

The Cyclical Effects of Monetary Policy Regimes

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Abstract: A 1979 change in US monetary policy coincided with a break in the cyclical behavior of monetary aggregates, while the cyclical behavior of all other real and nominal variables remained relatively constant. A model is developed to assess the quantitative importance of a change in monetary policy in accounting for these observations. The monetary authority's reaction function is estimated conditionally on the theoretical model and accounts for upwards of 72-95 percent of all observed changes, including inside money preceding the business cycle and a qualitative change in the cyclical behavior of the monetary base.

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1 Introduction

Explaining post-war US business-cycle comovements between nominal variables and real output remain a principle challenge to monetary economics. To make this task even more demanding, Gavin and Kydland (1999) showed that the 1979 Federal Reserve policy change to combat inflation coincided with a significant break in the cyclical behavior of monetary aggregates. The observations are as follows: (i) the monetary base lags the cycle pre-79, leads post-79; (ii) M1 peaks with the cycle pre-79, leads post-79; (iii) M1 is more correlated with output than the monetary base pre-79, less correlated post-79. In contrast, there are little or no measurable differences between the pre and post-79 cyclical behavior of real aggregates, aggregate prices, or nominal interest rates.

These observations for US data from 1959:Q1 to 2002:Q2 are illustrated in figures 1 and 2 by comparing the pre and post-79 cyclical behavior of several business cycle variables.² When comparing episodes moment for moment, none of the 28 real moments are significantly different from one another. When undergoing the same comparison for nominal variables, 13 out of 28 moments significantly change at the 10 percent critical level or better.³

The goal of this paper is to assess the quantitative importance of the change in the monetary policy regime in accounting for these observations. The research strategy employed here attempts to account for the observations discussed above in a business-cycle model with endogenously determined inside and outside monetary aggregates. Movements in outside money (i.e. the currency base) are made endogenous via decisions followed by the monetary authority, while movements in inside money (i.e. the non-currency component of M1) are made endogenous via a financial intermediary sector.

The modelling framework follows Freeman and Kydland (2000) and assumes no nominal rigidities or limited participation effects. In addition to endogenous monetary policy, two extensions are added to the financial intermediary sector. First, a need for financial intermediation is established by assuming that a firm must borrow funds in order to pay its wage bill prior to production as in Christiano and Eichenbaum (1995). Second, commercial banks fill a deposit-creation role as in

²The actual break date is October 1979. See appendix for sources and construction of variables.

³A Wald test is constructed to test the null that each correlation coefficient in the post-79 episode is equal to the corresponding coefficient in the pre-79 episode (see Ostle, 1963, pp. 225-7). A previous version of the paper addressed the non-borrowed reserves targeting episode (post-83). The number of measureable nominal differences across the pre-79 and post-83 episodes increase by 3, but there are no measureable differences between the post-79 and post-83 samples.

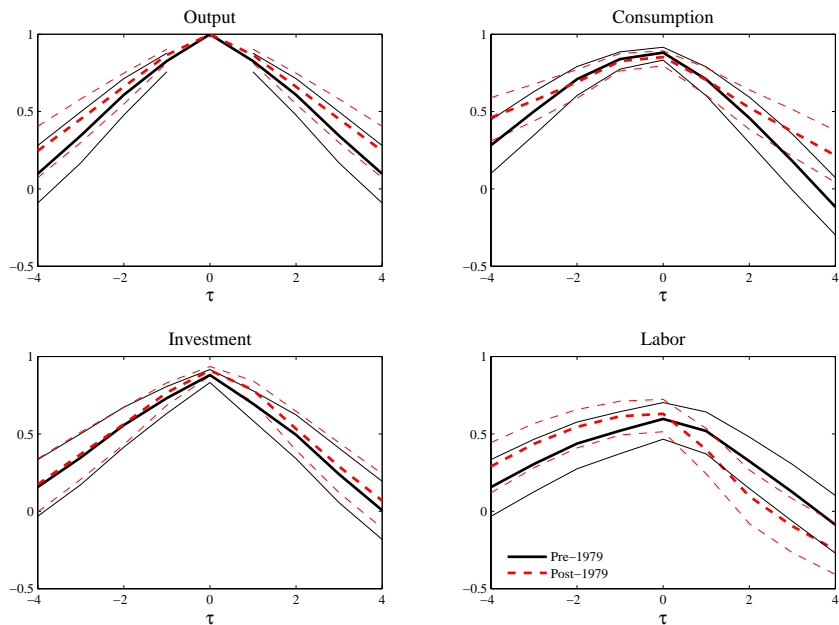


Figure 1: Correlations with Real Output, $\rho(Y_t, x_{t+\tau})$. Thick lines denote correlations between the variable and real output at leads and lags of the cycle. Thin lines denote a 10 percent confidence interval around that measure.

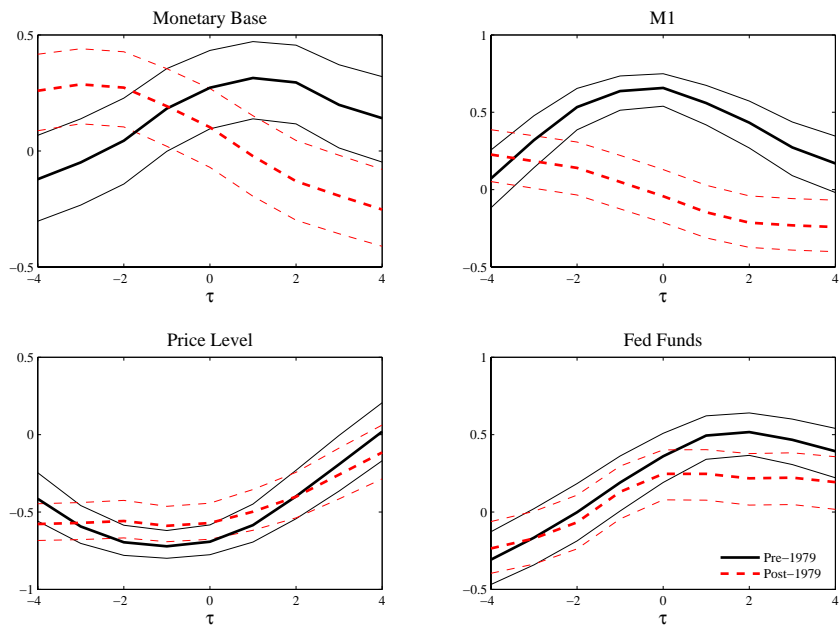


Figure 2: Correlations with Real Output, $\rho(Y_t, x_{t+\tau})$. Thick lines denote correlations between the variable and real output at leads and lags of the cycle. Thin lines denote a 10 percent confidence interval around that measure.

Chari, et al. (1995). Banks use cash deposits from households as the reserve base for much larger deposit holdings, some of which are also considered to be loans to firms.⁴ These extensions allow for endogenous monetary policy to break the link between output and inside monetary aggregates which is a prevailing feature of Freeman and Kydland's model.

A central issue of this analysis pertains to quantifying the central bank's systematic reaction to movements in the economy. Woodford (2003) makes the case that models with Taylor (1993)-type rules are necessary for understanding important monetary business-cycle features. However, Clarida, et al. (2000) and many others have established that pre-79 US monetary policy can be characterized by an interest rule which exhibits instability and results in a continuum of equilibria in DSGE models. In order to restrict this analysis to unique and stable equilibria, a rule used by Ireland (2003) is adopted which defines the money growth rate as the policy variable while the nominal interest rate serves as a target along with the output gap and inflation rate.⁵ In other words, the rule can be considered the FOMC decision process rather than the operating procedure used to implement the FOMC decisions. The central bank's systematic response to the environment is isolated and quantified by matching the model to episodes of US data using a combination of calibration and estimation techniques. The calibrated model parameters are those that are identifiable in the steady state, and are set to match long-run properties of the data. The coefficients of the monetary policy reaction function are then obtained pre and post-79 using simulated method of moments (SMM) estimation.

The results indicate that the change in the monetary policy regime can account for many of the observed changes in the cyclical behavior of monetary aggregates. When comparing the predictions of a baseline model under exogenous monetary policy with the data, the model with endogenous monetary policy accounts for 72 (95) percent of the discrepancy in the cyclical behavior of monetary aggregates pre (post) -79. An additional feature of the model is the post-79 observation of monetary aggregates *preceeding* real output. When analyzing data generated from the model as in Sims (1972), both monetary aggregates are found to significantly Granger-cause output. This result is not due to a causal channel from money to output, but due to model features enabling

⁴In 1990, firms held more than two-thirds of all zero-interest bearing demand deposits (source: Federal Reserve Bulletin, 1990).

⁵An additional reason for employing this type of reaction function is to allow for a general framework to capture the change in the monetary regime instead of imposing a particular policy rule. See Sims and Zha (2004) for empirical results supporting this approach.

the central bank to manipulate monetary aggregates to return to steady state *before* output in the event of a non-monetary shock. This result is new to the literature involving business-cycle models which exhibit monetary neutrality, and accords with Tobin's (1970) critique of interpreting Granger-causality from money to output as true causality.⁶

The paper is organized as follows. Section 2 presents the model and equilibrium. Section 3 presents the quantitative results. Section 4 concludes.

2 The Model

2.1 Environment Overview

The economy is populated by a large number of infinitely-lived households, perfectly competitive firms and commercial banks, and a central bank. A continuum of good types is indexed by $j \in (0, 1)$.

Each household is endowed with an initial capital stock and one unit of time in every period. Households rank the consumption of each good type (c_{jt}) and leisure (ℓ_t) in each period. The utility of a representative household is expressed as

$$(1) \quad E_0 \sum_{t=0}^{\infty} \beta^t u \left(\min \left(\frac{c_{jt}}{2j}, \ell_t \right), \ell_t \right),$$

where $u(\cdot, \cdot)$ is assumed to be increasing in each argument, quasi-concave, twice continuously differentiable, and to satisfy the Inada conditions. E_0 is the expectation operator conditional on information available at time 0 and $\beta \in (0, 1)$ is the discount rate.

A single production process produces capital and all consumption goods. Let k_t denote the *end-of-period* capital stock, which evolves according to $k_t = (1 - \delta)k_{t-1} + i_t$ where i_t denotes capital investment in period t and $\delta \in (0, 1)$ is the depreciation rate. Output at time t is a CRS function of capital and labor (h_t): $y_t = z_t f(k_{t-1}, h_t)$, where z_t denotes the exogenous level of technology and evolves according to $z_t = \kappa_z + \rho_z z_{t-1} + \varepsilon_t$ with $\kappa_z > 0$, $\rho_z \in [0, 1)$, and $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$.

The central bank controls the end-of-period stock of currency, M_t , which evolves according to

⁶While Freeman and Kydland (2000) are able to observe a contemporaneous correlation between M1 and real output, the extensions mentioned previously are necessary to observe this leading behavior.

$M_t = \mu_t M_{t-1}$. Changes in the growth rate μ_t are determined according to

$$(2) \quad \log(\mu_t/\mu) = \varpi_R \log(R_t/R) + \varpi_y \log(y_t/y) + \varpi_\pi \log(\pi_t/\pi) + \xi_t,$$

where π_t is the gross inflation rate (P_t/P_{t-1}), R_t is the gross nominal interest rate, variables without a time subscript denote their long-run (steady state) values, and ξ_t denotes a shock which has zero mean and evolves according to $\xi_t = \rho_\xi \xi_{t-1} + v_t$ with $\rho_\xi \in [0, 1)$ and $v_t \sim N(0, \sigma_v^2)$. The shock can either be interpreted as non-systematic changes in the preferences of the central bank or discrepancies attributable to measurement error.⁷ Changes in μ_t are facilitated through lump-sum transfers of currency (T_t) to the households. The central bank budget constraint is $T_t = (\mu_t - 1) M_{t-1}$.

The agents interact in three markets: a financial market, a factor market, and a goods market. After all shocks to the economy are realized (z_t, ξ_t), the financial market opens where commercial banks accept household deposits and issue loans to firms at gross real rates r_t^D and r_t^L , respectively. A commercial bank is required to keep a certain fraction θ of its total deposits in currency reserves. While the financial market is open, the factor market opens where labor services are hired and capital is rented from households by firms in exchange for competitively determined real wage (w_t) and gross rental (r_t) rates, respectively. It is assumed that capital loans can be repaid at the end of the period, while wages must be paid prior to the sale of present output. These assumptions imply that firms must go to financial intermediaries to finance their wage bills. After loans are made to firms and wages are paid to households (in the form of checks), the factor market closes and production takes place.

Consumption goods can be purchased with either currency (m_t) or deposits (d_t), jointly referred to as money balances. Currency is free to use, while deposits incur a real fixed cost γ for each *type* of good purchased. This can be interpreted as a check-clearing or identity-verification cost, and is independent of the amount of the good type purchased. While the goods market is open, the household organizes her money balances to make n_t trips in order to purchase consumption. A trip begins with a household using her present holdings of currency and deposits to purchase

⁷This reaction function was previously used by Ireland (2001) and is general enough to become the rule studied by Gavin and Kydland (1999) with $\varpi_y > 0$, and $\varpi_r, \varpi_\pi = 0$, a rule argued by McCallum (1993) with $\varpi_r = 0$ and $\varpi_y, \varpi_\pi \neq 0$, or a purely exogenous policy with $\varpi_y, \varpi_r, \varpi_\pi = 0$. A following section considers a rule similar to Taylor (1993) by removing the left-hand term and setting $\varpi_r = -1$ and $\varpi_y, \varpi_\pi \neq 0$.

consumption goods, and requires ϕ units of time.⁸ The household's time constraint is given by $1 = h_t + \ell_t + \phi n_t$.

Trips to the goods market is a feature which captures a need for households to hold money balances much like standard cash-in-advance constraints. However, the timing allows contemporaneously chosen money balances to facilitate purchases. Money balance conditions state that the amount of consumption purchased throughout a period cannot exceed the total amount of money balances taken to the goods market,

$$(3) \quad n_t \tilde{m}_t \geq \int_{J(\tilde{m})} P_{jt} c_{jt} dj$$

$$(4) \quad n_t \tilde{d}_t \geq \int_{J(\tilde{d})} P_{jt} c_{jt} dj,$$

where \tilde{m}_t and \tilde{d}_t denote the per-trip balances of currency and deposits, P_{jt} is the price of consumption good j , and $J(\cdot)$ is a notation for the measure of consumption good types purchased with each type of money balance.⁹ While these features increase the flexibility of the household's choice set with respect to holding money balances, it lacks a reason to hold money balances across periods. Following Freeman and Kydland (2000), households are required to replenish their money balances after each trip to the goods market. This can be expressed as households choosing end-of-period money balances which cannot be less than the amount of money balances held during the period.

$$(5) \quad m_t \geq \tilde{m}_t$$

$$(6) \quad d_t \geq \tilde{d}_t$$

Constraints (5) and (6) are necessary to have return-dominated assets valued in equilibrium. They can be interpreted as solvency conditions set forth by the commercial bank as in Balke and Wynne (2000).

It is assumed that all checks clear, and all interest, transactions costs, and loans are simultaneously paid at the end of the period. Household's choose $\{k_t, \tilde{d}_t, \tilde{m}_t, d_t, m_t, c_{jt}, \ell_t, h_t, n_t\}$ to

⁸This transaction technology is similar to that considered by Baumol (1952) and Tobin (1956), but with a cost quantified in units of time as in Karni (1973).

⁹These conditions contain the implicit assumption that households take identical amounts of money balances for each trip to the goods market. This is not a drastic imposition since no interest payments or additional information is received throughout the transaction process.

maximize (1) subject to (3) through (6), the time constraint, and a series of end-of-period budget constraints

$$(7) \quad w_t h_t + r_t k_{t-1} + \frac{m_{t-1} + d_{t-1} + T_t}{P_t} \geq \int_J c_{jt} dj + k_t + \frac{m_t}{P_t} + \frac{d_t}{P_t r_t^D} + \gamma (J(d)).$$

The budget constraint states that all wealth and income accumulated throughout a period cannot be less than the household's consumption, accumulation of new assets, and payment of transaction costs.

It should be noted that the returns to deposits appear in the denominator of the fourth element on the right-hand side of (7), capturing the timing assumption of households receiving and spending interest payments in the present period. This is an important departure from Freeman and Kydland (2000) due to the fact that deposits in their model are physical capital which is indirectly invested into the firms via the intermediary, resulting in inside money behaving exactly like capital investment. The supply of cash deposits in this environment is not only affected by shocks to technology, but also by the endogenous monetary response to these shocks.

2.2 Equilibrium

Consider the household's consumption decision for each type j . Given a desired level of total consumption over *all* good types, c_t^* , the Leontief argument in (1) induces agents to follow an optimizing rule when distributing c_t^* over the j types, $c_{jt} = 2j c_t^*$. Substitution of this rule delivers a standard objective function.

$$(8) \quad E_0 \sum_{t=0}^{\infty} \beta^t u(c_t^*, \ell_t)$$

Now consider the composition of money balances needed to purchase c_t^* . For every c_{jt} , a household must decide whether deposits or currency should be used to facilitate the purchase. Deposits pay interest at the end of the period, but incur a transactions cost for their use. Since households are required to bring portions of both money balances into the next period, the optimal composition can be analyzed by comparing the real opportunity cost of funds necessary to make n_t purchases totaling c_{jt} with currency (c_{jt}/n_t), and deposits ($c_{jt}/n_t r_t^D + \gamma$). Comparing these costs

and rearranging yields the relation

$$(9) \quad \frac{1}{r_t^D} + \frac{\gamma n_t}{2j_t c_t^*} \leq 1,$$

where the left (right)-hand side is the normalized opportunity cost to using deposits (currency). The left-hand side of (9) is decreasing in j ; the opportunity cost associated with using deposits for purchasing consumption approaches infinity as j approaches zero. This implies that there is a critical good type j^* such that the opportunity costs to purchasing c_{j^*t} with either money balance are equal, and every good type indexed by $j < (>) j^*$ will be purchased with currency (deposits).¹⁰ The remainder of the analysis concentrates on the case in where $j^* < 1$.¹¹

Substituting j_t^* and c_t^* into (3), (4), and (7) yield simpler expressions of the constraint set.

$$(10) \quad w_t h_t + r_t k_{t-1} + \frac{m_{t-1} + d_{t-1} + T_t}{P_t} \geq c_t^* + k_t + \frac{m_t}{P_t} + \frac{d_t}{P_t r_t^D} + \gamma(1 - j_t^*)$$

$$(11) \quad n_t \frac{\tilde{m}_t}{P_t} \geq (1 - j^{*2}) c_t^* \text{ and } n_t \frac{\tilde{d}_t}{P_t} \geq j^{*2} c_t^*$$

The household problem can now be stated as choosing $\{k_t, \tilde{d}_t, \tilde{m}_t, d_t, m_t, c_t^*, j_t^*, \ell_t, h_t, n_t\}$ to maximize (8) subject to the time constraint, (5), (6), (10), and (11).

A representative firm chooses capital (K_t) and labor (H_t) to maximize profits.

$$(12) \quad \max_{\{K_t, H_t\}} (z_t f(K_t, H_t) + (1 - \delta) K_t - r_t K_t - (1 + r_t^L - r_t^D) w_t H_t)$$

Note that the loan for the wage bill is charged r_t^L while the deposit for the same amount is paid r_t^D .

The firm equates the marginal product of each input to their marginal costs (inclusive of financing),

$$r_t = z_t f_{1t} + 1 - \delta, \text{ and } w_t = \frac{z_t f_{2t}}{(1 + r_t^L - r_t^D)},$$

where f_{1t} and f_{2t} denote the time t marginal products of capital and labor, respectively.

A representative commercial bank chooses real loans (L_t), deposits (D_t), and reserves (Q_t) to

¹⁰The preferences can now be seen an alternative to those used in standard cash / credit - type models which allow for the choice of ‘cash’ and ‘deposit’ good proportions through the choice of j_t^* .

¹¹Given the model parameters below, it has been numerically verified that $1/r_t^D + \gamma n_t / 2j_t c_t^* - 1$ is monotonically decreasing in j_t and equals zero for a single value j^* within $(0, 1)$.

maximize profits subject to reserve requirement and balance-sheet constraints. The deposit and loan-creation technologies of the commercial bank are assumed to be linear, and the bank solves

$$(13) \quad \max_{\{L_t, D_t, Q_t\}} (r_t^L L_t - r_t^D D_t + Q_t)$$

subject to a reserve requirement ($Q_t \geq \theta D_t$) and a balance-sheet condition ($D_t = L_t + Q_t$). Note that since the commercial bank facilitates lending and repays depositors within the same period, they do not face an (inflationary) opportunity cost for holding currency reserves.

As long as the gross real lending rate is greater than one, the reserve requirement will bind and a representative bank will issue loans until the marginal benefits and costs associated with lending funds are equal ($r_t^D = (1 - \theta) r_t^L + \theta$).

The model is closed by the clearing of the various markets. The clearing of the factor market requires $K_t = k_{t-1}$, and $H_t = h_t$. Firms require loans equal to the amount of their wage bills ($L_t = w_t H_t$), while the total amount of deposits equal the sum of aggregate bank loans to firms and deposits from households ($D_t = w_t H_t + \frac{d_t}{P_t r_t^D}$). The clearing of the loan market can be expressed by combining these conditions with the bank's constraints.

$$(14) \quad w_t H_t = \frac{(1 - \theta)}{\theta} \frac{d_t}{P_t r_t^D}$$

The clearing of the currency market requires that the monetary base equals the currency held by the households and commercial banks.

$$(15) \quad M_t = m_t + \theta P_t r_t^D D_t = m_t + d_t$$

The total stock of money ($M1_t$), is defined to be the sum of the monetary base and the entire stock of deposits.

$$M1_t = M_t + P_t r_t^D D_t = M_t \left(1 + \frac{d_t}{\theta (m_t + d_t)} \right)$$

The third expression uses (14) and (15) to express the total stock of money as the product of the base and the endogenously determined money multiplier.

Finally, goods market clearing requires

$$(16) \quad y_t + (1 - \delta) k_{t-1} = k_t + c_t^* + \gamma (1 - j_t^*).$$

An equilibrium is defined as a list of prices $\{r_t, r_t^L, r_t^D, w_t, P_t\}_{t=0}^{\infty}$ and allocations for households $\{k_t, \tilde{d}_t, \tilde{m}_t, d_t, m_t, c_t^*, j_t^*, \ell_t, h_t, n_t\}_{t=0}^{\infty}$, firms $\{K_t, H_t\}_{t=0}^{\infty}$, commercial banks $\{L_t, D_t, Q\}_{t=0}^{\infty}$, and the central bank $\{\mu_t\}_{t=0}^{\infty}$ such that: (i) Households maximize (8) subject to their constraint sets; (ii) Firms and commercial banks maximize profits; (iii) Firms and commercial banks earn zero profits; (iv) The central bank's policy satisfies (2); and (v) All markets clear.

3 Quantitative Analysis

The model is linearized around its steady state and solved via a method of undetermined coefficients (see Christiano, 2002). The model parameters are divided into two subsets. One is calibrated so the model's steady state matches several long-run properties of the US economy. The other subset focuses on the central bank's implementation of monetary policy and is determined for each episode via SMM (see Lee and Ingram, 1991).

3.1 Parameter Values and Functional Forms

The parameters chosen to be calibrated are summarized in Table 1. Investment is one quarter of steady state output. With a 10 percent annual depreciation rate, the capital stock to annual output ratio is 2.5. The production function is assumed to be $z_t K_t^\alpha H_t^{1-\alpha}$, and α is calibrated so labor's share of national income is roughly two-thirds.

The utility function is assumed to be $(c_t^* \ell_t^{1-\varsigma})^{1-V} / (1 - V)$. The parameter ς is calibrated so a household's average allocation of time to market activity (net of sleep and personal care) is 0.3 which is in line with estimates of Ghez and Becker (1975). V is set to 2 which is within the range of results reported by Hansen and Singleton (1983) and Neely, et al. (2001).

The annual money growth rate $(\mu - 1)$ is set to 3 percent. The reserve requirement θ is set to 10 percent, and the discount parameter β is calibrated so the annual real interest rate is 4 percent.

The parameters governing the law of motion of technology shocks $(\rho_z, \sigma_\varepsilon)$ are independent of

the model's steady state, but share a large agreement on values which should be assigned (see Prescott, 1986). They are assumed to be 0.95 and 0.0076, respectively.

The remaining parameters, γ and ϕ , correspond to frictions associated with using deposits to purchase consumption goods and to replenish money balances. These parameters are calibrated to match the ratio of currency reserves held in banks to currency held by the public, and the ratio of the corporate bond rate to the prime lending rate. In the context of the model, these ratios correspond to $\theta DP/m$ and r/r^L , respectively. In determining the first ratio, Porter and Judson (1996) estimate that the amount of US currency held abroad ranges between two-thirds to three-quarters of the total currency base. Excluding this portion of the base results in average values of the ratio to lie between 0.7 and 1.00 in the data. The value chosen for the baseline case is 0.9. For the second ratio, the average annual lending rate over the course of the postwar period is about 20 basis points higher than the annual corporate bond rate. In quarterly terms, this difference is negligible and the ratio is set to one. Calibrating the model to these ratios requires setting ϕ equal to $2e^{-4}$ and γ equal to $2e^{-3}$. An analysis concerning these ratios is conducted below to show that the following results are insensitive to the values of the resulting model parameters.¹²

The SMM estimates of (2) are presented in Table 2. The moments used for each episode include the standard deviation of the monetary base, the contemporaneous correlation between output and the price level, and six of the ten correlations between output and both the monetary base and M1 at leads and lags of up to two quarters.¹³ The asymptotic standard errors were calculated as in Duffie and Singleton (1993).

To consider the statistical fit of the estimates, an asymptotically distributed χ^2 test statistic is calculated to be 6.65 and 0.85 using the pre and post-79 policy estimates, respectively (see Lee and Ingram, 1991).¹⁴ The model fails to reject the null that the value of the SMM objective function

¹²The calibration of γ and ϕ closely follow the calibration procedure outlined in Freeman and Kydland (2000). However, having capital deposits allow for them to use the share of intermediated capital as a calibrating ratio as opposed to the lending rate ratio.

¹³These moments were selected to satisfy two criteria. First, the SMM procedure had to capture the observed moments that changed across episodes. If more price level or interest rate moments were included, the optimal weighting matrix would focus the estimation on them (due to their smaller standard deviations) instead of the ones that changed. Second, within the set of the relevant variables, only moments which emphasized the phase shift were selected in order to keep the degrees of freedom comparable across episodes. The specific moments are denoted on the horizontal axes of Figures 3 and 4.

¹⁴In the pre-79 episode, the estimate of $\rho_\xi = 3.6 \times 10^{-6}$ contributes nothing to the model's dynamics. Dropping this estimate results in the pre-79 test statistic having four degrees of freedom, while the post-79 test statistic has three degrees of freedom.

Table 1: Model Parameters Obtained via Calibration

Symbol	Description	Value
α	capital's share	0.3397
β	discount factor	0.9879
δ	depreciation rate	0.0241
θ	reserve requirement	0.10
ς	consumption's share	0.3308
V	risk aversion	2
γ	check clearing cost	$2.0e^{-3}$
ϕ	bank trip cost	$2.0e^{-4}$
ρ_z	AR coefficient (Technology)	0.95
σ_ε	standard deviation (Technology)	0.0076

Table 2: Model Parameters Obtained via Estimation

	ϖ_R	ϖ_y	ϖ_π	ρ_ξ	σ_v	χ^2
Pre-1979	3.354 (1.8208)	-0.065 (0.0287)	-3.543 (1.9285)	$3.6e^{-6}$ (0.0524)	0.0067 (0.0009)	6.65^b
Post-1979	-2.994 (2.3811)	-0.051 (0.0179)	2.818 (2.3270)	0.775 (0.3013)	0.0037 (0.0033)	0.85^c

Notes: ^aAsymptotic standard errors are in parentheses.
^bAsymptotically distributed with 4 degrees of freedom (by dropping ρ_ξ).
^cAsymptotically distributed with 3 degrees of freedom.

is equal to zero at the ten percent critical level in both cases.¹⁵

It should be stressed that as in Ireland (2003), the estimates in Table 2 can be interpreted as the identified policy responses of a monetary authority. To elaborate further, with all non-policy parameters of the model being calibrated at steady state, the household's demand for both currency and deposits are explicitly determined in the solution to the household's optimization problem. The amount of money balances the household chooses is ultimately influenced by the supply of money in the economy as well as the remaining endogenous and exogenous state variables. Therefore, taking the general equilibrium model as the 'true' data generating process dependent upon the parameters of (2), the estimation procedure delivers the policy function which allows the equilibrium dynamics of the model to match as close as possible to the moments selected from the data.¹⁶

¹⁵Although some asymptotic standard deviations associated with the estimates are large, the remainder of the analysis utilizes the point estimates. One way of reconciling this is to examine the business-cycle correlations which were used in the estimation procedure. While these point estimates are different from zero, a 10% confidence interval includes the possibility of zero correlation. This greatly influences the point estimates' asymptotic standard deviations.

¹⁶In other words, the general equilibrium framework provides the necessary cross-equation restrictions which identify money supply given money demand.

3.2 Quantitative Results

3.2.1 Exogenous Monetary Policy

This section reports simulations of the model where the central bank is operating under several exogenous policy rules.¹⁷ For the first policy (Policy A), $[\varpi_R, \varpi_y, \varpi_\pi, \rho_\xi, \sigma_v]$ were set to zero resulting in a purely inactive monetary authority (i.e. $\mu_t = \mu, \forall t$). For the second and third policies, AR(1) processes for the growth rate of pre and post-79 monetary base data were estimated to determine how plausible (exogenous) monetary policies would influence the model’s cyclical behavior. The pre-79 episode (Policy B) is described by $\rho_\mu = 0.8465$ ($se = 0.0631$) and $\sigma_v = 0.0040$. The post-79 episode (Policy C) is described by $\rho_\mu = 0.3898$ ($se = 0.1086$) and $\sigma_v = 0.0055$. The resulting predictions are presented along with the actual data in Tables 3 and 4.

The model predictions for the real variables share several features with the data: consumption, investment, and labor hours are procyclical and concurrent with the cycle; and investment is more volatile than output in percentage terms while consumption and labor hours are less volatile. As in the data, the model’s predictions for the real variables are unaffected by changes in monetary policy (endogenous or exogenous), so only the predictions for policy A are reported.¹⁸

The model predictions for the nominal variables share several features across exogenous policies: M1 is procyclical and concurrent with the cycle; prices are countercyclical and concurrent with the cycle; and nominal interest rates are countercyclical at leads and procyclical at lags. One important feature to stress from this exercise is that M1 exhibits a strong contemporaneous correlation with real output for all exogenous policies. Without systematic movements in outside money, movements in inside money are strongly determined by the real side of the economy. For intuition, consider the stream of events following a positive technology shock: the demand for productive inputs increase; the increase in labor demand implies an increase in loan demand and further implies an increase in lending and deposit rates. The increase in output induces households to purchase more *total* consumption (i.e. c_t^* increases), while the increase in the deposit rate induces households to purchase less (more) consumption good *types* with currency (deposits) (i.e. j_t^* decreases). The

¹⁷For every numerical experiment reported below, the model was fitted with the respective monetary policy parameters and used to simulate 80 periods of data for 100 replications. Business-cycle statistics for each simulated data set were calculated as in the true data, and averaged across replications.

¹⁸To quantify this statement, comparing the cyclical behavior of all real variables at all leads and lags under policies A, B, and C results in a maximum correlation difference of 0.015 in absolute value.

Table 3: Model Results - Exogenous Monetary Policy

x		σ_x	Correlations with RGDP at time $t^{a,b,c}$						
			x_{t-3}	x_{t-2}	x_{t-1}	x_t	x_{t+1}	x_{t+2}	x_{t+3}
Y_t	< 79	1.63	.34	.60	.82	1.0	.82	.60	.34
	> 79	1.39	.45	.66	.87	1.0	.87	.66	.45
	A	1.34	.21	.41	.67	1.0	.67	.41	.21
C_t	< 79	1.28	.50	.71	.84	.88	.71	.45	.17
	> 79	1.11	.57	.69	.82	.85	.71	.53	.37
	A	0.52	.09	.31	.60	.97	.72	.51	.35
I_t	< 79	7.13	.35	.56	.73	.88	.69	.49	.23
	> 79	6.47	.37	.57	.78	.91	.78	.53	.29
	A	4.01	.25	.44	.69	.99	.63	.35	.15
L_t	< 79	1.03	.36	.53	.59	.69	.53	.30	.07
	> 79	1.03	.44	.53	.58	.61	.39	.08	-.11
	A	0.59	.27	.45	.69	.99	.61	.32	.11

Notes: ^aThe data are measured as deviations from trend.
^bRow labeled <79 (>79) corresponds to Pre-79 (Post-79) Data
^cPolicy A uses $\rho_\xi = 0.0$, $\sigma_v = 0.0$

increase in household deposits implies more loans / deposits for firms and delivers an increase in M1. Adding a stochastic component to money growth (policies B and C) influences the strength of these correlations as well as the standard deviations of the nominal variables, but their lead-lag behavior remains intact.

It should be noted that the results presented here closely follow Freeman and Kydland (2000). As previously mentioned, their model intermediates physical capital and creates a link between inside money and investment which cannot be broken by endogenous or exogenous changes in monetary policy. The extensions in the present model create a weaker link between the two types of loans offered to firms. Once monetary policy becomes endogenous, the difference between the two environments is apparent because the link can be broken in this model, while it holds strong in the former.

3.2.2 Endogenous Monetary Policy

The predictions of the model using the SMM estimates are compared with the pre and post-79 data in Figures 3 and 4. The predictions for the nominal variables are also presented in Table 5. The model predicts identical relationships among the real variables as in Table 3 and are not presented.

The model tracks all drastic changes in monetary aggregates across episodes: the base lags

Table 4: Model Results - Exogenous Monetary Policy

x		σ_x	Correlations with RGDP at time $t^{a,b,c,d,e}$						
			x_{t-3}	x_{t-2}	x_{t-1}	x_t	x_{t+1}	x_{t+2}	x_{t+3}
M_t	< 79	0.88	-.05	.04	.18	.27	.31	.30	.21
	> 79	1.20	.28	.26	.19	.10	-.02	-.13	-.19
	A	0	0	0	0	0	0	0	0
	B	1.13	.03	.01	-.00	-.01	-.02	-.02	-.02
	C	0.94	-.03	-.04	-.05	-.05	-.04	-.03	-.03
$M1_t$	< 79	0.95	.32	.53	.63	.66	.55	.44	.29
	> 79	3.18	.18	.14	.05	-.04	-.15	-.22	-.24
	A	0.93	.28	.46	.70	.99	.62	.33	.12
	B	2.61	.19	.28	.40	.57	.35	.17	.05
	C	1.31	.14	.25	.38	.55	.34	.18	.04
P_t	< 79	0.79	-.59	-.70	-.72	-.69	-.58	-.39	-.17
	> 79	0.85	-.57	-.56	-.59	-.57	-.50	-.40	-.25
	A	0.68	-.05	-.26	-.56	-.94	-.74	-.56	-.41
	B	2.79	.00	-.09	-.21	-.34	-.28	-.21	-.15
	C	1.16	-.05	-.13	-.24	-.36	-.29	-.22	-.17
R_t	< 79	2.35	-.16	0.0	.19	.36	.48	.52	.48
	> 79	3.35	-.16	-.06	.14	.25	.25	.23	.23
	A	1.99	-.23	-.26	-.34	-.40	.39	.33	.26
	B	8.70	-.07	-.10	-.12	-.12	.11	.10	.09
	C	3.64	-.08	-.09	-.11	-.11	.12	.10	.08

Notes: ^aThe data are measured as deviations from trend.

^bRow labeled <79 (>79) corresponds to Pre-79 (Post-79) Data

^cPolicy A uses $\rho_\xi = 0.0$, $\sigma_v = 0.0$

^dPolicy B uses $\rho_\xi = 0.85$, $\sigma_v = 0.0040$

^ePolicy C uses $\rho_\xi = 0.39$, $\sigma_v = 0.0055$

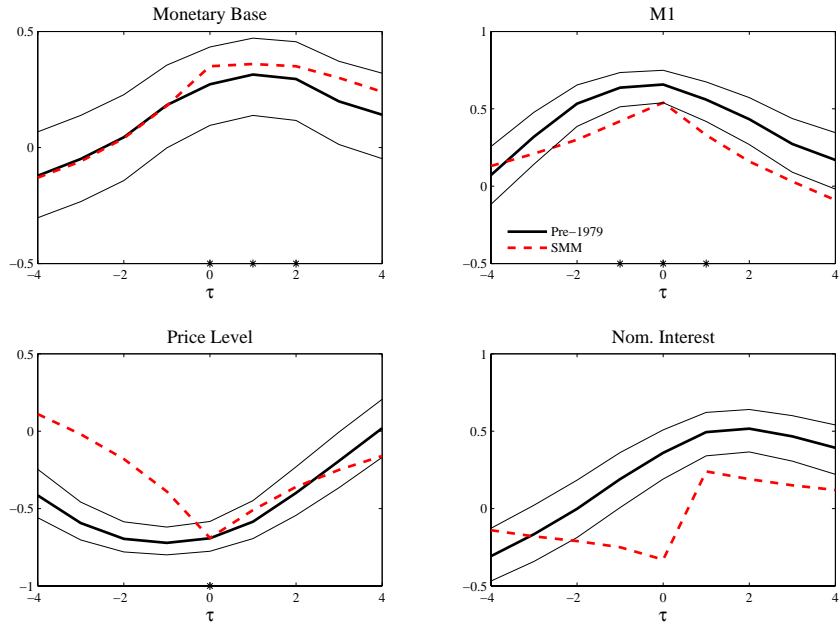


Figure 3: Pre-79 Correlations with Real Output, $\rho(Y_t, x_{t+\tau})$. Solid lines denote the data moments and their 10 percent confidence interval. Asterisks on the x-axes indicate moments used in the SMM procedure.

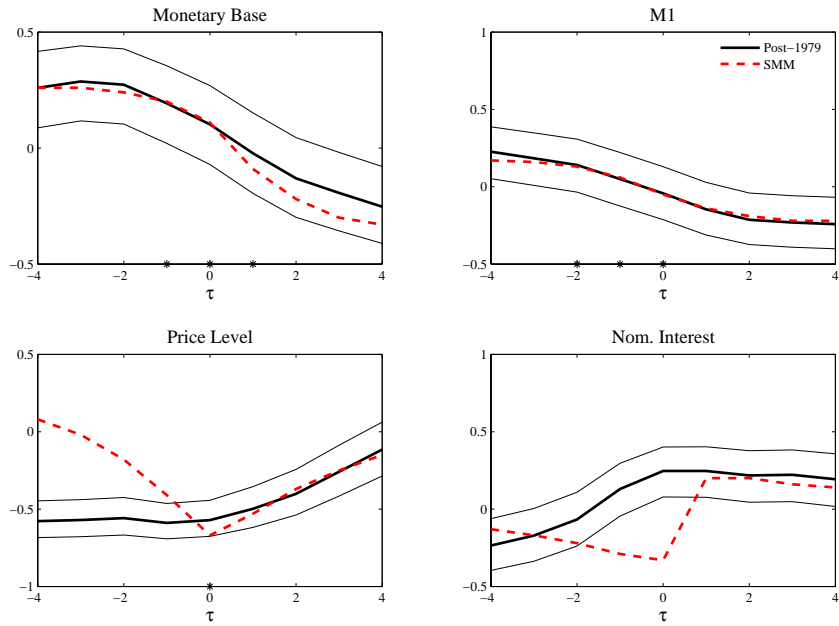


Figure 4: Post-79 Correlations with Real Output, $\rho(Y_t, x_{t+\tau})$. Solid lines denote the data moments and their 10 percent confidence interval. Asterisks on the x-axes indicate moments used in the SMM procedure.

pre-79, leads post-79; M1 is contemporaneous pre-79, leads post-79; and M1 is more correlated with real output than the base pre-79, less correlated post-79. The predictions exhibit an increase in volatility for monetary aggregates across episodes (from 0.86 to 1.08 for the base, from 0.92 to 1.36 for M1), but M1 volatility is understated in the later episode (3.12 in the data). With respect to other nominal variables: the price level is countercyclical in both episodes, but fails to exhibit a slight lead pattern as in the data, and the nominal interest rate is countercyclical at leads and procyclical at lags, but fails to capture a positive, contemporaneous correlation. The nominal interest rate is more volatile than output, which is observed in the data (2.35 pre-79, 3.35 post-79), but the prediction is around twice as high (3.51 pre-79, 6.59 post-79).

For intuition on the model with endogenous monetary policy, consider again the stream of events following a positive technology shock. As in the exogenous policy case, consumption will increase under both sets of estimates. However, the monetary policy response alters how households will choose monetary balances in order to make their consumption purchase. Figure 5 shows the responses for the monetary base and the price level under the pre and post-79 regimes. The larger increase in base growth pre-79 induces households to hold more deposits relative to currency (i.e. j_t^* decreases), while the smaller increase in base growth post-79 induces households to hold more currency relative to deposits (i.e. j_t^* increases). These actions result in a larger decline in the price level post-79 than pre-79, and when examining the sign of ϖ_π in Table 2, the monetary response next period is a contraction of the base post-79 and a smaller expansion of the base pre-79. The response post-79 allows the economy to quickly realign their money balances and return to steady state before output, hence the appearance of monetary aggregates leading output. The continued response pre-79 delays the economy's return to steady state, hence the appearance of the base slightly lagging output (although M1 is concurrent). Another point to make concerning Figure 5 is that the policy responses appear to be consistent with the well documented operational behavior of the Federal Reserve: the pre-79 episode can be regarded as a period accommodating inflationary deviations, while the post-79 episode can be regarded as a period of heightened sensitivity for deviations from inflation targets.

Table 5: Model Results - SMM Estimation

x_t		σ_x	Correlations with RGDP at time $t^{a,b,c}$						
			x_{t-3}	x_{t-2}	x_{t-1}	x_t	x_{t+1}	x_{t+2}	x_{t+3}
M_t	< 79	0.86	-.06	.04	.18	.35	.36	.35	.31
	> 79	1.08	.26	.25	.20	.11	-.09	-.22	-.30
$M1_t$	< 79	0.92	.21	.30	.42	.54	.33	.16	.03
	> 79	1.36	.16	.13	.06	-.05	-.14	-.19	-.22
P_t	< 79	1.12	-.02	-.18	-.39	-.69	-.51	-.36	-.25
	> 79	2.15	-.02	-.18	-.41	-.68	-.53	-.37	-.25
R_t	< 79	3.51	-.18	-.21	-.25	-.33	.24	.19	.15
	> 79	6.59	-.17	-.22	-.29	-.33	.20	.20	.16

Notes: ^aThe data are measured as deviations from trend.

^bStandard deviations are expressed in percentage terms.

^cRow labeled <79 (>79) corresponds to simulated data using Pre-79 (Post-79) estimates.

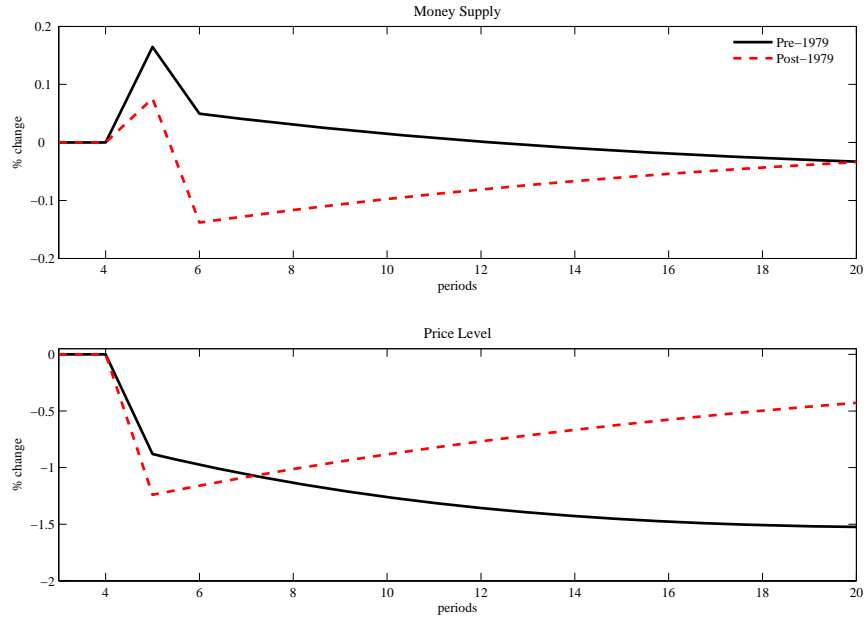


Figure 5: Impulse responses to a positive standard deviation shock to technology. Paths are measured as percentage changes from steady state values.

3.2.3 The Quantitative Importance of Monetary Policy

Quantifying the importance of monetary policy in accounting for the change in the cyclical behavior of monetary aggregates is accomplished by asking how much of the total discrepancy between the cyclical behavior of monetary aggregates in the data and the model predictions can be accounted for by changing the form of monetary policy. In other words, starting from either an inactive (A) policy or an exogenous (B or C) policy, what is the improvement of the model predictions under an endogenous policy? The discrepancy for a variable is defined as the sum of the squared difference between the data moments and the model's prediction for those moments.¹⁹ The importance of monetary policy is quantified as the percentage of this discrepancy accounted for and is reported in Table 6.

Table 6 indicates that when measuring the discrepancy using an inactive policy (Policy A), endogenous monetary policy accounts for 34 (98) percent of the discrepancy pre (post)- 79. Furthermore, when measuring the discrepancy using an estimated exogenous policy (Policy B pre-79, Policy C post-79), endogenous monetary policy accounts for 71 (95) percent of the discrepancy pre (post)- 79. Interestingly, the quantitative importance of the model actually increases pre-79 under the estimated exogenous policy. This is due to the fact that discrepancy in the monetary base prediction under policy B is roughly twice as large as the discrepancy under policy A, giving endogenous policy a larger error to account for. Ultimately, these results suggest that endogenous monetary policy has the potential to account for a large portion of the change in the cyclical behavior of monetary aggregates observed in the data.

3.2.4 Money-Output Causality

Given that the model can capture the post-79 observation of monetary aggregates preceding output, this section asks if the model predicts a significant causal relationship from money to output as in the seminal work of Sims (1972) and his use of Granger (1969) causality tests. This question is of

¹⁹For example, the discrepancy for M1 in the baseline case is calculated to be

$$(\Psi^* - \Psi)'(\Psi^* - \Psi)$$

where Ψ^* is the 10×1 vector containing the observed moments (standard deviation and cross-correlations at lead and lags of up to one year), and Ψ is the column vector containing the respective correlations from the model with exogenous monetary policy. The standard deviations are scaled by 100 in order to equalize the weight given to each individual discrepancy.

Table 6: Quantitative Importance of Monetary Policy

	Pre-79	Post-79
Policy A	34	98
Policy B/C	71	95
Notes:	Percentage of discrepancy between data and baseline model under stated policy accounted for by endogenous monetary policy.	

interest because the central bank in the model has no significant influence on output.²⁰

The procedure involves a series of bivariate Granger-causality tests outlined by Hamilton (1994, pp. 304-5), since Sims' original analysis assumes zero autocorrelation of the error terms without a lagged dependent variable. The estimated equation is

$$(17) \quad y_t = a + \sum_{i=1}^{\tau} (\eta_i y_{t-i} + b_i \omega_{t-i}) + e_t,$$

where y denotes real output, and ω denotes either the monetary base or M1. If all of the coefficients on the lags of the independent variable in (17) are jointly equal to zero, then that variable has no Granger-causal power for the present value of real output. The equation was estimated by OLS and the null is that ω does not Granger-cause output (i.e. $H_0 : b_1 = \dots = b_{\tau} = 0$). The resulting test statistic is asymptotically distributed as $\chi^2(\tau)$.

The exercise uses the post-79 estimates to generate 80 periods of data for 1000 replications. For each replication, the logged data were either differenced, filtered as in Sims' analysis, or HP filtered.²¹ The transformed data were used to estimate (17) for τ up to 8, and the percentage of replications where the null was rejected at the ten percent critical level or better for select lag-lengths is reported in Table 7. The simulated data display robust Granger-causality running from both monetary aggregates. The strongest amount of Granger-causality is uncovered using the HP filter, which is to be expected since this filter was used in the original SMM estimation. However, there is evidence of Granger-causality using other data transformations, indicating that the results

²⁰To quantify this statement, the post-79 estimates are used to assess the isolated effects of a monetary policy shock. A monetary policy shock (i.e. an impulse in ξ_t) resulting in a 1 percent change in money growth yields slightly more than a 0.01 percent change in real output. This maximum single-period effect occurs immediately after the shock and quickly returns to trend so there are no cumulative effects. Furthermore, when technological shocks are removed from the moment analysis, the standard deviation of the monetary base falls from 1.08 to 0.91 percent, while the standard deviation of output falls from 1.35 to $5.0e^{-3}$ percent.

²¹Sims replaces x_t with $x_t - 1.5x_{t-1} + 0.5625x_{t-2}$ which flattens the spectral density of most economic time-series.

Table 7: Causality Results

Estimated Equation: $M_t/M1_t$			
τ	Log Δ	Sims' Filter	HP Filter
1	31/32	20/20	97/97
4	23/22	35/36	69/71
8	29/31	32/34	57/56

Notes: Percentage of 1000 replications in which the null was rejected at the 10 percent confidence level or better.

are not an artifact of HP filtering.²²

3.3 Sensitivity Analysis

To assess the sensitivity of the calibrating ratios, the model under policy A was compared across values of the cash reserves ratio ($\frac{\theta DP}{m}$) from 0.4 to 1.4, and values of the interest rate ratio ($\frac{r^L}{r}$) up to 1.01. The range for the cash reserve ratio captures the lower and upper bounds throughout the entire postwar sample, while the interest rate ratio implies an exaggerated eight percent annual lending rate. Comparing the results from the first exercise with Table 3, the largest change in the correlation coefficients across all eight variables examined at all leads and lags was 0.0306. There were similar variations when changing the value of the interest rate ratio (0.0422).²³

To assess the choice of the variables in (2), the SMM procedure was repeated several times using alternative forms. Table 8 reports the form of several estimated reaction functions and the resulting χ^2 statistics for each episode. As indicated by the larger values of the test statistic, the removal of the money growth target or the restriction of one of the three reaction coefficients to be zero can greatly hinder the ability of the model to match the selected moments. The reaction function immediately below the baseline result is similar to the rule proposed by Taylor (1993), and the model performs poorly in both episodes. When considering other forms with money growth as the instrument variable: the lower χ^2 statistics indicate that output gap targeting is more important

²²The overall percentage of model replications where there is at least one significant rejection of the null using log-differences, Sims' filtering, or HP filtering is 78, 83, and 99 percent, respectively. These conclusions are robust to using nominal output in place of real output in (17), and Durbin-Watson tests were performed on each regression to confirm that the residuals were close to white noise.

²³The results are also robust to changes in the reserve requirement because θ enters linearly in (14). This conclusion differs from Freeman and Kydland again due to the fact that they treat deposits as physical capital and not as a balance-sheet entry partially reserved with currency as in this model.

Table 8: Stability Analysis

Equation ^a	Test Statistic	
	Pre-79	Post-79
Baseline	6.70	0.85
$\tilde{R}_t = \varpi_y \tilde{y}_t + \varpi_\pi \tilde{\pi}_t + \xi_t$	64.79	167.17
$\tilde{\mu}_t = \varpi_y \tilde{y}_t + \varpi_\pi \tilde{\pi}_t + \xi_t$	19.17	1.50
$\tilde{\mu}_t = \varpi_{rL} \tilde{R}_t + \varpi_\pi \tilde{\pi}_t + \xi_t$	14.43	16.52
$\tilde{\mu}_t = \varpi_{rL} \tilde{R}_t + \varpi_y \tilde{y}_t + \xi_t$	– ^b	1.03
$\tilde{\mu}_t = \varpi_y \tilde{y}_t + \xi_t$	29.69	3.99
Restricted Information	8.86	3.28

Notes: ^atilda denotes log change: $\tilde{x}_t = \log(x_t/x)$
^bmodel failed to attain a stable solution

in the later episode, while nominal interest rate and inflation rate targeting are more important in the earlier episode. The estimates in the later episode still perform fairly well when either nominal interest rates or the inflation rate is dropped from the rule. However, dropping both does hinder the accuracy of the predictions. These results indicate that from the perspective of the model, taking explicit account of money growth is important for capturing the observed dynamics.²⁴

In addition to the form of the reaction function, there is the criticism that the central bank in the model is provided with too much information while conducting monetary policy (see McCallum, 1993). To address this issue, the environment is altered so the central bank chooses μ_t before all relevant information can be observed. Let Ω_{t-1} denote the set of information available at the end of period $t - 1$. Equation (2) can be rewritten as

$$(18) \quad \log(\mu_t/\mu) = E[\varpi_R \log(R_t/R) + \varpi_y \log(y_t/y) + \varpi_\pi \log(\pi_t/\pi) + \xi_t \mid \Omega_{t-1}, v_t]$$

which implicitly states that the present period's technology shock is unobservable when the central bank conducts monetary policy. The model was reestimated and the test statistic increases to 8.86 and 3.28 for the pre and post-79 episodes, respectively. For both episodes the test statistics indicate that the model still performs reasonably well despite the informational restriction, and the cyclical behavior for both monetary aggregates are qualitatively obtained. Again, the test still fails to reject the post-79 model at the ten percent confidence level.

²⁴This conclusion is similar to the empirical results of Sims and Tao (2004).

4 Conclusion

This paper set out to assess the quantitative importance of the 1979 monetary policy regime change in accounting for observed changes in postwar US business cycles. Estimates of the monetary authority's policy reaction conditional on the theoretical model account for a large portion of the drastic movements in monetary aggregates across the pre and post-79 episodes, while the cyclical behavior of real variables, aggregate prices, and nominal interest rates remain relatively intact. Although monetary policy does not have direct influence over inside monetary aggregates, it has enough influence (through manipulation of opportunity costs of outside money holdings) to explain its cyclical behavior, as well as Granger-causing (but not actually causing) real output.

These results address several topics in monetary economics. First, there is the literature concerned with inside money and the behavior of broad monetary aggregates.²⁵ This paper demonstrates that although the central bank does not have sole influence over inside money, its control over the monetary base can influence movements in broader monetary aggregates. Second, there is the literature pertaining to endogenous monetary policy. Clarida, et al. (2000) estimate Taylor-type rules pre and post-79, but do not examine business-cycle moments. Gavin and Kydland (1999) show that the cyclical behavior of nominal variables in a shopping-time model can be largely dependent on the parameters of a similar monetary policy rule, but do not examine movements in inside money nor attempt to explicitly take their model to the data. As mentioned previously, focusing on moments generated by stable and unique model solutions from both the pre and post-79 episodes result in standard Taylor-type rules being beyond the scope of this exercise. However, this paper combines these two approaches and shows that endogenous monetary policy can account for a large portion of the observed business-cycle changes. Finally, there is the controversy on how to model the monetary transmission mechanism. The model considered here does not assume any nominal rigidities or limited participation, and should be seen as a cautious first step to a broader analysis by determining how much of the observations can be explained in a model where money is approximately neutral.

The model's successes and shortcomings both give rise to further extensions. Among the most

²⁵King and Plosser (1984), Chari et al. (1995), Coleman (1996), and Freeman and Kydland (2000) all examine the cyclical behavior of inside money, with the first three explicitly attempting to capture the precedence of broad monetary aggregates over the business cycle.

prominent is an analysis of this environment with more traditional monetary policy (interest rate targeting) rules. While an analysis using this class of rules would not help the question addressed here (due to pre-79 instability), it could extend our understanding of the cyclical behavior of the post-79 US. In addition, the countercyclical behavior of nominal interest rates in the model may facilitate the need for nominal rigidities, limited participation mechanisms, or the inclusion of real frictions associated with capital or credit creation. To explore this further, the monetary authority could engage in money transfers directly with the commercial banks who are allowed to borrow or lend reserves at a nominal interest rate directly controlled by the central bank (i.e. an explicit Federal Funds rate). This feature would allow an analysis of the bank lending channel in an otherwise standard business-cycle framework, and yield a rich environment potentially useful for examining many competing features of monetary business-cycle models. This avenue is presently being explored.

A Data Appendix

All real variables are from the Bureau of Economic Analysis at the US Department of Commerce (BEA) and expressed in chained 1996 dollars, unless noted otherwise. Real Gross Domestic Product is GDPC1. Consumption is Real Personal Consumption Expenditure (PCECC96). Investment is Real Gross Private Domestic Investment (GPDIC1). The measure for labor was taken from the Bureau of Labor Statistics, US Department of Labor (BLS) and is Average Weekly Hours of Manufacturing (AWHMF).

All nominal variables are taken from the Federal Reserve Board of Governors, with the exceptions of the Gross Domestic Product Implicit Price Deflator (GDPDEF) which was taken from the BEA. The Base is the Currency Component of the Money Stock (CURRSL), M1 is M1SL.

All variables discussed above, with the exception of labor hours, prices, and interest rates, were transformed into per capita terms by dividing by the Working-age, Civilian Noninstitutional Population (CNP16OV) available from the BEA. In the instance of the variable being monthly, only the third month of the quarter was used. All variables were logged, and all variables (with the exception of interest rates) were then detrended using the Hodrick-Prescott filter.

References

- [1] Baumol, W.J., “The Transactions Demand for Cash: An Inventory Theoretic Approach,” *Quarterly Journal of Economics* 66(4) (November 1952), 545-556.
- [2] Balke, N.S. and Wynne, M.A., “An Equilibrium Analysis of Relative Price Changes and Aggregate Inflation,” *Journal of Monetary Economics* 45(1) (February 2000), 269-292.
- [3] Chari, V.V., Christiano, L.J. and Eichenbaum, M., “Inside Money, Outside Money, and Short-Term Interest Rates,” *Journal of Money, Credit, and Banking* 27(4) (November 1995), pp. 1355-1385.
- [4] Christiano, L.J. and Eichenbaum, M., “Liquidity Effects, Monetary Policy, and the Business Cycle,” *Journal of Money, Credit, and Banking* 27(4) (November 1995), 1113-1136.
- [5] _____, “Solving Dynamic Equilibrium Models by a Method of Undetermined Coefficients,” *Computational Economics* 20(1-2) (October 2002), 21-55.
- [6] Clarida, R., Gali, J. and Gertler, M., “Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory,” *Quarterly Journal of Economics* 115(1) (February 2000), 147-180.
- [7] Coleman, W.J. II, “Money and Output: A Test of Reverse - Causation,” *American Economic Review* 86(1) (March 1996), pp. 90-111.
- [8] Cooley, T.F. and Hansen, G.D., “Money and the Business Cycle,” in T. F. Cooley, ed., *Frontiers of Business Cycle Research*. (Princeton, NJ: Princeton University Press, 1995).
- [9] Duffie, D. and Singleton, K.J., “Simulated Moments Estimation of Markov Models of Asset Prices.” *Econometrica* 61(4) (October 1993), 929-952.
- [10] Federal Reserve Bulletin, Board of Governors of the Federal Reserve System, Washington, DC, 76(1990), A22.
- [11] Freeman, S. and Kydland, F.E., “Monetary Aggregates and Output,” *American Economic Review* 90(5) (December 2000), 1125-1135.

- [12] Gavin, W.T. and Kydland, F.E., "Endogenous Money Supply and the Business Cycle," *Review of Economic Dynamics* 2(2) (April 1999), 347-369.
- [13] Ghez, G.R. and Becker, G.S., *The Allocation of Time and Goods over the Life Cycle*, (New York: Columbia University Press, 1975).
- [14] Granger, C.W.J., "Investigating Causal Relationships by Econometric Models and Cross-Spectral Methods," *Econometrica* 37(3) (July 1969), 424-438.
- [15] Hamilton, J.D., *Time Series Analysis*, (Princeton: Princeton University Press, 1994).
- [16] Hansen, L.P. and Singleton, K.J., "Stochastic Consumption, Risk Aversion, and the Temporal Behavior of Asset Returns," *Journal of Political Economy* 91 (April 1983), 249-265.
- [17] Ireland, P.N., "Endogenous Money or Sticky Prices?" *Journal of Monetary Economics* 50(8) (November 2003), 1623-1648.
- [18] Karni, E., "The Transactions Demand for Cash: Incorporation of the Value of Time into the Inventory Approach," *Journal of Political Economy* 81(5) (October 1973), 1216-1225.
- [19] King, R.G. and Plosser, C.I., "Money, Credit, and Prices in a Real Business Cycle," *American Economic Review* 74(3) (June 1984), 363-380.
- [20] Lee, B. and Ingram, M.B.F., "Simulation Estimation of Time-Series Models," *Journal of Econometrics* 47(2-3) (February 1991), 197-205.
- [21] McCallum, B.T., "Discretion versus Policy Rules in Practice: Two Critical Points, a comment," *Carnegie - Rochester Conference Series on Public Policy* 39 (December 1993), 215-220.
- [22] Neely, C.J., Roy, A. and Whiteman, C.H., "Identification Failure in the Intertemporal Consumption CAPM," *Journal of Business and Economic Statistics* 19 (October 2001), 395-403.
- [23] Newey, W.K. and West, K.D. "A Simple, Positive, Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix," *Econometrica* 55(3) (July 1987), 703-708.
- [24] Ostle, B., *Statistics in Research*, (Ames, IA: Iowa State University Press, 1963).

- [25] Porter, R.D. and Judson, R.A., "The Location of US Currency: How Much is Abroad?" *Federal Reserve Bulletin* 82(10) (1996), 883-903.
- [26] Prescott, E.C., "Theory Ahead of Business Cycle Measurement." *Federal Reserve Bank of Minneapolis Quarterly Review* (Fall 1986), 9-22.
- [27] Sims, C.A., "Money, Income, and Causality." *American Economic Review* 62(4) (September 1972), 540-552.
- [28] _____ and Zha, T., "Were There Regime Switches in Monetary Policy?" Federal Reserve Bank of Atlanta Working Paper 2004-14, June 2004.
- [29] Taylor, J.B., "Discretion Versus Policy Rules in Practice," *Carnegie - Rochester Conference Series on Public Policy* 39 (December 1993), 195-214.
- [30] Tobin, J., "The Interest Elasticity of Transactions Demand for Cash," *Review of Economics and Statistics* 38(3) (August 1956), 241-247.
- [31] _____, "Money and Income: Post Hoc Ergo Propter Hoc?" *Quarterly Journal of Economics* 84(2) (May 1970), 301-317.
- [32] Woodford, M., *Interest and Prices: Foundations of a Theory of Monetary Policy*, (Princeton, NJ: Princeton University Press, 2003).