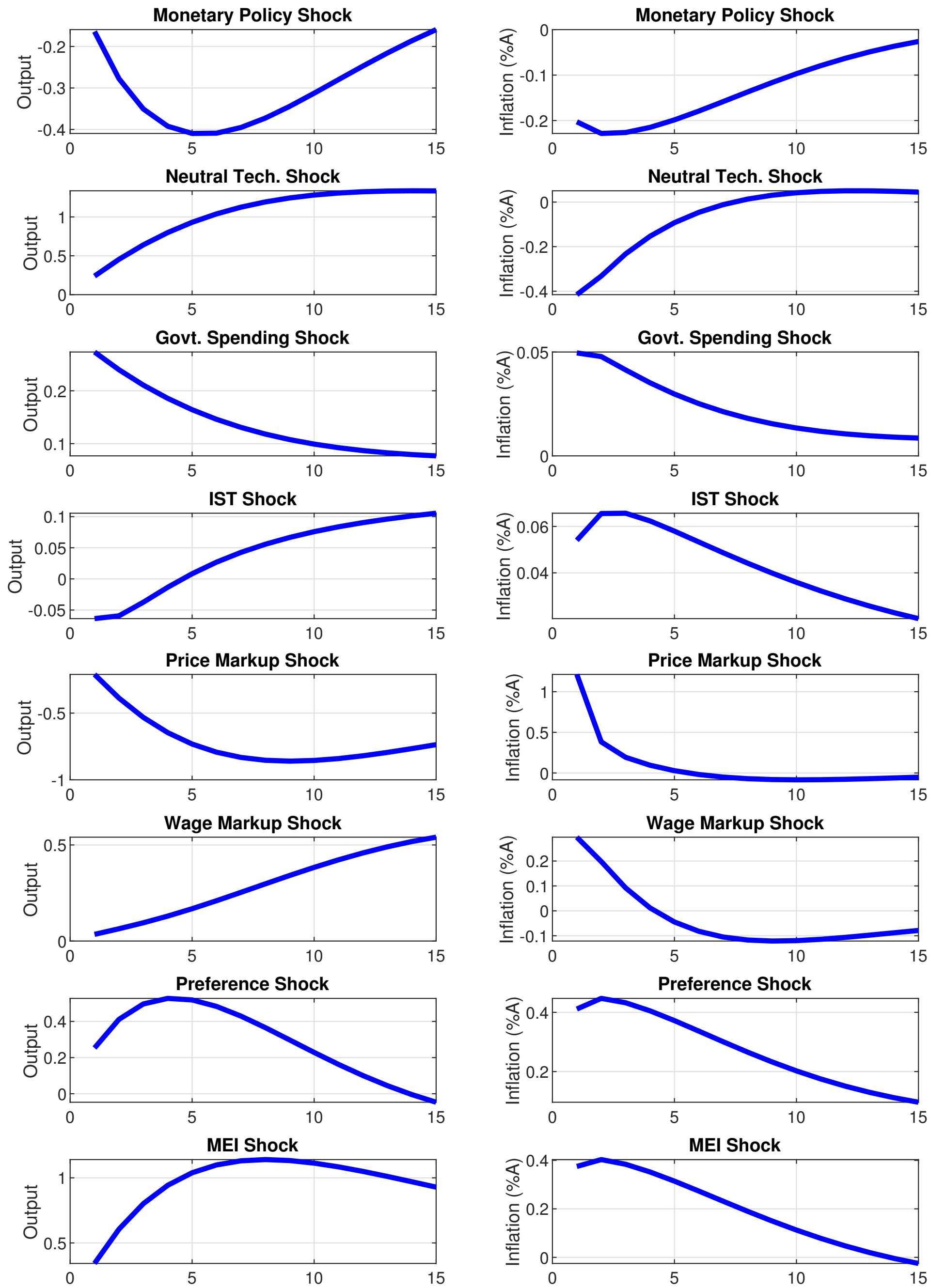

Figure 4: OUTPUT GROWTH SHOCK DECOMPOSITION

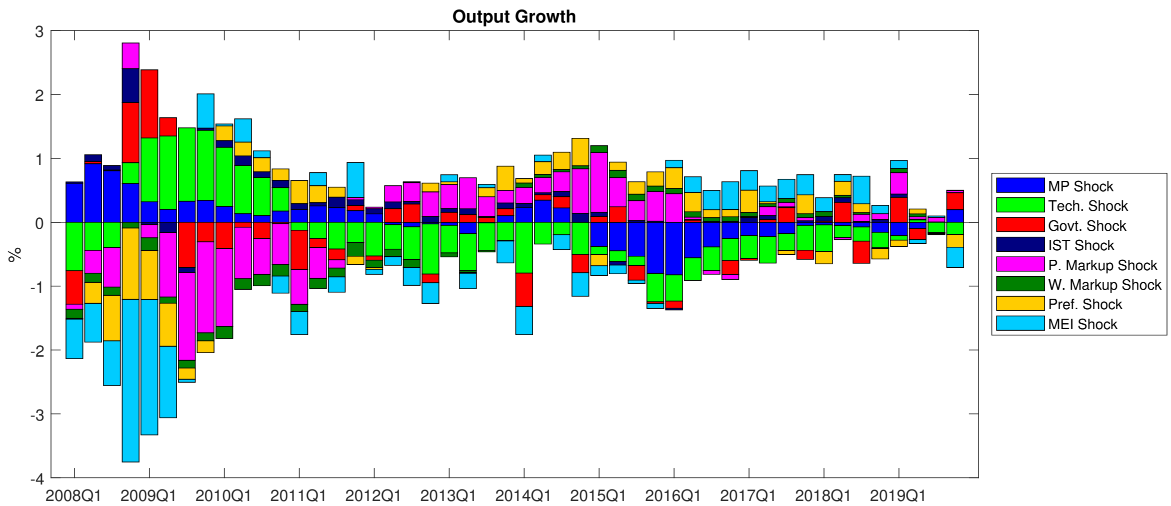

Figure 5: CONSUMPTION GROWTH SHOCK DECOMPOSITION

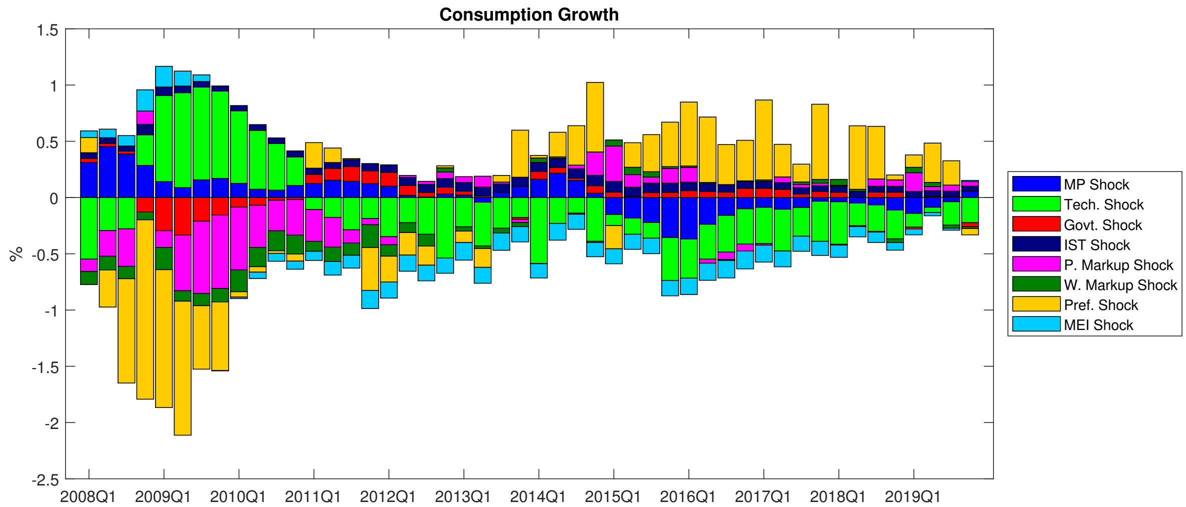

Figure 6: INVESTMENT GROWTH SHOCK DECOMPOSITION

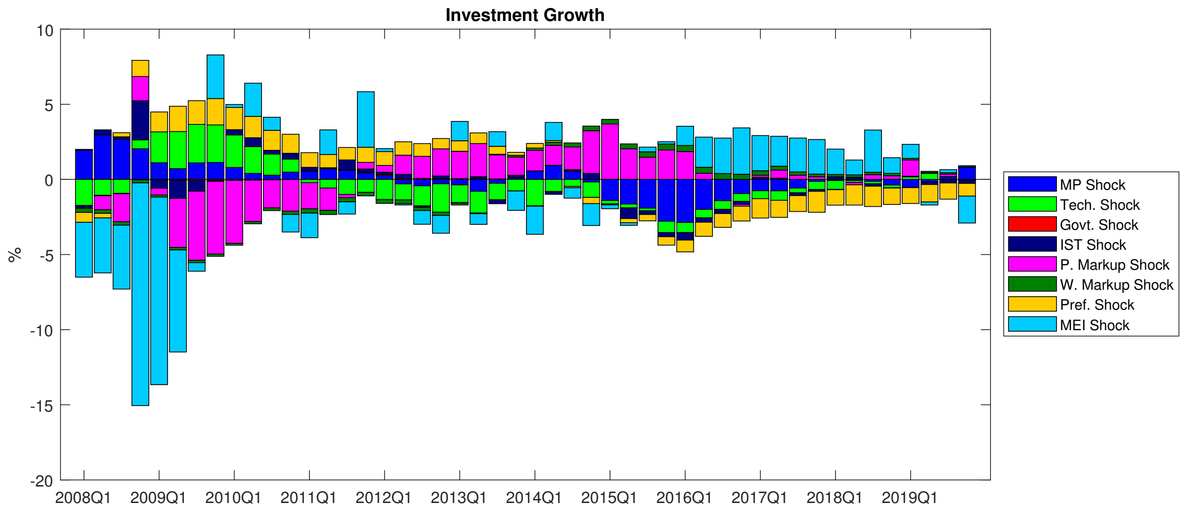

Figure 7: LOG HOURS SHOCK DECOMPOSITION

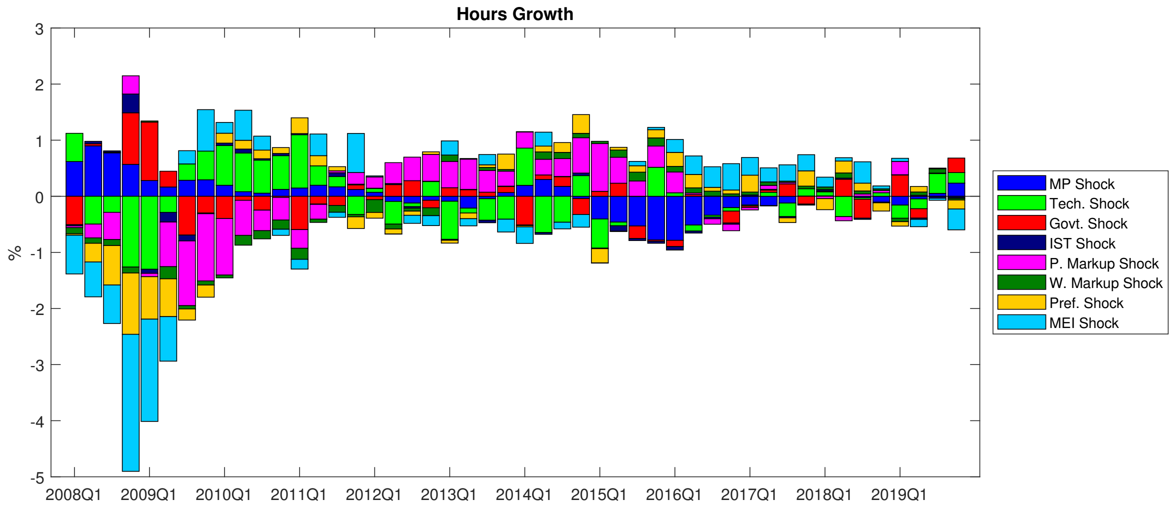

Figure 8: INFLATION SHOCK DECOMPOSITION

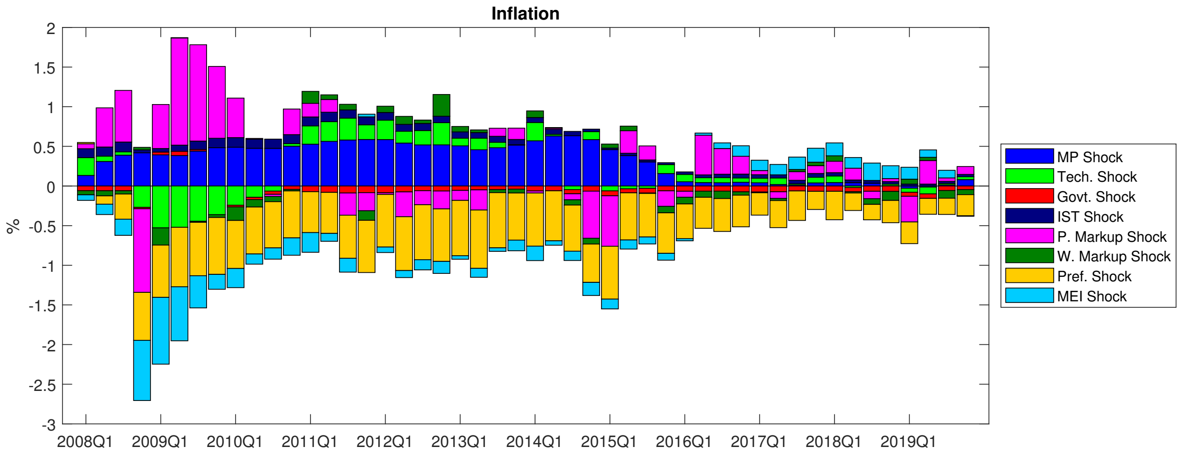

Figure 9: Counterfactual: No Fiscal Policy

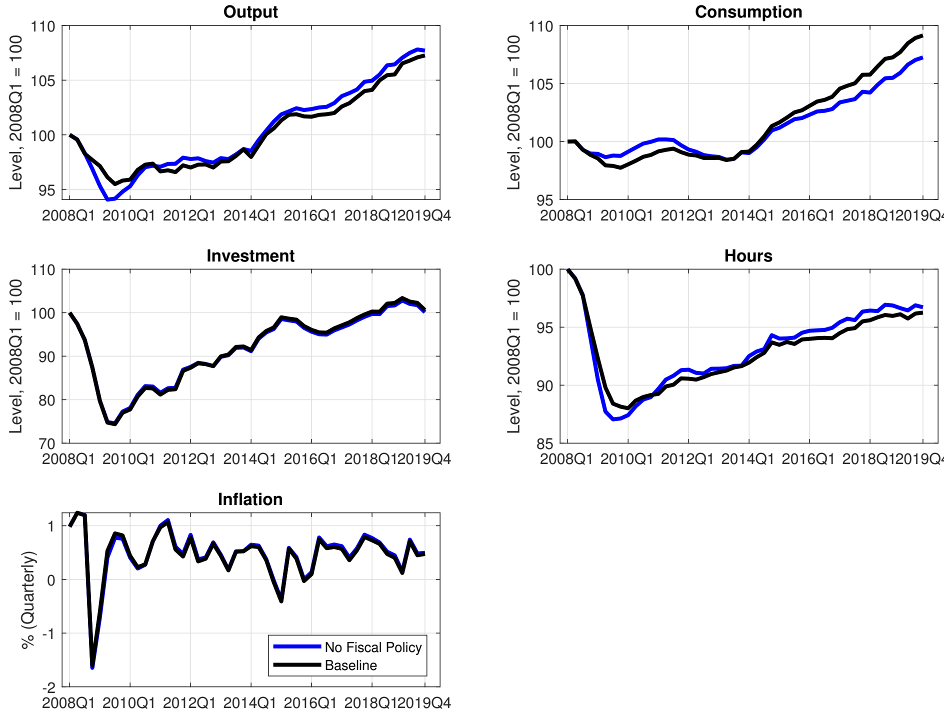

Figure 10: COUNTERFACTUAL: NO MONETARY POLICY