

MONETARY REGIMES, MONEY SUPPLY, AND THE USA BUSINESS CYCLE SINCE 1959: IMPLICATIONS FOR MONETARY POLICY TODAY

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The monetary authority's choice of operating procedure has significant implications for the role of monetary aggregates and interest rate policy on the business cycle. Using a dynamic general equilibrium model, we show that the type of endogenous monetary regime, together with the interaction between money supply and demand, does well to capture the actual behavior of a monetary economy—the USA. The results suggest that the evolution toward a stricter interest rate-targeting regime renders central bank balance sheet expansions ineffective. In the context of the 2007–2009 Great Recession, a more flexible interest rate-targeting regime would have led to a significant monetary expansion and more rapid economic recovery in the USA.

Keywords: Monetary Regimes, Monetary Policy, Money Demand, USA Business Cycle

1. INTRODUCTION

Most central bank models base their conventional policy analysis on a strict interest rate reaction function; a Taylor-type policy rule, with little or no role for the money stock [Fernández-Villaverde et al. (2010)]. This characterization of the operational procedures of central banks has not only divorced money from monetary policy analysis, it has also led to the assertion that interest rate policy can be made independent from all things monetary—the so-called “decoupling principle” (e.g. Borio and Disyatat (2010)).¹ The principal problem with this policy position is the long-standing confusion over the effect of the monetary authority's choice between reserves and interest rate manipulation [Hetzel (1986);

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Ireland (2014)]. And to understand the effect of monetary policy, we require an endogenous monetary framework consistent with *both* theory and empirical regularity. We, therefore, introduce an explicit monetary transmission mechanism for the money supply process in a standard New Keynesian (NK) framework—with special emphasis on the importance of broad Divisia monetary aggregates [Hendrickson (2014); Belongia and Ireland (2016, 2019)].

The purpose of this paper is twofold. First, we show that the type of monetary policy regime—that is, the monetary policy rule chosen to determine the money stock, and hence the price level—has significant implications as to the role of monetary aggregates and interest rate policy in a standard NK framework. Second, we show that the USA economy need not succumb to the stagnant state, with below-target inflation and a near zero policy rate, observed since the onset of the Great Recession. On one hand, an interest rate targeting regime (*de facto* or *de jure*) renders central bank balance sheet expansions ineffective. At the zero lower bound (ZLB), this regime is also ineffective. On the other hand, an expansion of the central bank's balance sheet will be effective if the central bank relaxes its interest rate peg. This result obtains if we add a tractable banking sector with an explicit monetary transmission mechanism for the money supply process.

Specifically, we highlight three characteristics of a monetary economy in favor of a traditional model of money stock determination that is based on the Fisher relation, price-level determination, and the behavior of money demand. Together, these three conditions form the core of the general equilibrium framework envisaged by McCallum (1981, 1986), McCallum and Hoehn (1983) and Hetzel (1986), which we incorporate into an NK dynamic stochastic general equilibrium (DSGE) model. The key contribution here is that for nominal money to play a causal role in determining the price level, at least some of the determinants of nominal money supply must differ from the determinants of real money demand. And by implication, the price level adjusts to equate the real quantity of money supply with the real quantity demanded. Put another way, changes in the supply of money arise from the disequilibrium between the real (market) rate of interest and the natural rate of interest. And the ability of monetary policy to manipulate this disequilibrium (through, e.g. the policy rate, bank reserves, or price expectations) generates temporary real effects.

The model is estimated by Bayesian methods over the period 1959Q1–2019Q4. The estimation period is chosen for two reasons. First, the long sample period serves to highlight the empirical and theoretical coherence of the model within a framework that incorporates an explicit monetary transmission mechanism for the money supply process. In doing so, we provide a detailed account of the USA business cycle under alternative monetary regimes (see, e.g. Belongia and Ireland, 2016; Benchimol and Fourçans, 2019). Second, we want to simulate counterfactual scenarios of monetary regimes given the estimated structure of the model economy before the onset of the Great Recession and the structural break in free reserves in 2007Q4.² Specifically, we simulate the counterfactual scenario of a monetary expansion for the recovery period of the Great Recession, and

we evaluate the output-inflation trade-off of alternative monetary regimes in an optimal policy analysis.

The main findings show that monetary aggregates are important, not only for monetary policy, but for capturing the actual behavior of a monetary economy. The interaction between money supply and demand and the type of monetary regime captures the dynamics of the USA business cycle remarkably well over the observed 50 years. The results suggest that the evolution toward a stricter interest rate-targeting regime renders central bank balance sheet expansions ineffective. In the context of the 2007–2009 Great Recession, a more flexible interest rate-targeting regime would have led to a significant monetary expansion and a more rapid economic recovery in the USA. Specifically, counterfactual simulations at the ZLB indicate that a one-off permanent increase in the stock of (broad) money would have reduced the 2009Q3 output gap from -6% to -2% , maintained the central bank's 2% inflation target, and seen the normalization of interest rates from the ZLB. Although stylized, these results offer a clear alternative characterization of monetary policy that is often missing (or dismissed) from the contemporary narrative (see, e.g. Thornton, 2014; Belongia and Ireland, 2017).

Another principal contribution of this paper is to demonstrate that neither an interest rate-targeting regime nor a money growth rule is desirable. At the same time, a two instrument–two goal operational framework (the “decoupling principle”) overlooks money’s essential role in economic activity and the determination of the general level of prices.³ Rather than treating interest rates and reserves as unrelated, monetary authorities in a market economy should stabilize nominal income (or, equivalently, the product of the broad money supply and velocity) using both their monopoly over the monetary base and their interest rate policy. Under certain states of the world, at either the ZLB or highly elastic reserve demand, either interest rate policy or money base creation can be ineffective. Indeed, the superiority of an optimal combination policy was traced clearly in the seminal work of Poole (1970). But recent literature on the optimal choice of monetary policy instruments highlights the lack of research on Poole’s basic insights into modern dynamic general equilibrium models (e.g. Auray and Fève (2008), Berentsen and Monnet (2008), Chowdhury and Schabert (2008), and Schabert (2009)). To our knowledge, even these models overlook the dynamic interaction between the demand and supply of money that makes explicit the endogenous money supply process in monetary transmission mechanisms. That is, it is often assumed that the central bank adjusts or influences the nominal stock of money to provide the *real* stock of money demanded (and that the price level is irrelevant for market clearing). This paper aims to fill that gap in the literature.

The remainder of this paper is organized as follows. Section 2 describes the model with money stock determination and a market for bank reserves.⁴ Sections 3 and 4 present the estimation results and main findings on the basis of that model. Section 5 discusses counterfactual simulations of alternative regimes for optimal policy. Section 6 concludes.

2. THE MODEL ECONOMY

McCallum's (1981; 1986) two-equation, full employment IS-LM model with a money supply rule showed it was possible to peg the nominal interest to some target value with a money rule and obtain price determinacy. Hetzel (1986) extended McCallum (1986) to include a traditional banking sector specification. His model contains four key equations: a Fisher relation, a demand function for real money balances, a monetary rule, and a banking sector relationship between nominal money supply, the short-term market interest rate, and bank reserves. Equations (1) through (4) represent these four equations as first-order Taylor approximations around a deterministic steady state:

$$\text{Fisher relation : } i_t = E_t \pi_{t+1} + r_t, \quad (1)$$

$$\text{Money demand : } m_t^d - p_t = \phi_y y_t - \phi_i i_t, \quad (2)$$

$$\text{Monetary policy : } h_t = \rho_h h_{t-1} - v_h (i_t - \bar{i}), \quad (3)$$

$$\text{Money supply : } m_t^s = \frac{1}{rr} (\phi_h h_t - \phi_{fr} fr_t), \quad (4)$$

where i_t , π_t , and r_t are the nominal interest rate, inflation rate, and real rate of interest; p_t , y_t , h_t , fr_t , and m_t denote the price level, output, nonborrowed bank reserves, net supply of settlement balances (free reserves), and nominal money stock, respectively. The parameters ϕ_y and ϕ_i are the real income elasticity and the interest rate semi-elasticity of the demand for money, ρ_h is a persistence parameter, and v_h measures the degree to which the monetary authority smooths the nominal interest rate. Finally, rr is the reserve requirement ratio, where ϕ_h and ϕ_{fr} are the steady-state ratios of nonborrowed reserves and free reserves to the money stock.⁵

In the spirit of Benhimol and Fourçans (2012) and Belongia and Ireland (2014), we use the above approach to money stock determination to deviate from the traditional NK model with a Taylor-type monetary rule to include a monetary rule, equation (3), and a money supply condition, equation (4), which allows for alternative operational instruments and intermediate targets. Specifically, v_h captures the degree of interest rate smoothing enforced by the central bank. As $v_h \rightarrow \infty$, the money supply schedule becomes horizontal and we enter a monetary regime of interest rate-targeting—either a “pure” peg or a strict dynamic Taylor rule (e.g. by letting \bar{i} follow some monetary policy reaction function that responds to inflation and output). Money and reserves become endogenous, and the reserve money multiplier becomes irrelevant to the determination of the money stock (Hetzel, 1986, 5–6, 13, 17–18, 20). Under this type of regime, the model reduces to the standard NK framework [Benhimol and Fourçans (2012)].⁶ As $v_h \rightarrow 0$, we enter into a “pure” monetary aggregate targeting regime. The bank's decision problem for free reserves (fr_t) in an interest rate corridor or channel system is based on Whitesell (2006). In addition, we do not explicitly distinguish cash from reserve balances and deposits. Total bank reserves at the central bank therefore

represent the monetary base, and household deposits therefore represent the broad monetary aggregate.

2.1. System of Linearized Equations

Equations (5)–(16) form the system of 12 equations and 12 endogenous variables, excluding exogenous shock processes:

$$\text{Fisher relation : } i_t = E_t[\pi_{t+1}] + [r_t^n + \eta_c(E_t[\tilde{y}_{t+1}] - \tilde{y}_t)], \quad (5)$$

$$\text{Money demand : } m_t - p_t = \frac{\eta_c}{\eta_m} y_t - \frac{1}{\eta_m} i_t + \xi_{m_d,t}, \quad (6)$$

$$\text{Consumption Euler equation : } r_t = r_t^n + \eta_c(E_t[\tilde{y}_{t+1}] - \tilde{y}_t), \quad (7)$$

$$\text{Natural rate : } r_t^n = \eta_c(E_t[y_{t+1}^n] - y_t^n), \quad (8)$$

$$\text{Money supply : } m_t = h_t + \phi_{rr}(h_t - fr_t) + \xi_{m_s,t}, \quad (9)$$

$$\text{Nonborrowed reserve supply : } h_t = \rho_h h_{t-1} - v_h(i_t - i_t^T), \quad (10)$$

$$\text{Free reserve demand : } fr_t = \rho_{fr} fr_{t-1} - \frac{v_{fr}}{s}(i_t - i_t^T), \quad (11)$$

$$\text{Policy target rate : } i_t^T = \rho_i i_{t-1}^T + (1 - \rho_i)(\kappa_\pi \pi_t + \kappa_y \tilde{y}_t) + \epsilon_t^i, \quad (12)$$

$$\text{NK Phillips curve : } \pi_t = \beta E_t[\pi_{t+1}] + \tilde{\kappa} \tilde{y}_t, \quad (13)$$

$$\text{Output gap : } \tilde{y}_t = y_t - y_t^n, \quad (14)$$

$$\text{Natural output : } y_t^n = (1 + \eta_n)/(\eta_c + \eta_n) \xi_{z,t}, \quad (15)$$

$$\text{Inflation definition : } \pi_t = p_t - p_{t-1}, \quad (16)$$

where $\phi_{rr} = \frac{FR}{rrM} = \frac{FR}{RR}$ is the ratio of free reserves to required reserves. We assume that the policy rate target follows a Taylor-type rule. That is, the equation $\bar{i} = i^T$, therefore, represents the policy instrument (rule or target) that guides policy decisions. The natural rate r_t^n and natural output y_t^n are determined by the flexible price equilibrium.

Following Hetzel (1986), we capture four exogenous sources of shocks to the economy: a money demand shock, $\xi_{m_d,t}$; a money supply shock, $\xi_{m_s,t}$; a technology shock, $\xi_{z,t}$; and an interest rate target shock, ϵ_t^i . Notice that we exclude the standard price markup shock in the NK Phillips curve, which implies that firm price markups are constant. The idea here is to show that shifts in aggregate demand that arise from the interaction between money supply and demand and the policy rate target—that is, nominal shocks—are well able to account for business cycle fluctuations. As will be shown, the sticky price equation is still key to generating real effects in a rational expectations framework. A non-separable utility function, as in Benchimol and Fourçans (2012) and Li et al. (2020), would ensure temporary real effects from monetary fluctuations without sticky pricing, but the point of this paper is to show that the standard NK framework—with separable utility, monetary neutrality, and sticky prices—assumes a special case in a continuum of monetary regimes. As such, we show that the type of monetary

regime significantly alters the transmission mechanism of shocks through the economy.

3. ESTIMATION

The model is estimated by Bayesian methods over the period 1959Q1–2019Q4. Specifically, we compare estimated versions of the model over the periods 1959Q1–1983Q4, 1984Q1–2007Q3, and 2007Q4–2019Q4 (see also, Belongia and Ireland, 2016; Benchimol and Fourçans, 2019). Each period broadly corresponds to alternative eras of monetary regimes. The first period covers the Great Inflation era (a period of greater monetary policy discretion and macroeconomic instability), the second period covers the Great Moderation era (a period of more predictable monetary policy and macroeconomic stability), and the third period covers the Great Recession and subsequent stagnated recovery (a period that saw the shift to a strict interest rate targeting or “floor” regime).

We set the prior parameter values and distributions of the model to fit the USA economy following the example of Smets and Wouters (2007) and Ireland (2009). All persistence parameters are set to 0.8, with standard deviations of 0.10. We use the USA data obtained from St. Louis Federal Reserve Economic Data (FRED) database and the Center for Financial Stability to calibrate the relevant steady-state ratios for the banking sector and to estimate the model. The discount factor, $\beta = (1 + r)^{-1}$, is fixed at 0.98, corresponding to a steady-state quarterly real interest rate of 2%. The output gap, inflation, money growth, and the nominal interest rate are treated as observables, linearly detrended as follows:

- π_t : log-difference of GDP implicit price deflator (year-on-year).
- \tilde{y}_t : difference between the log of real GDP per capita and real potential GDP per capita.
- Δm_t : log-difference of Divisia M4 money stock per capita.
- i_t : short-term (3-month) nominal interest rate.

Following the recommendations of Barnett (1980, 2016); Belongia and Ireland (2016, 2019); Hjertstrand et al. (2018); Jadidzadeh and Serletis (2019), we make use of a Divisia monetary aggregate (a superlative index), as opposed to simple sum aggregation, to internalize substitution effects among assets.⁷ Given that the 3-month Treasury bill (market) rate tracks the effective funds rate over the sample period very closely, and that the objective of the policymaker is to influence market interest rates, we use the 3-month Treasury bill rate to represent the nominal interest rate (i). Furthermore, to provide a more accurate description of monetary policy when confronted with the ZLB on nominal interest rates, we use the shadow federal funds rate developed by Wu and Xia (2016) for the 2007Q4–2019Q4 period (see also Benchimol and Fourçans, 2019). This shadow rate summarizes the macroeconomic effects of USA unconventional monetary policy (credit easing, quantitative easing, and forward guidance) by allowing the policy rate to be negative.⁸

Table 1 reports the prior distribution, means, and standard deviations, as well as the posterior means, medians and confidence intervals of the estimated parameters.⁹ The estimated structural parameters for households and firms are stable across all estimation periods. The value $\eta_m = 5$ implies an interest elasticity of money demand of -0.2 . This means that a 100-basis point increase in the interest rate reduces the quantity of money demanded by 20%. The relative risk aversion parameter η_c is less than η_m in all estimation periods and falls in the range of 3–5, which implies an intertemporal elasticity of substitution of between 0.2 and 0.33. The elasticity of labor supply and labor's share in production are approximately unity and two-thirds. A value of θ of approximately 0.875 implies that firms adjust their prices on average every eight quarters.

The estimated parameters characterizing the monetary regime show that both free reserves and nonborrowed reserves are highly elastic over the Great Moderation period; whereas, nonborrowed reserves have a much greater influence over the money stock in the earliest sample period. For the most recent sample period, the estimated elasticities of free reserves and nonborrowed reserves are inconsequential since ϕ_{rr} is very large under the floor regime, which renders money supply shocks ineffective (see Figure 1). This finding corresponds well with the evolution of the Federal Reserve's monetary operating procedures toward an interest rate-targeting regime. Given this slant toward an (intermediate and then strict) interest rate target since 1959Q1, money demand shocks largely “determine” the price level, which is highly persistent.¹⁰ Innovations to the target policy rate can best be described as a highly smoothed AR(1) process. As such, cyclical fluctuations to the short-term nominal interest rate are largely determined endogenously through money demand and supply.

4. EMPIRICAL FINDINGS FOR THE USA BUSINESS CYCLE

4.1. Impulse Response Functions

Figures 1 and 2 show the impulse responses to a technology shock, an interest rate target shock, a money supply shock, and a money demand shock for our three subsample periods: 1959Q1–1983Q4, 1984Q1–2007Q3, and 2007Q4–2019Q4. Three overall observations are worth highlighting. First, for all four shocks, the dynamic responses of the variables are closely consistent across the two sample periods before the Great Recession, with most of the variables exhibiting larger deviations on impact for the earliest sample. Second, nominal money balances and the degree of price stickiness consistently determine the dynamic adjustment of the price level in these two periods. Third, in the most recent sample (characterized by a strict interest rate targeting regime), money supply and demand become endogenous for the determination of the price level, and exogenous shocks are therefore negligible.¹¹ These results highlight the evolution toward a strict interest rate-targeting regime in the USA, and suggest an important role for monetary aggregates, not only for monetary policy, but for capturing the actual behavior

TABLE 1. Bayesian estimation of structural parameters

		Prior distribution			1959Q01–1983Q04 Posterior distribution			1984Q01–2007Q03 Posterior distribution			2007Q04–2019Q04 Posterior distribution		
Parameter		Type	Mean	Std.dev	Mean	90% HPD interval		Mean	90% HPD interval		Mean	90% HPD interval	
<i>Households</i>													
η_c	Relative risk aversion	Normal	2	0.50	3.454	2.826	4.042	3.390	2.777	3.984	3.804	3.039	4.592
η_m	Inverse elasticity of money demand	Normal	5	0.20	5.061	4.729	5.387	5.094	4.771	5.396	5.144	4.823	5.464
η_l	Inverse elasticity of labor supply	Normal	1	0.10	0.993	0.670	1.314	0.972	0.632	1.300	0.993	0.665	1.311
β	Discount factor		0.98										
<i>Firms</i>													
α	Labor’s share in production	Beta	0.67	0.05	0.669	0.583	0.751	0.668	0.585	0.749	0.669	0.585	0.750
θ	Price stickiness	Beta	0.75	0.05	0.850	0.829	0.872	0.868	0.847	0.891	0.826	0.798	0.853
<i>Monetary regime</i>													
ν_h	Elasticity of nonborrowed reserves	Inv.Gamma	1	10	1.011	0.221	1.926	11.51	1.116	20.83	9.635	3.103	17.05
ν_{fr}	Elasticity of free reserves	Inv.Gamma	10	10	37.82	24.59	51.64	11.61	4.274	18.61	9.274	3.030	16.31
ρ_h	Nonborrowed reserve persistence	Beta	0.8	0.10	0.687	0.561	0.812	0.413	0.289	0.541	0.800	0.648	0.960
ρ_{fr}	Free reserves persistence	Beta	0.8	0.10	0.251	0.159	0.333	0.184	0.111	0.242	0.801	0.647	0.956

TABLE 1. Continued

		Prior distribution			1959Q01–1983Q04 Posterior distribution			1984Q01–2007Q03 Posterior distribution			2007Q04–2019Q04 Posterior distribution		
Parameter		Type	Mean	Std.dev	Mean	90% HPD interval		Mean	90% HPD interval		Mean	90% HPD interval	
κ_π	Weight on inflation	Gamma	1.5	0.20	1.466	1.137	1.773	1.486	1.153	1.812	1.467	1.153	1.789
κ_y	Weight on output	Beta	0.5	0.20	0.526	0.208	0.846	0.530	0.206	0.860	0.705	0.482	0.945
ϕ_{rr}	Ratio of free reserves to req. reserves				0.003			0.017			14.59		
AR(1) coefficients													
ρ_z	Technology	Beta	0.8	0.10	0.706	0.655	0.759	0.756	0.712	0.796	0.636	0.563	0.710
ρ_i	Interest rate target	Beta	0.8	0.10	0.997	0.995	1.000	0.996	0.992	0.999	0.930	0.910	0.951
ρ_{m_s}	Money supply	Beta	0.8	0.10	0.833	0.800	0.867	0.759	0.706	0.814	0.801	0.649	0.958
ρ_{m_d}	Money demand	Beta	0.8	0.10	0.997	0.994	0.999	0.992	0.986	0.999	0.943	0.902	0.983
Standard deviations													
ϵ_z	Technology	Inv.Gamma	0.02	2.00	0.071	0.059	0.082	0.037	0.031	0.043	0.047	0.037	0.057
ϵ_i	Interest rate target	Inv.Gamma	0.02	2.00	0.004	0.003	0.006	0.004	0.003	0.005	0.005	0.004	0.006
ϵ_{m_s}	Money supply	Inv.Gamma	0.02	2.00	0.172	0.122	0.221	0.072	0.050	0.091	0.017	0.005	0.031
ϵ_{m_d}	Money demand	Inv.Gamma	0.02	2.00	0.035	0.030	0.039	0.014	0.012	0.015	0.012	0.010	0.014
Log-data density					1018.24			1250.33			612.07		
Acceptance ratio range					[24%;25%]			[24%;26%]			[26%;26%]		
Observations					100			95			49		

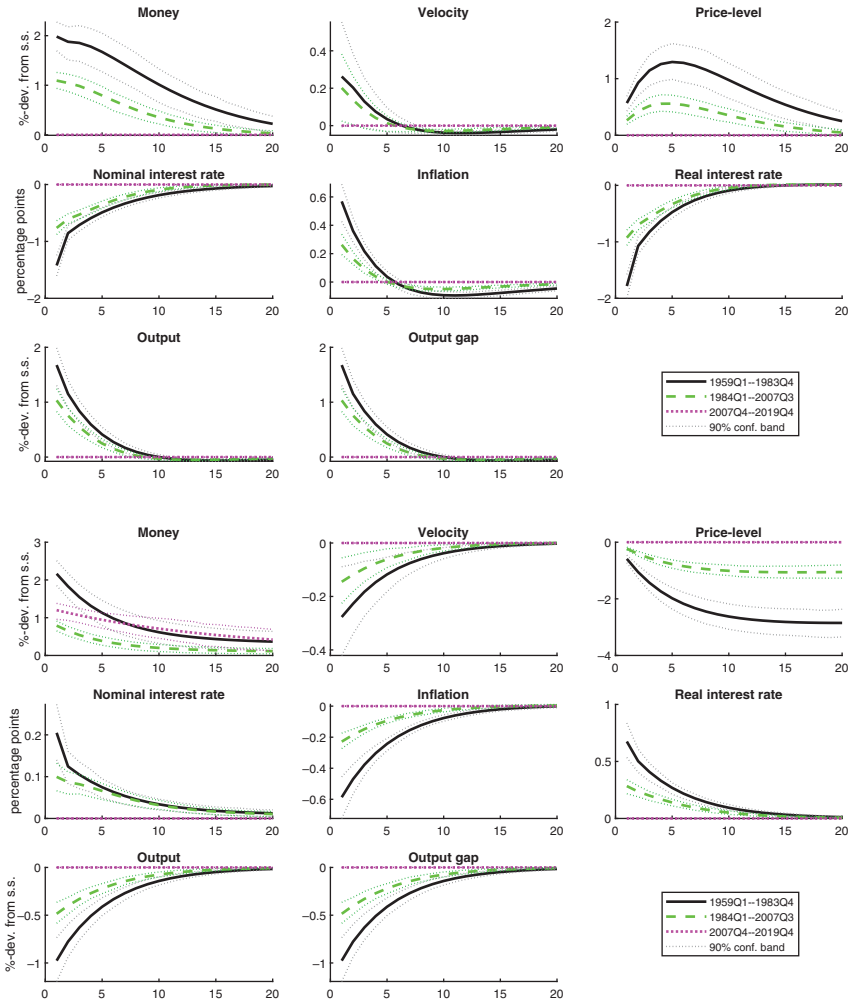


FIGURE 1. Impulse response to positive money supply shock (top) and positive money demand shock (bottom). Note: SS = steady state.

of a monetary economy. To make our discussion concise, we will focus on the dynamics of the Great Moderation subsample estimation.

The nominal money supply shock (top panel, Figure 1) highlights the effect of sticky prices on real variables. An initial 1.1% increase in the money supply results in a 0.56% increase in the price level, but only after four quarters. As a result, the monetary stimulus pushes the real interest rate down 0.93 percentage points and generates a cumulative positive output gap of 2.8%. A money demand shock (bottom panel, Figure 1), on the other hand, affects the economy negatively, as households demand higher *real* money balances. Prices, therefore, fall below

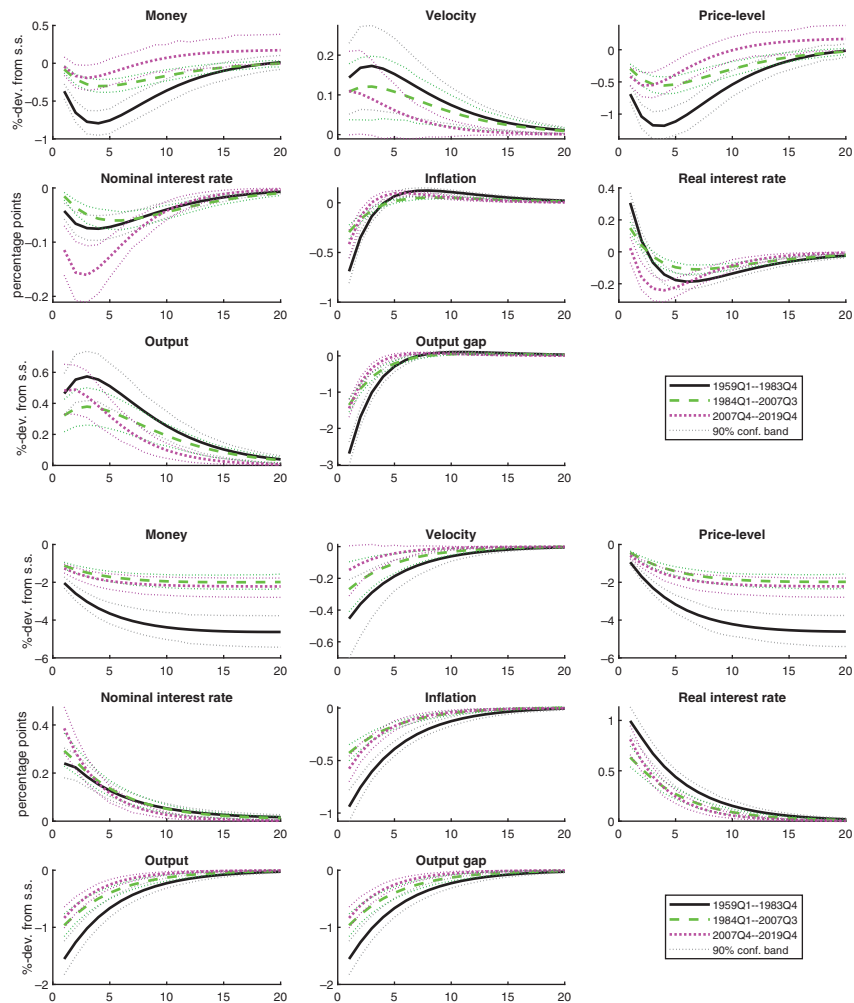


FIGURE 2. Impulse response to positive technology shock (top) and positive interest rate target shock (bottom). Note: SS = steady state.

trend as households substitute away from consumption goods to money. This negative demand shock is somewhat offset by a rise in the nominal stock of money. In the flexible equilibrium, the price level would adjust downward to immediately satisfy the increase in demand for real money balances.

A positive technology shock (top panel, Figure 2) generates greater output, lower inflation, and a negative output gap. The downward adjustment of the nominal interest rate is small, and the economy converges from an initial negative output gap of 1.35% to its flexible price equilibrium after eight quarters. The net effect on real money balances is positive. A positive shock to the target interest

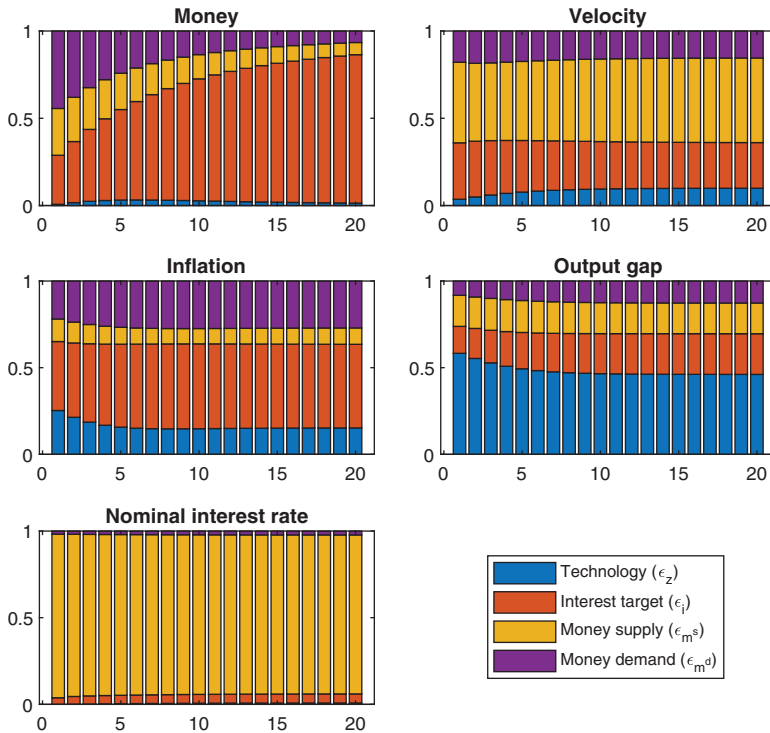


FIGURE 3. Variance decomposition (1959Q1–2007Q3). Money (top-left); velocity (top-right); inflation (middle-left); output (middle-right); nominal interest rate (bottom-left).

rate (bottom panel, Figure 2) follows a standard NK monetary policy shock. A 30-basis point increase in the short-term nominal interest rate reduces output by 1.0% and inflation by 0.43 percentage points. The higher interest rate reduces real money balances (equation (6)) and generates a persistent decline in both nominal money supply and the price level.

4.2. Variance Decomposition

Figure 3 reports the contribution of the structural shocks to the forecast error variance of money, velocity, inflation, the output gap, and the nominal interest rate up to a 20-quarter horizon. Results are presented for the combined sample period: 1959Q1–2007Q3.¹² As such, the results represent a monetary regime with some degree of interest elasticity to nonborrowed reserves ($v_h = 3$).

The contribution of the shocks to velocity are remarkably stable across the forecast horizon, with the money supply shock and the interest rate shock contributing 42% and 33% of the forecast error variance, respectively. The effect of technology (supply-side) shocks on the output gap is large, but declines steadily for

eight quarters thereafter. More than half of the output deviations from the flexible price equilibrium are attributable to nominal shocks (53%). As will be shown in Section 5.3, monetary authorities can easily eliminate any nominal shock to inflation ($\pi_t = p_t - p_{t-1}$), the output gap ($\tilde{y}_t = y_t - y_t^n$), and nominal income ($p + y$), whereas supply-side (technology) shocks present a nontrivial trade-off between nominal income stability and inflation-output gap stability. Exogenous shocks to the policy rule contribute the most to inflation variance (51%), with about a quarter of this variance originating from nominal money demand shocks. Finally, there is a clear strong liquidity effect between nominal interest rates and the nominal money stock. On one hand, money supply shocks contribute the bulk of the forecast error variance of nominal interest rates (93%). On the other hand, interest rate shocks contribute the bulk of variation in the money stock over the forecast horizon (69%). That said, the interaction between money supply and money demand is still important: the on-impact contribution of money demand and money supply to money stock variance is 68%, which declines steadily over the forecast horizon.

Overall, the prevalence of exogenous interest rate target shocks corroborates the consistency of the Taylor rule in approximating interest rate responses to output and inflation over the USA business cycle. Moreover, corresponding to the estimated structural parameters, there is evidence of a strong liquidity effect over the entire forecast horizon. In addition, the interaction between money supply and demand does matter over the short run to the money stock.

4.3. Historical Decomposition

Figures 4 through 6 provide the historical shock decomposition of the main macroeconomic variables. Here, we focus on how the structural shocks predict the USA business cycle over the sample period 1959Q1–2007Q3. To assist our discussion, each figure has been subdivided into Federal Reserve governor tenures: William M. Martin (1951Q2–1970Q1), Arthur Burns and William Miller (1970Q1–1979Q2), Paul Volcker (1979Q3–1987Q2), Alan Greenspan (1987Q3–2006Q1), and Ben Bernanke (2006Q1–2014Q1).¹³

The dawn of the Great Inflation period came toward the end of Martin's tenure [Bremner (2004)]. In fact, from as early as 1963, Martin expressed his deep concern that the USA was heading for "an incipient expansion at an unsustainable rate" and an "inflationary mess" (Bremner, 2004, 184, 191). The USA output gap began to rise rapidly in 1964 and stayed positive until the end of Martin's tenure in 1969 (see Figure 5). Over the same period, inflation rose from a low and stable average of 1.25%–5%. First, an adverse technology shock and then a negative money demand shock contributed to the overheating economy. Figure 4 shows how velocity rose sharply from 1966 in three consecutive bouts over the Martin, Burns-Miller, and Volcker tenures. Throughout these periods, the interaction between money supply and demand reinforced spending (velocity) and nominal growth so that the money stock fell steadily as a share of nominal GDP (cross-marker line). Throughout the sample period up to 2000, we can observe

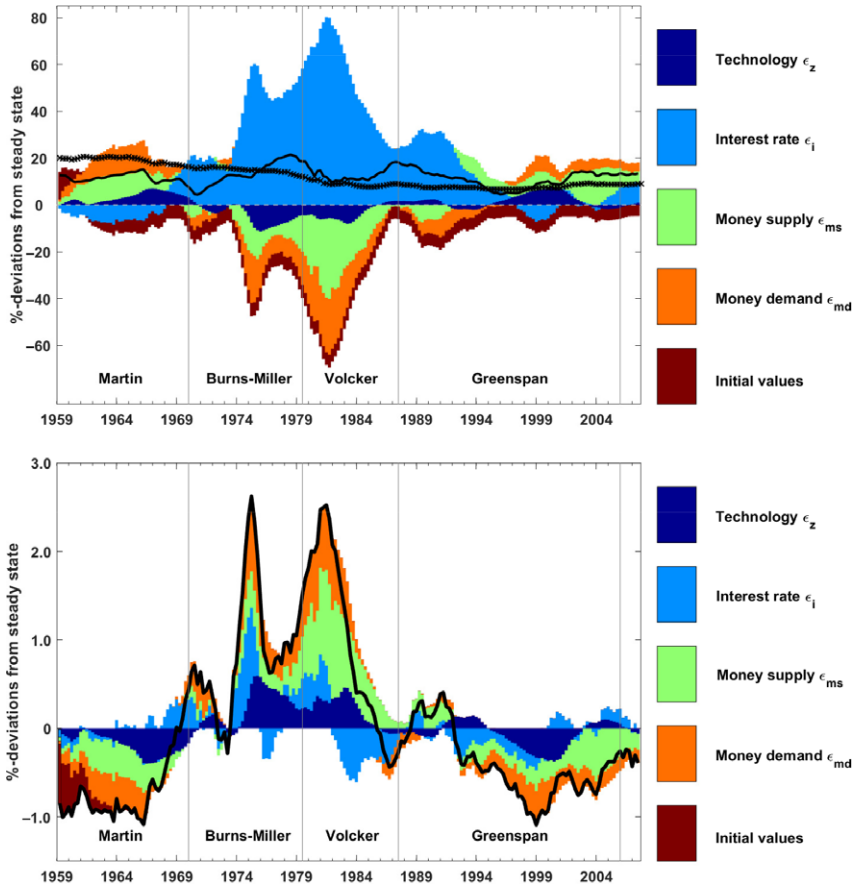


FIGURE 4. Historical decomposition (1959Q1–2007Q3): money (top) and velocity (bottom). Note(s): The solid lines represent the percentage deviation of the latent variable from its long-run trend (the steady state). The cross-marker line represents actual data for the log of the money-to-output ratio. The *growth rate* of money is the observable variable for estimation.

a clear liquidity effect between interest rate shocks and shocks to money supply and demand (top panel, Figure 4).

It is a common fallacy to associate high (low) interest rates with excessively tight (loose) monetary policy. As the Fisher relation (equation (5)) suggests, high levels of inflation are associated with high nominal interest rates. The impulse responses from Figure 2 (section 4.1) show, however, that expansionary monetary policy (i.e. negative shocks to the policy target rate) should *raise* the money stock, inflation, and the output gap (as shown in Figures 4 and 5). How, then, can we reconcile the Great Inflation period of *high* nominal interest rates with upward pressure on the money stock, inflation, and the output gap?

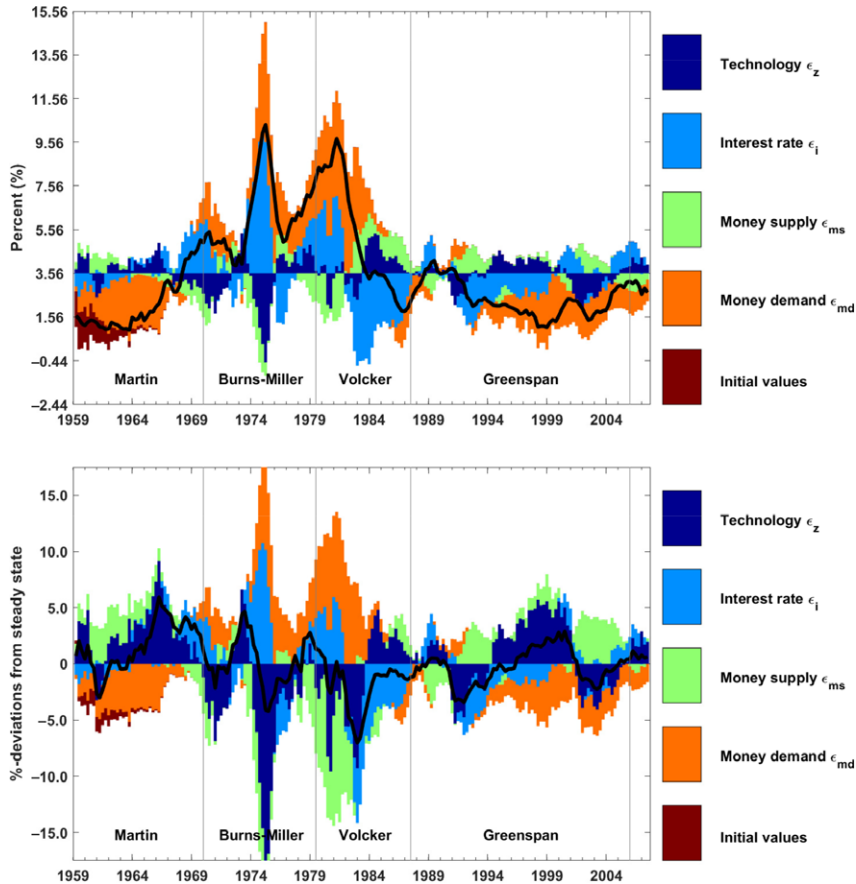


FIGURE 5. Historical decomposition (1959Q1–2007Q3): inflation (top) and output gap (bottom).

Figure 6 plots the implied deterministic Taylor rule (DTR) fit from the estimated monetary policy rule (equation (11)) using the data for the output gap and inflation. Here, we can clearly see that for the entire Burns-Miller tenure, the observed short-term nominal interest rate was below the estimated model's implied policy rate level—indicating an accommodative policy stance (i.e. successive negative shocks to the target interest rate, i_t^T).¹⁴ This expansionary policy narrative is further corroborated by the real interest rate in the bottom panel of Figure 6—which fell below zero for much of the 1970s (−7% by 1975Q1). In fact, Fernández-Villaverde et al. (2010, 13) find, by using time-varying parameter estimates on inflation in the Taylor rule, that the Federal Reserve under Burns and Miller put significantly less weight on inflation (less than 1) than it did under Martin and Volcker (± 2). Clarida et al. (2000) and Collard and Dellas (2008) suggest that this deviation from the Taylor principle in the 1970s triggered

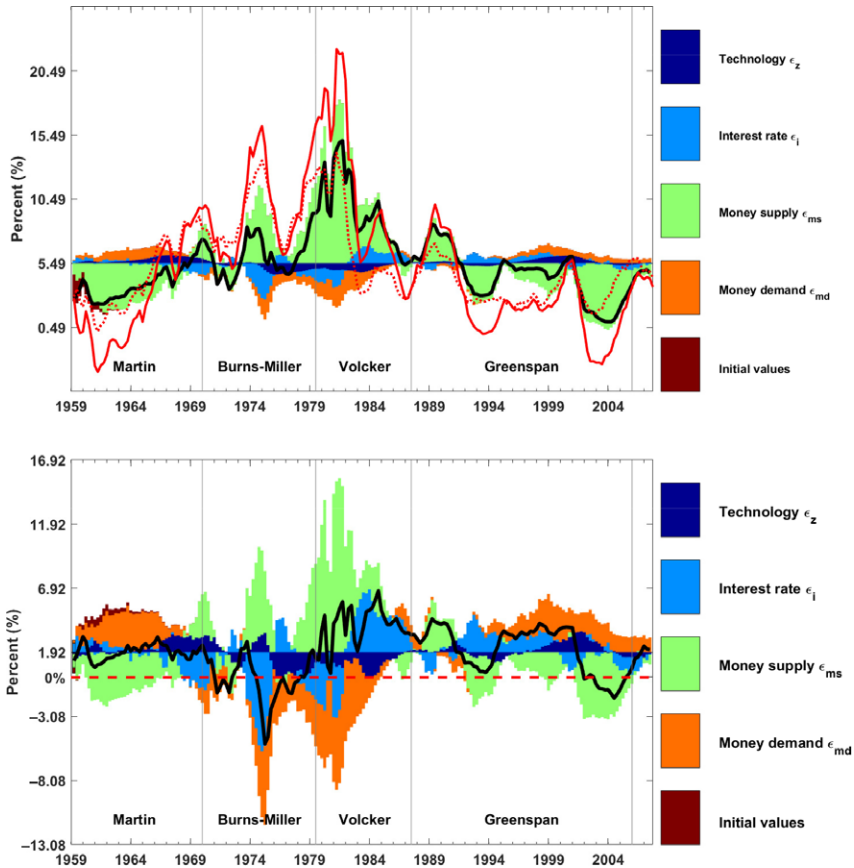


FIGURE 6. Historical decomposition (1959Q1–2007Q3): nominal interest rate (top) and real interest rate (bottom). Note(s): The solid red line represents deterministic Taylor rule (DTR) fit. The dotted red line represents DTR fit without interest rate smoothing. The dashed red line represents the zero real interest rate level.

self-fulfilling inflation expectations. At first glance, our estimated model suggests that the inflation of the 1970s is solely the result of discretionary policy actions (described as “monetary policy shocks”), but significant endogenous velocity fluctuations (bottom panel, Figure 4) and exogenous money demand shocks (top panel, Figure 5) show support for the self-fulfilling inflation expectations narrative.¹⁵

A few years after Volcker’s appointment, we see a marked decline in velocity (spending), inflation, and nominal interest rates. But, a relatively high responsiveness between nonborrowed reserves and the policy rate corresponds to the dominance of money supply shocks on the sustained high interest rate levels going into the Volcker period. The output gap closed by 1985, and the ratio of money to nominal income rose steadily into the Great Moderation period.

From the mid-1980s until 2007, the successful reining in of inflation led to successive bouts of benign macroeconomic shocks and stable business cycle fluctuations. Although it is clear that the Great Inflation can be attributed largely to a lack of policy responsiveness to inflation—and, in particular, to *expected* inflation—this was not the case in the latter days of the Great Moderation. Signs that the USA economy was on an unsustainable trajectory began after 2001. Figure 6 shows the well-known example that the Fed kept rates too low for too long from 2002 to 2005: the nominal interest rate was lower than what the Taylor rule prescribed (top panel: dotted red line vs. solid black line),¹⁶ and the real interest rate fell below zero (bottom panel). During this period, the Fed accommodated a positive technology shock (Figure 5) by raising the money supply. As inflation picked up, the negative output gap closed and turned positive leading into Bernanke's tenure—a mere year and a half before the first signs of the global financial crisis.

Without going into too much more detail, Figures 4, 5 and 6 suggest that the model does well to explain stylized business cycle facts for the USA economy. Section 5 presents counterfactual simulations of alternative monetary policy regimes to assess the effectiveness of the current strict interest rate-targeting regime and whether a more flexible monetary regime is preferable: that is, whether there is a more preferable optimal combination policy.

5. COUNTERFACTUAL SIMULATIONS

5.1. The Behavior of Alternative Monetary Regimes

To illustrate how the choice of monetary regime changes the behavior of the economy, Table 2 shows the variance decomposition of all the macroeconomic variables for two types of endogenous monetary regimes. The four shocks are a technology shock, an interest rate target shock, a money supply shock, and a money demand shock. The structural parameters and sizes of the shocks are calibrated to the posterior estimates of the Great Moderation period (see Table 1). For the interest rate-targeting regime, the elasticity of reserves is high: $\{\nu_h, \nu_{fr}\} = \{12, 12\}$. The monetary authorities therefore prefer to minimize (smooth) interest rate variations by allowing the money supply curve to flatten, which leaves money and reserves endogenous and thus weakly relevant for price determination. For the interest-sensitive monetary regime, $\nu_h = 1$ and $\nu_{fr} = 1$. Here, an exogenous shock to money supply directly influences the interest rate and generates real effects in the short-run. The following result goes to show that the choice of monetary regime has a significant influence on the role of monetary aggregates and that money may be neutral in the long run, but sticky prices generate the distortion necessary for it to have a significant influence over real economic variables.

First, to illustrate price level determination, we show the variance decomposition of the nominal and real variables under a strict interest rate-targeting regime,

TABLE 2. Variance decomposition of business cycle under two monetary regimes (in %)

Shock	Great moderation monetary rule ($v_h = 12$; $v_{fr} = 12$)				Interest sensitive monetary rule ($v_h = v_{fr} = 1$)				Flexible prices ($v_h = v_{fr} = 1$)			
	ϵ_z	ϵ_i	ϵ_{m^s}	ϵ_{m^d}	ϵ_z	ϵ_i	ϵ_{m^s}	ϵ_{m^d}	ϵ_z	ϵ_i	ϵ_{m^s}	ϵ_{m^d}
Money (m)	0.1	98.1	1.3	0.5	0	4.3	95.4	0.3	0.6	3.2	96.2	0
Velocity (v)	22.7	43.3	19.9	14.2	17.6	0.2	69.5	12.8	72.6	0	27.3	0.1
Prices (p)	0.4	85.1	0.5	14.1	0.8	2.3	14.0	82.9	3.4	1.2	33.9	61.5
Output (y)	15.7	38.5	35.1	10.8	4.9	0.2	89.0	5.9	100	0	0	0
Real rate (r)	3.4	33.2	56.2	7.2	0.6	0.2	96.3	3.0	100	0	0	0
Nominal rate (i)	1.5	15.3	80.8	2.4	0.3	0.1	98.0	1.6	34.6	0.1	65.2	0.2
Nominal target rate (i^T)	0	100	0	0	0	99.7	0.2	0.1	0	100	0	0
Inflation (π)	15.6	52.3	15.6	16.5	5.4	0.3	78.5	15.8	10.7	0.2	83.7	5.5
Output gap (\tilde{y})	37.0	28.8	26.2	8.1	7.1	0.2	86.9	5.8	100	0	0	0
Natural output (y^n)	100.0	0	0	0	100	0	0	0	100	0	0	0
Natural rate (r^n)	100.0	0	0	0	100	0	0	0	100	0	0	0
Nonborr. res. (h)	0.1	92.9	6.6	0.3	0.2	43.4	55.3	1.1	6.1	81.5	12.3	0.1
Free reserves (fr)	0.1	92.3	7.2	0.4	0.2	40.1	58.7	1.1	6.7	79.6	13.6	0.1

as observed over the actual Great Moderation period and in a counterfactual flexible (interest-sensitive) monetary regime. It is immediately clear that long-run variations in money, velocity, prices, and output are mainly determined by shocks to the target interest rate under the Great Moderation monetary rule. But given that money supply shocks still have a strong effect on the interest rate, exogenous innovations in money supply still have a significant impact on real variables because of sticky price adjustment. The final two columns clearly show that nominal (monetary) shocks in an NK model are neutral under flexible prices. A flexible (interest-sensitive) monetary rule, in contrast, highlights the importance of exogenous innovations in money supply and demand to business cycle fluctuations. Here, money supply and demand interact to determine variation in inflation and the price level over the entire forecast horizon. And, as shown analytically by McCallum (1986), we see that the type of monetary regime can influence the transmission mechanism of monetary policy dramatically *without changing the dynamic adjustment path of the economy*.¹⁷ A strict interest rate-targeting regime becomes problematic, however, if the operational instrument—the policy rate—cannot lower the real interest rate enough. It is the monetary regime, not the ZLB, that renders monetary policy ineffective.

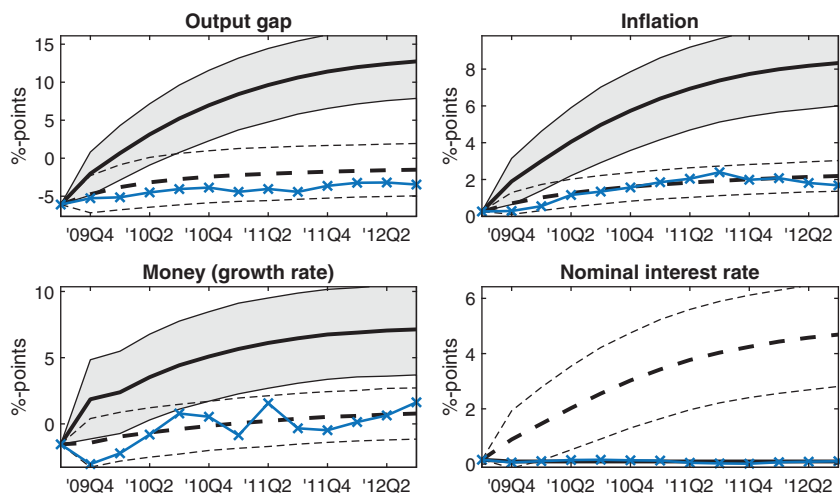


FIGURE 7. The recovery period 2009Q3–2012Q3. Forecast conditional on maintaining the nominal interest rate path near the ZLB (solid line). Unconditional forecast (dashed line). Actual data (cross-marker). Plotted with 90% confidence intervals.

5.2. An Alternative Economic Recovery?

This section provides two counterfactual scenarios for the economic recovery of the USA from the Great Recession. For the entire post-Great Recession period, we assume that the de facto monetary regime follows a strict interest rate (floor) regime such that the stock of money is not driven by changes in bank reserves.

For our first counterfactual exercise, Figures 7 and 8 compare conditional and unconditional forecasts of the output gap, inflation, money growth, and nominal interest rate to the actual data for the recovery period 2009Q3–2012Q3.¹⁸ Here, we re-estimate the model for the Great Moderation period, up to the trough of the Great Recession and the imposition of the effective ZLB on nominal interest rates (1984Q1–2009Q3). For the conditional forecasts, we assume the Fed controls the policy rate (ϵ_t^i) to obtain the constrained path of either the nominal interest rate target at the ZLB (Figure 7) or the inflation rate target at 2% (Figure 8). Overall, the unconditional forecasts of the model do well to capture the actual paths of inflation and money growth. Although the trajectory of the actual output gap is captured, the model predicts a more speedy economic recovery: a -1.5% output gap instead of the observed -3.8% output gap by 2012Q3. In stark contrast to actual developments, the model predicts the normalization of nominal interest rates to slightly above 4% by 2012Q3.

Figure 7 provides the counterfactual paths of the output gap, inflation, and money growth for the Great Moderation monetary regime under the scenario that the Federal Reserve maintained interest rates at the ZLB. The results highlight the far greater responsiveness of the variables when the growth rate of

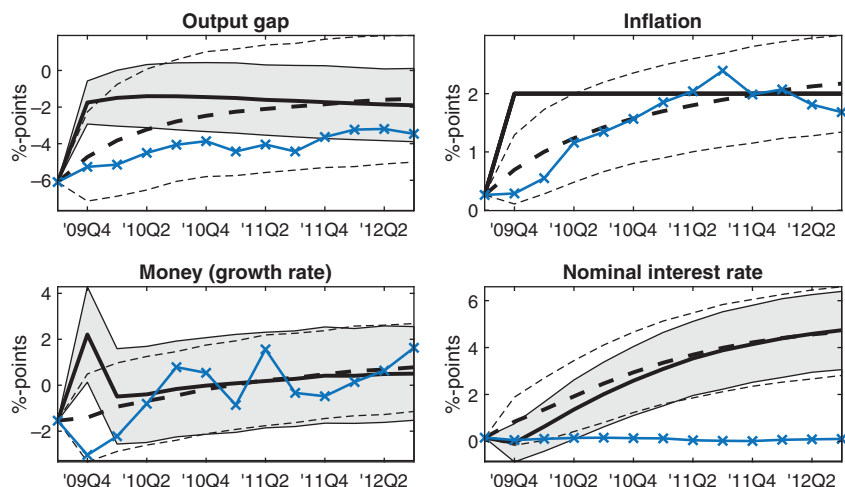


FIGURE 8. The recovery period 2009Q3–2012Q3. Forecast conditional on maintaining 2% inflation target (solid line). Unconditional forecast (dashed line). Actual data (cross-marker). Plotted with 90% confidence intervals.

the money stock is not constrained by a floor regime associated with a satiated market for bank reserves. Turning to Figure 8, we observe that both the actual data and the unconstrained forecast show the Federal Reserve achieving its 2% inflation target after seven quarters (2011Q2). In contrast, a one-off permanent increase in the stock of (broad) money reduces the 2009Q3 output gap from -6% to -2% , maintains the central bank's 2% inflation target after first quarter, and sees the normalization of interests rates from the ZLB. This result corroborates one explanation for the observed stagnant recovery: the Federal Reserve was unable to make a credible commitment to permanently expand the monetary base [Beckworth (2017)]. In the context of the 2007–2009 Great Recession, the results confirm that a strict interest rate-targeting regime renders the monetary expansion ineffective. A more flexible interest rate regime would have, in contrast, led to a significant monetary expansion and more rapid economic recovery in the USA.¹⁹

Of course, this stylized example fails to capture post-2008 uncertainty and regulatory constraints in the banking sector that constrain the (inside) money creation process.²⁰ Moreover, the Fed's "unconventional" policy responses in the post-crisis period largely targeted long-term government securities and alternative private asset classes—that is, quasi-debt management policies and credit policies (Borio and Disyatat, 2010, 62). The result is therefore more indicative of the constraint on the type of monetary regime (operational framework) adopted by the Federal Reserve going into the crisis—which ignores the income (and wealth) effect that arises from changes in, for example, asset portfolio reallocations or long-term yields.

5.3. Optimal Policy

Distortions caused by price stickiness lead to short-run nonoptimal fluctuations in relative prices. This price dispersion in the intermediate goods sector generates a welfare loss. The central bank therefore dislikes output gaps and inflation, and setting $\pi_t = \tilde{y}_t = 0$ will eliminate price distortions from the Phillips curve (equation (13)). We assume that the central bank seeks to minimize the following quadratic loss function:²¹

$$\min_{\pi_t, \tilde{y}_t} \frac{1}{2} E_0 \left(\sum_{t=0}^{\infty} \beta^t \left(\pi_t^2 + \omega \tilde{y}_t^2 \right) \right), \quad (17)$$

s.t.

$$\pi_t = \beta E_t[\pi_{t+1}] + \tilde{\kappa} \tilde{y}_t,$$

where $\omega = \tilde{\kappa}/\epsilon$ and ϵ is the price elasticity of demand. The optimal policy rules under discretion and commitment follow as

$$\tilde{y}_t = -\frac{\tilde{\kappa}}{\omega} \pi_t, \quad \tilde{y}_t = -\frac{\tilde{\kappa}}{\omega} p_t. \quad (18)$$

For all shocks considered so far, optimal discretion and commitment policy deliver the same global minimum of the above objective function in the standard NK framework. That is, there is no gain from commitment to a price level target over period-by-period policy discretion.

In what follows, we discuss possible optimal rules for the central bank under alternative regimes. Indeed, it is always possible for the central bank to eliminate output gaps and inflation under any nominal or technology shock. We take the pragmatic position that the estimated model for the Great Moderation period represents the best abilities of the monetary authorities under the imposed structural regime, whereas, the following modified optimal Taylor rule represents the efficient benchmark:

$$i_t = r_t^n + \kappa_\pi \pi_t + \kappa_y \tilde{y}_t. \quad (19)$$

That is, when $\pi_t = \tilde{y}_t = 0$, equation (19) accomplishes the optimal policy goal of the central bank: $r_t = r_t^n$. We compare these results with our extreme cases of a pure interest rate policy ($v_h = v_{fr} \rightarrow \infty$) and a pure monetary growth rule ($v_h = v_{fr} \rightarrow 0$). In each case, we allow the monetary authority to calibrate its rule to minimize the welfare loss function (the optimal simple rule (OSR)).

Figures 9 and 10 show the impulse responses of the output gap, inflation, and nominal income to a positive technology shock and a positive money demand shock. As expected, the optimal modified Taylor rule (OMTR) produces flat responses for the output gap and inflation. The OSR shows the optimized policy instrument parameters ($\rho_h, v_h, \rho_i, \kappa_\pi, \kappa_y$) of the Great Moderation estimated model. Although we see little improvement from the benchmark estimate, nominal income stability improves significantly. In contrast, the OMTR *accommodates* the positive technology shock to close the negative output gap and lower inflation,

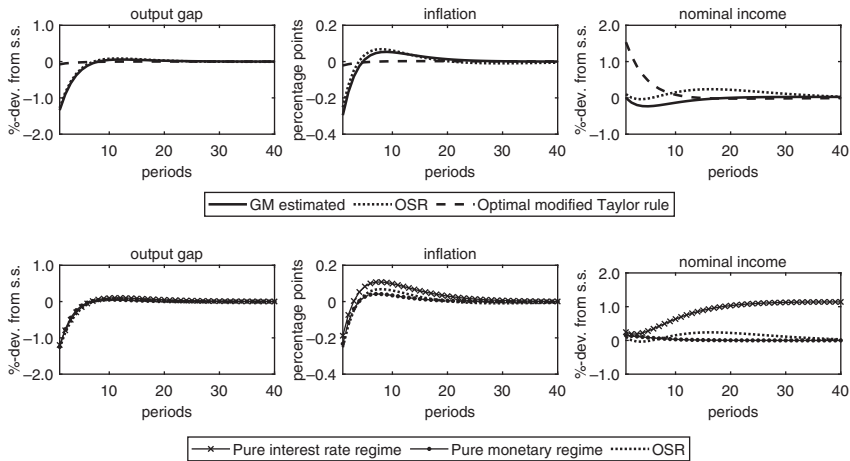


FIGURE 9. Impulse response to a positive technology shock. Note(s): GM = Great Moderation; OSR = optimal simple rule. Pure interest rate policy: $v_h = v_{fr} \rightarrow \infty$. Pure monetary growth rule: $v_h = v_{fr} \rightarrow 0$.

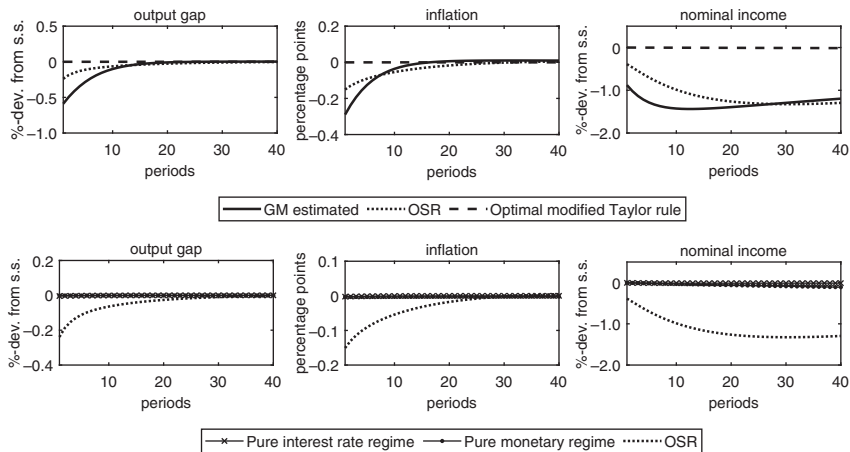


FIGURE 10. Impulse response to a negative money demand shock. Note(s): GM = Great Moderation; OSR = optimal simple rule. Pure interest rate policy: $v_h = v_{fr} \rightarrow \infty$. Pure monetary growth rule: $v_h = v_{fr} \rightarrow 0$.

which leads to *more rapid* nominal income growth. The bottom panel shows that moving from the strict interest regime of the Great Moderation toward a pure monetary regime would improve nominal income stability further. In fact, a pure monetary regime improves welfare by 28% (OSR)–39% (pure interest regime). For the money demand shock, however, either of the extreme regimes eliminates the nominal shock.

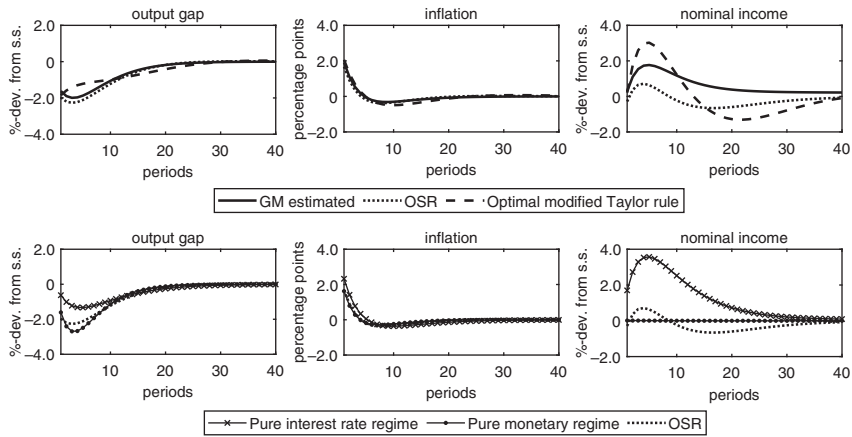


FIGURE 11. Impulse response to a positive price markup shock. Note(s): GM = Great Moderation; OSR = optimal simple rule. Pure interest rate policy: $v_h = v_{fr} \rightarrow \infty$. Pure monetary growth rule: $v_h = v_{fr} \rightarrow 0$.

One way to force an output-inflation trade-off is to introduce a cost-push shock to equation (13). The structural interpretation implies that price markups are possibly time-varying over the business cycle. This AR(1) shock process essentially shifts the Phillips curve, and persistent shifts in $E_t \pi_{t+1}$ require either the output gap or inflation (or both) to shift. This wedge in the output-inflation trade-off reduces welfare.

Figure 11 shows how possible exogenous shifts to the Phillips curve considerably weakens the OMTR. In fact, the OSR regime for the GM estimation improves welfare by 41% (objective function: 0.000864 to 0.000507). As with the technology shock, this supply-side shock engenders a OMTR policy response which generates significantly more nominal income instability. Notably, in comparing the “pure” regimes in the bottom panel, we can see that moving toward a pure monetary regime (i.e. a less-strict interest rate regime) can lead to far greater nominal income stability by not responding as aggressively to supply-side shocks.

6. CONCLUDING REMARKS

Most models base their conventional central bank policy analysis on a strict interest rate reaction function, a Taylor-type policy rule with little or no role for the money stock. In this paper, we present arguments in favor of a traditional model of money stock determination to show that the type of monetary policy regime has significant implications for the role of monetary aggregates and interest rate policy in a standard NK framework. We draw three main conclusions. First, the interaction between money supply and demand and the type of monetary regime in our model captures the dynamics of the USA business cycle remarkably well. Second, the model’s results suggest that the evolution toward a stricter interest rate-targeting regime renders central bank balance sheet expansions ineffective.

Third, neither an interest rate-targeting regime nor a money growth rule is desirable. Instead, monetary authorities should adopt an optimal combination policy to stabilize nominal income. In this regime, the central bank would adhere to its goal of price stability, not to a rule for the intermediate (interest rate or money growth) target, because under certain states of the world, either interest rate policy or money base creation can be ineffective. As a result, the stance of monetary policy is measured by the deviation of nominal income growth from its target.

NOTES

1. Borio and Disyatat (2010, 57) state that “in setting the interest rate, no open market operations need be involved at all . . . The interest rate is not controlled by moving up and down a well-behaved, traditional [money] demand schedule.” This decoupling of the short-term nominal interest rate from “money” leaves the central bank’s balance sheet “free” to pursue financial stability objectives. All too often, the consequential assumption is that conventional monetary policy objectives (of price stability and full employment) are achieved by the efficient allocation of resources conducted primarily through the interest rate transmission mechanism.

2. Free reserves represent funds available for interbank clearing and settlement, interbank loans, and the portion of excess reserves less borrowed reserves allocatable to reserve requirements in the deposit creation process. In December 2007, as the interbank market came under stress, borrowed reserves started to rise significantly (i.e. free reserves became negative), and once the Federal Reserve was authorized to pay interest on excess reserves (on October 6, 2008) the level of free reserves rose dramatically. By December 2008, with the federal funds rate pegged close to zero, a fundamental regime change had occurred.

3. That is, it inappropriately maps the implementation (or operating procedures) of monetary policy to the transmission mechanisms of monetary policy (see also, Thornton, 2014).

4. A full description of the model is provided in the Supplementary Appendix, wherein we also discuss the three fundamental conditions in favor of a traditional model of money stock determination.

5. Since our banking sector setup is different from Hetzel, the specification of the monetary rule is slightly different. Rather, it focuses on the liquidity effect between money and the interest rate in the market for reserves. The full details of the banking sector are discussed in the Supplementary Appendix. Note that Equations (15) and (16) in Hetzel (1986, 10) imply a log-linear relationship between reserve demand schedule and reserve supply schedule.

6. Note that the reserve money multiplier only becomes irrelevant as a result of the modeling assumption. This assumption does not mean that the real demand for money (purchasing power) *determines* the quantity of nominal money [Hetzel (1986), 19]. Empirically, the relationship depends on the degree to which monetary aggregates (or reserve money multipliers) become interest sensitive, that is, elastic [Inagaki (2009)], or on how monetary aggregates are measured [Belongia and Ireland (2014, 2017)]: an insensitive or structurally stable monetary aggregate results in a relevant and predictable reserve money multiplier.

7. For the period 1959Q1–1966Q4, we augment our monetary aggregate series with the Federal Reserve Bank of St. Louis’ MZM money stock measure. Our general results hold even if we use narrower monetary aggregate measures such as MZM (Divisia and simple-sum) for the full sample period. Divisia M4 is preferable since it is both the broadest measure and the series that provides the best fit of the data.

8. Under a floor regime, ϕ_{rr} is very large (see Table 1), which means that money supply shocks become irrelevant and stochastic singularity may arise. We, therefore, include a measurement error in equations (10) and (11) to capture the effects of monetary policy shocks not directly related to the Taylor rule (i.e. unconventional policy): $(i_t - i_t^T + \epsilon_t^{qe})$. For the period 1959Q1–2007Q3, ϵ_t^{qe} accounts for 0% of the forecast error variance (FEV) of Δm_t , \tilde{y}_t , and π_t , and 5% of i_t . For the period 2007Q4–2019Q4, ϵ_t^{qe} accounts for 0% of Δm_t and π_t , 2% of \tilde{y}_t , and 77% of i_t .

9. See the Supplementary Appendix for diagnostic statistics and estimation results.

10. By “determine,” we mean that money supply accommodates demand at the given interest rate.
11. Results for the full sample serve as a robustness exercise and are available in the Supplementary Appendix.
12. Results for the subsamples and the full sample are available upon request.
13. See Fernández-Villaverde et al. (2010) for a similar, and more detailed, reading of recent USA monetary history.
14. Figures for the observed (smoothed) shocks can be found in the Supplementary Appendix.
15. Comparing the dashed red line with the dotted red line in Figure 6 indicates that interest rate smoothing (i.e. persistence in the policy rate) was an important factor in the spillover of expansionary policy into the Volcker period.
16. It is interesting to note here that the Fed’s historical preference to smooth the interest rate *target* (solid red line) was not at odds with the decision to keep rates low during the 2002–2005 period. Of course, data come with lag and can often be revised. It is likely that both of these factors contributed to the Fed’s policy stance.
17. See impulse response functions F.7–F.9 in the Supplementary Appendix.
18. We take 2009Q3 to be the trough of the Great Recession. The conditional forecasts are computed using the `conditional_forecast` and `conditional_forecast_paths` commands in Dynare. It is important to note that the controlled exogenous variables are random and unforeseen shocks from the perspective of the households. For all uncontrolled periods, there is no forecast uncertainty arising from these exogenous variables.
19. As a second counterfactual exercise, we simulated results for alternative scenarios of a reduction in free reserves (see Figure F.10 in the Supplementary Appendix). Here, we assume that (inside) money creation will be observed as a decline in *ER* and rise in *RR*, holding total reserves (*TR*) constant. The results are analogous when the Federal Reserve increases *H* (nonborrowed reserves). For the period 2007Q4–2016Q3, the banking sector held on average approximately \$1570 billion in excess reserves (\$1483 billion in free reserves) at the Federal Reserve. On the basis of the post-crisis average free reserves held at the Federal Reserve, the counterfactual simulation—with the ZLB constraint on nominal interest rates imposed—indicates that a \$3.7 billion (0.25%) reduction in free reserves expands the money supply by 3.65% and output by 3.84%.
20. For example, paying interest on reserves, raising capital requirements, and implementing liquidity coverage ratios all raise bank demand for free reserves ($FR = H - RR$) and constrain credit and deposit creation (M^*). In equation (4), this would imply that the reserve-deposit (money) multiplier ($1/rr$) is not constant (i.e. it is an *effective* reserve ratio for the determination of the money stock). See Figure D.1 in the Appendix.
21. This standard loss function representation can be derived from a quadratic approximation of household welfare. This representation also requires a sufficiently small utility weight ($a \rightarrow 1$) on real money balances. Collard and Dellas (2005) show that welfare rankings are robust to a relative risk aversion coefficient greater than one ($\eta_c > 1$), and that the assumption of a separable utility function makes a negligible difference.

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