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The Optimal Monetary Instrument and the (Mis)Use of Causality Tests *

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Abstract

This paper uses a New-Keynesian model with multiple monetary assets to show that if the choice of instrument is based solely on its propensity to predict macroeconomic targets, a central bank may choose an inferior policy instrument. We compare a standard interest rate rule to a k -percent rule for three alternative monetary aggregates determined within our model: the monetary base, the simple sum measure of money, and the Divisia measure. Welfare results are striking. While the interest rate dominates the other two monetary aggregate k -percent rules, the Divisia k -percent rule outperforms the interest rate rule. Next we study the ability of Granger Causality tests – in the context of data generated from our model – to correctly identify welfare improving instruments. All of the policy instruments considered, except for Divisia, Granger Cause both output and prices at extremely high levels of significance. Divisia fails to Granger Cause prices despite the Divisia rule stabilizing inflation better than these alternative policy instruments. The causality results are robust to using a popular version of the Sims Causality test for which we show standard asymptotics remain valid when the variables are integrated, as in our case.

Keywords: Monetary Policy Instrument, Monetary Aggregates, Granger Causality

JEL codes: C43, C32, E37, E44, E52

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1 Introduction

At one time, economists debated what would best serve as the monetary policy instrument. Should a central bank operate by manipulating an interest rate or instead by use of a monetary aggregate? An enormous literature followed the seminal study of Poole (1970). However, monetary aggregates eventually lost out. Woodford (2003) presents a convincing theoretical case to support the view that central banks should utilize interest rates to optimally stabilize inflation and output. Within this workhorse framework, monetary aggregates have no information content to offer policymakers beyond that contained in interest rates, output, and inflation. This modern view of the role of money is not without empirical support. An influential literature in monetary economics has generally concluded that monetary aggregates fail to Granger Cause output and prices once interest rates are included in a forecaster's information set.

Other economists have argued that poor monetary measurement may be to blame for the lack of a useful relationship between money and other macroeconomic aggregates that could be exploited to improve upon monetary policy. This literature has its origins in the seminal work of Barnett (1980) who argued for the rigorous use of index number theory to measure the service flow from imperfectly substitutable monetary assets. While there are many such index numbers that could be used, two index measures are actually produced for the U.S.: simple-sum aggregates and Divisia monetary aggregates as advocated by Barnett. The monetary measurement literature has generally found that empirical specifications that utilize Divisia aggregates over simple-sum aggregates offer potentially more promise in advancing the goals of central banks (Belongia and Ireland, 2015, 2016).

This paper asks whether any connection can – or should – be drawn between the marginal predictive content of money and its potential role in monetary policy. Paying particular attention to monetary measurement, we find the answer is no in the context of a DSGE model. We write down a small New Keynesian model calibrated to U.S. macroeconomic data in which a policy authority following a Taylor type interest-rate rule could realize welfare improvements by switching to a constant money-growth rule. But, simulated data from this model would lead an econometrician to conclude that money fails to cause the price level in a bivariate test of causation. And in a trivariate relationship that adds interest rates, money fails to cause output. In other words, money offers no predictive content for output and prices in the presence of interest rates despite offering potential improvements in achieving the central bank's objectives.

Apart from these causality results, monetary measurement has important theoretical implications. If the central bank were to switch to a constant Divisia growth rule they would realize welfare gains over a Taylor type interest rate rule in our calibrated model. However, a simple-sum growth rule leads to multiple equilibria and, in turn, considerable welfare losses. Meanwhile, base money offers an intermediate case; fixing the growth rate of the monetary base leads to welfare losses relative to the Taylor type interest rate rule but, unlike simple-sum growth rules, can anchor expectations on a unique equilibrium. Therefore, the ranking of alternative money growth rules in our stylized model from best to worst welfare performance is: Divisia, monetary base, and then simple-sum. Despite this welfare ranking, both the monetary base and the simple-sum aggregate Granger Cause output and prices while the Divisia aggregate only Granger Causes output. Therefore, we ultimately conclude that, even across various measures of money, Granger Causality tests are unlikely to shed light on the optimal monetary instrument.

Conclusions regarding the link between Granger Causality and the optimal monetary instrument are susceptible to econometric criticisms. Since our DSGE model features a stochastic trend in technology and the price level, real and nominal variables inherit a unit root. Therefore, according to Sims et al. (1990), tests of Granger Causality using F-statistics and standard asymptotics are invalid. To check that our causality results are not driven by improper statistical inference, we prove that the Geweke et al. (1983) lagged-dependent variable version of Sims (1972) causality test is immune to issues associated with integrated regressors. Using this test on data simulated from our model, we reach the same conclusion as we did when using Granger Causality tests; both the monetary base and the simple-sum aggregate cause output and prices while the Divisia aggregate only causes output.

The remainder of the paper proceeds as follows. Section 2 lays out the DSGE model used in Section 3 to conduct normative analysis on the issue of the optimal monetary instrument. With knowledge of the optimal monetary instrument in hand, Section 4 then conducts Granger Causality testing to explore the usefulness of these tests in guiding central banks towards the best policy instrument. Section 5 concludes and discusses some of the opportunities for future research in light of the disconnect we find between the marginal predictive content of a macroeconomic aggregate and its potential role in improving policy outcomes.

2 Model

This section describes the New-Keynesian Model used in this paper. The model serves as a laboratory in which we ask: Given a central bank following a standard Taylor rule, is there scope for improving economic outcomes by switching to manipulating a monetary aggregate? Given the answer to this question, we then ask: Would Granger Causality test on simulated data consisting of real GDP, the price level, interest rates, and monetary aggregates lead a central bank economist to recommend the appropriate policy instrument? To this end, we augment the [Belongia and Ireland \(2014\)](#) model which features multiple monetary assets with habits and inflation indexation to enhance the model's internal propagation mechanisms. Both of these features have been shown to be important features for matching key features of U.S. macroeconomic data in larger DSGE models developed by [Christiano et al. \(2005\)](#) and [Smets and Wouters \(2007\)](#). Even with these modifications, the core of the model consists of a dynamic consumption Euler equation, an expectations augmented Phillips curve, a money demand equation, and a monetary policy rule.

2.1 The Household

The representative household enters any period $t = 0, 1, 2, \dots$ with a portfolio consisting of maturing bonds B_{t-1} and monetary assets totaling A_{t-1} . The household faces a sequence of budget constraints in any given period. In the first sub-period the household receives central bank transfers T_t which can be combined with their existing stock of monetary assets totaling A_{t-1} and maturing bonds B_{t-1} to invest in newly issued bonds B_t at a price of $1/R_t$, and allocate monetary assets between currency N_t and deposits D_t . Any loans L_t needed to finance these transactions are taken at this time as well. This is summarized in the following constraint below:

$$\frac{B_t}{R_t} + N_t + D_t = \frac{A_{t-1}}{\Pi_t} + \frac{B_{t-1}}{\Pi_t} + L_t + T_t, \quad (1)$$

where $\Pi_t = P_t/P_{t-1}$.

In the second sub-period the household receives income from hours worked H_t during the period at wage rate W_t , any dividends from the intermediate goods firm, F_t , and interest on deposits $R_t^D D_t$ made at the beginning of the period. These funds, together with any currency the household held during the period N_t , are used to repay their loans $R_t^L L_t$. Any remaining funds are then carried over into the next period in the form of monetary assets A_t , as summarized below:

$$C_t + A_t + R_t^L L_t = N_t + R_t^D D_t + W_t H_t + F_t. \quad (2)$$

The household seeks to maximize their expected lifetime utility, discounted at rate β , subject to these constraints. The period flow utility of the household takes the following form:

$$\exp(a_t)(\ln(C_t - bC_{t-1}^A) - \eta(H_t + H_t^s)),$$

where a_t is an exogenous preference shock:

$$\exp(a_t) = \exp(\rho_a a_{t-1} + \sigma_a \epsilon_t^a), \quad \epsilon_t^a \sim (0, 1). \quad (3)$$

The household receives utility from consumption and dis-utility from time spent working and shopping. Time spent shopping increases with aggregate consumption C_t^A (i.e. long lines) but is reduced with higher liquidity services derived from currency and deposit holdings. Therefore the time spent shopping is equal to:

$$H_t^s = \frac{1}{\chi} \left(\frac{\exp(v_t) C_t^A}{M_t} \right)^\chi,$$

where $\exp(v_t)$ is a money demand shock that evolves according to:

$$\exp(v_t) = \exp(v(1 - \rho_v) + \rho_v v_{t-1} + \sigma_v \epsilon_t^v), \quad \epsilon_t^v \sim (0, 1). \quad (4)$$

The monetary aggregate, M_t , which enters the shopping-time function takes a rather general CES form:

$$M_t = \left[\nu^{\frac{1}{\omega}} (N_t)^{\frac{\omega-1}{\omega}} + (1 - \nu)^{\frac{1}{\omega}} (D_t)^{\frac{\omega-1}{\omega}} \right]^{\frac{\omega}{\omega-1}} \quad (5)$$

where ν calibrates the relative expenditure shares on currency and deposits and ω calibrates the elasticity of substitution between the two monetary assets. Given these parameters, χ is left free to calibrate the interest semi-elasticity of money demand.

The representative household faces the problem of maximizing its lifetime utility subject to its budget constraints. Letting $\mathcal{C}_t = [C_t, H_t, M_t, N_t, D_t, L_t, B_t, A_t]$ denote the vector of choice variables, the household's problem can be recursively defined using Bellman's method:

$$\begin{aligned} V_t(B_{t-1}, A_{t-1}) = \max_{\mathcal{C}_t} & \left\{ \exp(a_t) \left[\ln(C_t - bC_{t-1}^A) - \eta H_t - \frac{\eta}{\chi} \left(\frac{\exp(v_t) C_t^A}{M_t} \right)^\chi \right] \right. \\ & - \Lambda_t^1 \left(\frac{B_t}{R_t} + N_t + D_t - \frac{A_{t-1}}{\Pi_t} - \frac{B_{t-1}}{\Pi_t} - L_t - T_t \right) \\ & - \Lambda_t^2 \left(M_t - \left[\nu^{\frac{1}{\omega}} (N_t)^{\frac{\omega-1}{\omega}} + (1 - \nu)^{\frac{1}{\omega}} (D_t)^{\frac{\omega-1}{\omega}} \right]^{\frac{\omega}{\omega-1}} \right) \\ & \left. - \Lambda_t^3 \left(C_t + A_t + R_t^L L_t - N_t - R_t^D D_t - W_t H_t - F_t \right) + \beta \mathbb{E}_t \left[V_{t+1}(B_t, A_t) \right] \right\}. \end{aligned}$$

The first order necessary conditions are given by the following equations:

$$\Lambda_t^3 = \frac{\exp(a_t)}{C_t - bC_{t-1}^A} \quad (6)$$

$$\Lambda_t^1 = \beta \mathbb{E}_t \left[\Lambda_{t+1}^1 \frac{R_t}{\Pi_{t+1}} \right] \quad (7)$$

$$W_t = \eta \frac{\exp(a_t)}{\Lambda_t^3} \quad (8)$$

$$M_t = \eta \frac{\exp(a_t)}{\Lambda_t^2} \left(\frac{\exp(v_t) C_t^A}{M_t} \right)^x \quad (9)$$

$$N_t = \nu M_t \left[\frac{\Lambda_t^2 / \Lambda_t^3}{(R_t^L - 1)} \right]^\omega \quad (10)$$

$$D_t = (1 - \nu) M_t \left[\frac{\Lambda_t^2 / \Lambda_t^3}{(R_t^L - R_t^D)} \right]^\omega \quad (11)$$

$$\frac{\Lambda_t^2}{\Lambda_t^3} = [\nu(R_t^L - 1)^{1-\omega} + (1 - \nu)(R_t^L - R_t^D)^{1-\omega}]^{\frac{1}{1-\omega}} \quad (12)$$

$$\Lambda_t^1 = \Lambda_t^3 R_t^L \quad (13)$$

$$R_t = R_t^L. \quad (14)$$

2.2 The Goods Producing Sector

The goods producing sector features a final goods firm and an intermediate goods firm. There are a unit measure of intermediate goods producing firms indexed by $i \in [0, 1]$ who produce a differentiated product. The final goods firm produces Y_t combining inputs $Y_{i,t}$ using the production technology,

$$Y_t = \left[\int_0^1 Y_{i,t}^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}}$$

in which $\theta > 1$ governs the elasticity of substitution between inputs. The final goods producing firm sells its product in a perfectly competitive market, hence solving the profit maximization problem:

$$\max_{Y_{i,t} \in [0,1]} P_t Y_t - \int_0^1 P_{i,t} Y_{i,t} di,$$

subject to the above constant returns to scale technology. The resulting first order condition defines the demand curve for each intermediate goods producing firm's product:

$$Y_{i,t} = \left(\frac{P_{i,t}}{P_t} \right)^{-\theta} Y_t. \quad (15)$$

Given the downward sloping demand for its product in (15), the intermediate goods producing firm has the ability to set the price of its product above marginal cost. To permit aggregation and allow for the consideration of a representative firm, we assume all such firms have the same constant returns to scale technology:

$$Y_{i,t} = \exp(z_t)H_{i,t}. \quad (16)$$

The term $H_{i,t}$ in the production function denotes the level of employment chosen by the intermediate goods firm while the term z_t is the exogenous technology process:

$$\exp(z_t) = \exp(z + z_{t-1} + \sigma_z \epsilon_t^z), \quad \epsilon_t^z \sim (0, 1). \quad (17)$$

The price setting ability of each firm is constrained as in Rotemberg (1982) whereby each firm must pay a resource cost to change prices by an amount different than prices increased in aggregate last period. Therefore, each firm maximizes the present value of its current and future discounted profits, taking into account the cost of adjusting its price:

$$\max_{P_{i,t}} \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t+j}^3 F_{t+j}$$

subject to

$$F_{i,t} = \left(\frac{P_{i,t}}{P_t} Y_{i,t} - H_{i,t} W_t - \frac{\phi}{2} \left[\frac{P_{i,t}}{P_{i,t-1} \Pi_{t-1}} - 1 \right]^2 Y_t \right),$$

$$Y_{i,t} = \left(\frac{P_{i,t}}{P_t} \right)^{-\theta} Y_t,$$

and

$$Y_{i,t} = \exp(z_t)H_{i,t}.$$

The firm's first order condition is given by:

$$\begin{aligned} \phi \left[\frac{P_{i,t}}{P_{i,t-1} \Pi_{t-1}} - 1 \right] \frac{P_t}{P_{i,t-1} \Pi_{t-1}} &= (1 - \theta) \left(\frac{P_{i,t}}{P_t} \right)^{-\theta} + \theta \left(\frac{P_{i,t}}{P_t} \right)^{-\theta-1} \frac{W_t}{e^{z_t}} \\ &+ \mathbb{E}_t \frac{\Lambda_{t+1}^3}{\Lambda_t^3} \frac{Y_{t+1}}{Y_t} \left[\frac{P_{i,t+1}}{P_{i,t} \Pi_t} - 1 \right] \frac{P_{i,t+1} P_t}{P_{i,t}^2 \Pi_t}. \end{aligned} \quad (18)$$

2.3 The Financial Firm

The financial firm performs the intermediation process of accepting household's deposits and making loans. The financial firm must satisfy the accounting identity which specifies assets (loans plus reserves) equal liabilities (deposits),

$$L_t + \exp(\tau_t) D_t = D_t. \quad (19)$$

Although changes in banking regulation have effectively eliminated reserve requirements, banks may often choose to hold reserves in lieu of making loans. Therefore, instead of assuming the central bank controls the reserve ratio $exp(\tau_t)$, we assume it exogenously evolves around the average ratio of reserves to deposits banks hold for regulatory and liquidity purposes:

$$exp(\tau_t) = exp(\tau(1 - \rho_\tau) + \rho_\tau\tau_{t-1} + \sigma_\tau\epsilon_t^\tau), \quad \epsilon_t^\tau \sim (0, 1). \quad (20)$$

The financial firm chooses L_t and D_t in order to maximize period profits

$$\max_{L_t, D_t} R_t^L L_t - R_t^D D_t - L_t + D_t - exp(x_t)D_t$$

subject to the balance sheet constraint (19). The term $exp(x_t)D_t$ denotes the real resource costs banks bear in making deposits. We assume $exp(x_t)$ evolves according to:

$$exp(x_t) = exp(x(1 - \rho_x) + \rho_x x_{t-1} + \sigma_x \epsilon_t^x), \quad \epsilon_t^x \sim (0, 1). \quad (21)$$

Since the loan and deposits markets are perfectly competitive, substituting the balance-sheet constraint into the profit function and imposing zero profits results in the loan-deposit spread,

$$R_t^L - R_t^D = (R_t^L - 1)exp(\tau_t) + exp(x_t). \quad (22)$$

This expression describes the loan deposit spread as the sum of the (opportunity) costs of accepting one unit of deposits. The fraction $exp(\tau_t)$ are held as reserves which bears the foregone revenue of making loans while all deposits require the use of real resources to be created.

2.4 Monetary Policy

We assume the central bank adheres itself to a monetary policy rule similar in form to Clarida et al. (2000):

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_r} \left(\left(\frac{\Pi_t}{\Pi}\right)^{\rho_\pi} \left(\frac{Y_t/exp(z_t)}{Y/exp(z)}\right)^{\rho_g}\right)^{(1-\rho_r)} exp(\sigma_r \epsilon_t^r) \quad \epsilon_t^r \sim (0, 1). \quad (23)$$

Therefore, the central bank is assumed to adjust the 1-period bond rate to deviations of inflation from target and detrended output, which could similarly be interpreted as a measure of the output gap.¹

¹Notice that specifying the reaction to output in detrended form is also consistent with the specification in Taylor (1993) as well as the specification estimated in Clarida et al. (2000) which guides our calibration.

2.5 Market Clearing and Equilibrium

Here we define the equilibrium conditions which close the model. Equilibrium in the final goods market requires that the accounting identity

$$Y_t = C_t + \frac{\phi}{2} \left[\frac{\pi_t}{\pi_{t-1}} - 1 \right]^2 Y_t + \exp(x_t) D_t \quad (24)$$

holds. Equilibrium in the money market and bond market requires that at all times: $A_t = A_{t-1}/\Pi_t + T_t$ and $B_t = B_{t-1} = 0$ respectively. Furthermore, in a symmetric equilibrium, all intermediate goods producing firms make identical choices for prices $P_{i,t} = P_t$, output $Y_{i,t} = Y_t$, hours employed $H_{i,t} = H_t$, and therefore profits $F_{i,t} = F_t$.

2.6 Monetary Aggregates

Three monetary aggregates are defined in the DSGE model. The first aggregate is a weighted non-parametric Divisia aggregate as defined by Barnett (1980), M_t^D , used to approximate the parametric aggregate M_t :

$$\ln \left(\frac{M_t^D}{M_{t-1}^D} \right) = \frac{S_t^N + S_{t-1}^N}{2} \ln \left(\frac{N_t}{N_{t-1}} \right) + \frac{S_t^D + S_{t-1}^D}{2} \ln \left(\frac{D_t}{D_{t-1}} \right), \quad (25)$$

where $S_t^N = (R_t - 1)N_t / ((R_t - 1)N_t + (R_t - R_t^D)D_t)$ is the share of total implicit spending on monetary assets allocated to currency and $S_t^D = 1 - S_t^N$ is the complimentary share allocated to deposits. The second aggregate is an unweighted non-parametric aggregate that simply sums (i.e. the simple-sum aggregate) the component assets. M_t^S is used to approximate the parametric aggregate M_t :

$$\ln \left(\frac{M_t^S}{M_{t-1}^S} \right) = \ln \left(\frac{N_t + D_t}{N_{t-1} + D_{t-1}} \right). \quad (26)$$

The third aggregate is the monetary base and is calculated by adding together currency and bank reserves, which can be verified to equal A_t (after imposing the monetary market clearing condition on equation (1) along with the bank's balance sheet constraint):

$$\ln \left(\frac{A_t}{A_{t-1}} \right) = \ln \left(\frac{N_t + \exp(\tau_t) D_t}{N_{t-1} + \exp(\tau_{t-1}) D_{t-1}} \right). \quad (27)$$

In addition to these quantity aggregates, we define a price aggregate, which is the price dual U_t to the quantity aggregate M_t meaning that total implied expenditures on monetary assets equals $U_t \times M_t$. The monetary price aggregate is defined by:

$$U_t = [\nu(R_t^L - 1)^{1-\omega} + (1 - \nu)(R_t^L - R_t^D)^{1-\omega}]^{\frac{1}{1-\omega}}. \quad (28)$$

From the household's first order conditions, it can be shown that $U_t = \Lambda_t^2 / \Lambda_t^3$.

2.7 Dealing With Sources of Non-Stationarity

Due to the unit root in the exogenous technology process most of the model's variables will be non-stationary. In addition, nominal (level) variables will inherit a second unit root from the way that monetary policy is conducted. All of the rules we consider stabilize the inflation rate or the nominal growth rate of a monetary aggregate; not the price level nor nominal levels in the case of quantity rules. As a result, the price level will not revert back to its pre-shock value after an exogenous disturbance. Therefore, we detrend all of the variables by dividing by $exp(z_{t-1})$ and solve for the growth rates of nominal variables (i.e. inflation as opposed to the price level and nominal money growth as opposed to nominal money balances).

2.8 Calibration

The model is calibrated to a quarterly frequency. Many of the parameters are common to the models of Ireland (2004a,b). We set $\beta = 0.99$. We set trend inflation to $\Pi = 1.02^{\frac{1}{4}}$ and trend growth to $exp(z) = 1.02^{\frac{1}{4}}$ which together imply nominal GDP growth of 4% per year. We set $exp(\tau) = 0.03$ which implies average bank reserves equal to 3% of deposits. And we set $exp(x) = 0.01$ which calibrates the share of resources devoted to deposit creation. These values come directly from Belongia and Ireland (2014). Finally, we set $exp(v) = 2.65$ which pegs the steady state ratio of simple-sum M2 to nominal PCE expenditures to its data value of 3.3 as described in Belongia and Ireland (2014).²

For the parameters governing consumer preferences, we set hours worked to equal 1/3 in steady state which implies that $\eta = 16.27$. We then set $\nu = 0.275$ which sets the share of the non-interest bearing components of M2 (currency, travelers checks, and demand deposits) to about 21%, which matches its average share in the data. We follow Ireland (2014) and set $\omega = 0.5$. For the degree of market power and price rigidity, we follow Ireland (2004a) and set $\theta = 6$ and $\phi = 50$, which together imply a Phillips curve slope of 0.1. This value is equivalent in a linearized model to the Calvo (1983) approach to modeling price rigidity with an implied Calvo parameter of about 0.75 which implies in that setting that prices remain fixed for about one year. This calibration is therefore largely consistent with the micro evidence on the frequency of price adjustment from Nakamura and Steinsson (2008).

²While Belongia and Ireland (2014) match the same moment using a value of $exp(v) = 0.4$ recall that our variant of their model assumes the real money balances are separable from consumption, households have habits in consumption, and firms index prices to lagged inflation.

The parameter governing the degree of external habits is set to $b = 0.85$ which is a bit higher than the value of $b = 0.65$ estimated by Christiano et al. (2005) and the value of $b = 0.71$ estimated in Smets and Wouters (2007). However, in our experimentation with this parameter we found that setting b to one of these lower values greatly diminished the model’s fit when calibrating the exogenous shock parameters. This suggests that despite flexibility over the model’s exogenous sources of propagation, a high degree of internal propagation via habits is helpful to match moments from the data. We calibrate the monetary policy rule as in Clarida et al. (2000) and set $\rho_r = 0.79$, $\rho_\pi = 2.15$, and $\rho_g = 0.93$. The values for these calibrated parameters are summarized in Table 1.

The exogenous shock parameters, together with the parameter governing the interest semi-elasticity of money demand, are calibrated to match the autocorrelation and standard deviation of GDP growth, GDP deflator inflation, the federal funds rate, the real user cost of Divisia M2, the growth rate of Divisia M2, and the growth rate of the St. Louis Fed’s adjusted monetary base. We therefore attempt to match these 12 moments with their model counterparts by searching over the 11 parameters: ρ_a , σ_a , ρ_v , σ_v , σ_z , ρ_τ , σ_τ , ρ_x , σ_x , σ_r , and χ . All of the data moments are calculated from 1967 through 2015. Except for Divisia data all series are obtained from Haver Analytics but can be also be obtained from the St. Louis Fed’s FRED data source fred.stlouisfed.org. The Divisia data come from the Center for Financial Stability www.centerforfinancialstability.org/amfm_data.php. Table 3 displays the resulting model fit.

The model is generally able to match the features of the data. Beginning with the auto-correlations, the largest miss is for the persistence of inflation and, in turn, for the federal funds rate, and the user cost of M2. It is a well known problem that DSGE models without mark-up shocks or some other source of exogenous Phillips curve variation fail to generate enough inflation persistence (see for example Fuhrer and Moore (1995)). With too little persistence in inflation, it is not surprising that the model also fails to generate enough persistence for the federal funds rate since inflation is a key determinant of the federal funds rate through the monetary policy rule and, similarly, the policy rate is a primary determinant of the user cost of Divisia M2.

Turning to the volatilities, the model generates too little volatility in output growth but matches the observed volatility of inflation. Since both inflation and output are primarily driven by the preference and technology shocks, increasing the volatility of either of these shocks to match the observed volatility of output growth would result in too much inflation

volatility. The choice of standard deviations for the deposit cost, reserves demand, and money demand shocks gives the model sufficient flexibility to generally match the observed volatilities of money growth (both base money and Divisia M2) and the user cost of money.

3 The Optimal Monetary Policy Instrument

New Keynesian models are closed by an equation describing monetary policy. We compare the performance of the economy under four different assumptions about the monetary policy rule. The instrument rules we consider are a [Taylor \(1993\)](#) type interest rate rule, a fixed growth rate for the monetary base, a fixed growth rate for simple sum money, and a fixed growth rate for the Divisia monetary aggregate. Then for each rule we evaluate welfare for the representative household in the calibrated model. The conditional value function can be used to calculate household welfare, which can be expressed recursively by:

$$\mathcal{W}_t = \exp(a_t) \left[\ln(C_t - bC_{t-1}) - \eta H_t - \frac{\eta}{\chi} \left(\frac{\exp(v_t)C_t}{M_t} \right)^\chi \right] + \beta \mathbb{E}_t \mathcal{W}_{t+1} \quad (29)$$

Under a first-order approximation, or linear perturbation solution, conditional welfare is invariant to changes in policy and always equal to the discounted flow of period utility at the non-stochastic steady-state. Therefore, following [Schmitt-Grohe and Uribe \(2007\)](#), we solve the model using a second-order approximation around the model's steady-state. Under a second order approximation (with pruning, as we implement) the conditional mean of welfare depends on the conditional variances of the model's endogenous variables as calculated under a first-order approximation. Therefore, as suggested by the closed form cases presented in [Woodford \(2003\)](#), household welfare in our analysis is influenced, in part, by the conditional variance of inflation and output.

The welfare results are reported in Table 4 which expresses welfare costs in terms of the steady-state consumption cost of conducting monetary policy under an alternative policy rule as opposed to the interest rate rule described in Section 2.4. The constant Divisia growth rule outperforms all other rules considered. The interest rate rule performs next best followed by the constant monetary base growth rule. The constant simple-sum growth rule fails to anchor expectations on a unique equilibrium and so generates indeterminacy. Therefore, we assign an infinite welfare loss to this outcome.

The primary source of welfare gains under a constant money growth rule is from the countercyclical policy response to aggregate demand and aggregate supply shocks. This can

be seen in Table 5 which shows the stochastic means and standard deviations of some key model variables. Welfare costs in this model come in the form of resources inefficiently devoted to firms adjusting their prices and banks creating deposits. The first of these costs is largely dictated by the volatility of inflation.

The constant Divisia growth rule limits the volatility of inflation through a greater degree of history dependence. To see this, simply substitute the money demand equation into the money growth rule and solve for the nominal interest rate by dividing through by the interest semi-elasticity. The resulting equation is a first difference rule for interest rates with a response to inflation, output growth, and lagged output growth, plus other exogenous shocks. The constant money growth rule is therefore a price-level and output level targeting rule in first difference form. In response to aggregate demand and supply disturbances, the increased history dependence of this rule reduces inflation volatility as shown by Woodford (2003). One drawback of the rule; however, is its aggressive response to the level of output compared to the interest rate rule's more modest response. In response to productivity shocks, this feature of the rule slows the economy's transition to its efficient level of output (Schmitt-Grohe and Uribe, 2007). However, this effect is dominated (in welfare terms) by the constant money growth rule's ability to better anchor inflation expectations.

The Achilles' heel of money-growth targeting is its inability to shield the economy from shifts in money demand (Bernanke and Blinder, 1988). In our model, there are three such shifters: classic money-demand shocks, deposit-cost shocks, and reserves-demand shocks. Poole (1970) shows in a simpler model that using money as the instrument of policy transmits these shocks to interest rates and in turn output and inflation. By failing to accommodate these shifts in the money-demand equation, monetary policy exposes households to undue volatility and, by typical logic, decreases their well-being. Indeed, Table 6 shows that interest-rates are significantly more volatile under the money-growth rule in response to these shocks compared to the interest-rate rule. However, the overall size of these shocks is fairly small so that even under a constant Divisia growth rule the effect on inflation and output volatility is negligible.

The basic intuition in Poole (1970) suggests that increasing the size of the disturbances in the money-demand equation would reduce the welfare gain of switching to a constant money growth rule. However, this is not the case in our model. When we experimented with increasing the size of the money-demand shocks, deposit-cost shocks, and reserves-demand shocks we found larger welfare gains. The source of the welfare *improvements* under a

constant money growth rule in response to these shocks stems from the reduction in the stochastic mean of deposits. Since fewer deposits result in fewer resources spent producing deposits, fewer hours worked are needed to produce the same average level of consumption which results in welfare increases when money-demand shifters are more volatile.

The mechanism underlying the relationship between welfare and volatility in our model is highlighted in Lester et al. (2014). It can be best understood by considering an increase in the volatility of the deposit cost shock. For a given exogenous reduction in banking sector productivity (an increase in deposit creation costs), the price of deposits increases and the household naturally substitutes towards currency. However, the substitution is incomplete so without an aggressive monetary policy response the monetary aggregate declines. A constant Divisia growth rule seeks to stabilize this reduction in monetary services by injecting more currency into the economy and, in turn, promoting a greater substitution out of high-resource cost deposits. Increasing the size of banking productivity shocks, or more generally, shocks which generate a change in the relative prices of currency and deposits, results in larger substitutions out of currency and into deposits. This logic also explains why a constant monetary base growth rule fails to deliver similar welfare gains. The central bank must be willing to elastically supply currency to promote efficient reductions in deposits. A central bank overly focused on stabilizing “narrow” measures of money will tend to limit the substitution into currency when banking sector technology is relatively low.³

4 Causality Testing

Causality testing has a long history in monetary economics starting with Sims (1972). Arguments in favor of switching monetary instruments – or not – often begin with tests of interest rate or money’s predictive content for output and prices. For example, in an important contribution to this literature, Feldstein and Stock (1994) argue that the central bank should consider switching to an operating procedure which targets nominal GDP growth by way of controlling M2 growth to achieve reductions in economic volatility and, hence, increase welfare. This policy recommendation is motivated, in part, by their finding that the M2 monetary aggregate Granger causes nominal GDP.

³Our result also depends critically on the willingness of the consumer to accept higher volatility in lieu of a lower mean level consumption, as discussed in Lester et al. (2014). The household in our model has a low degree of risk-aversion (log-utility) and an infinite Frisch elasticity of labor supply, two features which contribute to their willingness to substitute consumption and leisure across periods.

However, it is now well known that the results of tests inspecting money’s ability to Granger cause output and prices are often unstable across samples and specifications.⁴ These patterns of instability likely contributed to the consensus view among macroeconomists that monetary aggregates have limited policy value. The Granger causality evidence for interest rates also played a key role in reaching this conclusion. In circumstances when monetary aggregates were found to have some predictive content for output or prices, the information content of money was often subsumed by interest rates once they were added to the empirical model (Bernanke and Blinder, 1992).

We question whether the results from this large literature on monetary causality should have played such a key role in policy debates around the optimal monetary instrument. Our approach is to bring a structural model to bear on the question of whether marginal predictive content can or should inform a policy makers decision on the choice of the optimal monetary instrument.⁵ Using the DSGE model presented in the previous section, we ask whether the evidence of a policy indicators ability to cause output or prices is consistent with the normative conclusions from that model. We conduct our causality tests on simulated data from our DSGE model under the baseline calibration which features a central bank following an interest rate rule. Our exercise can therefore be interpreted as follows: Suppose the central bank is following an interest rate rule, but wants to know whether there is scope to improve policy by stabilizing the growth rate of money. The metric used to evaluate alternative indicators is their ability to cause output and prices, following much of the monetary literature on causality testing.

To ensure our exercise is as realistic as possible we assume the economists enlisted to study the fruitfulness of alternative monetary instruments is given raw time series on output, the price level, various monetary aggregates, and interest rates. As would be true in the case of actual U.S. time-series data, the series for output, the price level, and monetary aggregates feature a unit root. We construct these series by adding back the stochastic technology trend to output and the monetary aggregates and we create the price level by compounding past inflation rates. This price level series is then added to the level of various real monetary aggregates to arrive at nominal measures of money. Thus, output, the price level, and various money measures are all $\mathcal{I}(1)$.

⁴See for example Stock and Watson (1989) and the related article by Friedman and Kuttner (1993).

⁵Caraiani (2016) uses a DSGE model to ask what shocks are important in driving money’s Granger causal relationship with output and inflation. Our approach focuses much more on the normative policy question of the optimal instrument and whether Granger causality can be brought to bear on this question.

We next provide a brief overview of the various causality tests employed in this paper before presenting the results from each tests. We pay particular attention to the issue of which tests can be easily implemented via ordinary least squares (OLS) in the presence of integrated regressors, as in our application. Our review of these tests lead us to favor a version of Sims (1972) test as put forth by Geweke et al. (1983) for a novel reason. In particular, we show that the test statistic for the causality test presented in Geweke et al. (1983) has a standard asymptotic F-distribution in the presence of integrated regressors unlike tests of Granger (1969) and Sims (1972). In our application, results for causality were invariant across these various tests; however, the result we establish for the Geweke et al. (1983) version of Sims (1972) test could be useful in other applications.

4.1 The Causality Tests

Granger's (1969) test is probably the most prevalent test for causality. The Granger (1969) test is performed using a regression of y on lags of itself and another variable x :

$$y_t = c + \beta_{yy}(L)y_{t-1} + \beta_{yx}(L)x_{t-1} + e_t. \quad (30)$$

Assuming ℓ lags of each variable, we test the joint hypothesis:

$$\beta_{yx1} = \beta_{yx2} = \dots \beta_{yx\ell} = 0 \quad (31)$$

A rejection of this hypothesis is interpreted as evidence that x Granger causes y .

The Sims (1972) test is based on a regression of x on past, present, and future values of y :

$$x_t = c + \beta(L)y_t + \Gamma(L^{-1})y_{t+1} + e_t. \quad (32)$$

in which future y are chosen for some value of m :

$$\Gamma(L^{-1})y_{t+1} = \Gamma_1 y_{t+1} + \Gamma_2 y_{t+2} + \dots + \Gamma_m y_{t+m} \quad (33)$$

If the joint hypothesis:

$$\Gamma_1 = \Gamma_2 = \dots = \Gamma_m = 0. \quad (34)$$

is rejected, then x is said to cause y according to Sims (1972).

In practice, the Sims test requires a correction for serial correlation in the residuals. Consequently, a generalized least squares estimator is often used. Geweke et al. (1983)

advocate instead what they call the Sims lagged dependent variable test:

$$x_t = c + \beta_{xx}(L)x_{t-1} + \beta_{xy}(L)y_t + \Gamma(L^{-1})y_{t+1} + e_t \quad (35)$$

which adds lags of x , given as $\beta_{xx}(L)x_{t-1}$, to the Sims regression to eliminate serial correlation in residuals. Once again rejecting the hypothesis that coefficients on future y are zero implies that x causes y . An advantage of augmenting the Sims regression with lagged dependent variables is that this version of the test can be performed by ordinary least squares regression.

In addition to ease of estimation, the Geweke et al. (1983) modification to the Sims test has another advantage when regressors have unit roots. It is well-known that Granger's test has a non-standard distribution in the case of non-stationary regressors. It turns out that the Sims lagged dependent variable test, which is the term used by Geweke, Meese, and Dent to describe their variant of Sims (1972) test, is not subject to this problem.⁶ We show this with the help of a result in Sims et al. (1990). They found that if a statistical test is performed on coefficients for non-stationary variables, and the regression can be re-written such that those coefficients are on a stationary processes, then standard asymptotic theory will apply.⁷

The Geweke et al. (1983) test is based on coefficients on future y . Using lag operator notation these coefficients can be written as:

$$\Gamma(L^{-1}) = \Gamma_1 L^{-1} + \Gamma_2 L^{-2} + \dots + \Gamma_{m-1} L^{-m+1} + \Gamma_m L^{-m}. \quad (36)$$

Adding and subtracting $\Gamma_m L^{-m+1}$ in the last expression:

$$\Gamma(L^{-1}) = \Gamma_1 L^{-1} + \Gamma_2 L^{-2} + \dots + \Gamma_{m-1} L^{-m+1} + \Gamma_m L^{-m+1} - \Gamma_m L^{-m+1} + \Gamma_m L^{-m} \quad (37)$$

and then rewriting the equation yields:

$$\Gamma(L^{-1}) = \Gamma_1 L^{-1} + \Gamma_2 L^{-2} + \dots + (\Gamma_{m-1} + \Gamma_m) L^{-m+1} + (1 - L) \Gamma_m L^{-m}. \quad (38)$$

Working backwards in this fashion for any positive integer m , it is easy to show that the polynomial of coefficients on future y can be re-written as:

$$\Gamma(L^{-1}) = \Gamma(1) + (1 - L)\Gamma^*(L^{-1}) \quad (39)$$

⁶This idea was suggested in a discussion on The RATS Software Forum. However, the proof provided there is incorrect.

⁷Our approach contrasts with the strategy in Toda and Yamamoto (1995) who argue for adding extra lags to the VAR and then ignoring those lags when testing for causality.

where

$$\Gamma^*(L^{-1}) = \sum_{j=1}^m \Gamma_j^* L^{-j} \quad (40)$$

and

$$\Gamma_j^* = \sum_{i=j}^m \Gamma_i. \quad (41)$$

While reminiscent of Beveridge and Nelson (1981), our decomposition is not equivalent. The most obvious difference is that the polynomial of interest for the Sims test is a function of leads (L^{-1}) whereas the Beveridge-Nelson decomposition addresses lag polynomials. Another difference pertains to how each decomposition affects dynamic specification. For our decomposition the number of differenced lead variables is the same as the number of lead variables in levels (m is the same for $\Gamma(L^{-1})$ and for $\Gamma^*(L^{-1})$), whereas in a Beveridge-Nelson decomposition differencing reduces the number of lags by one.

Separating current y from lagged y 's in $\beta_{xy}(L)$:

$$\beta_{xy}(L)y_t = \beta_{xy}^+(L)y_{t-1} + \beta_{xy0}y_t \quad (42)$$

and applying this equation along with our decomposition of future y to the Sims lagged dependent variable regression yields:

$$x_t = c + \beta_{xx}(L)x_{t-1} + \beta_{xy}^+(L)y_{t-1} + (\Gamma(1) + \beta_{xy0})y_t + \Gamma^*(L^{-1})\Delta y_{t+1} + e_t \quad (43)$$

This transformation rewrites the lagged dependent variable version of the Sims test in levels as a regression of x on future values of differenced y as well as current y and lags of both x and y . If y is an $\mathcal{I}(1)$ process, then differenced y are stationary, and an F test on $\Gamma^*(L^{-1})$ coefficients would use a standard distribution.

Using earlier equations it is easy to show how coefficients from this transformed equation (Equation 43) are related to coefficients in the Sims lagged dependent variable regression (Equation 35):

$$\Gamma_m = \Gamma_m^* \quad (44)$$

and

$$\Gamma_j = \Gamma_j^* - \Gamma_{j+1}^* \quad (45)$$

for $j = 1, 2, \dots, m - 1$. Clearly, $\Gamma_i = 0$, for $i = 1, \dots, m$, if and only if $\Gamma_i^* = 0$ over exactly the same range of i . Based on a key insight of Sims et al. (1990), a test of the coefficients on future y is asymptotically equivalent to testing linear combinations of the coefficients on

first differences of future y . Hence, inference with the Sims lagged dependent variable test and undifferenced variables can use a standard F-distribution even when the regressors are $\mathcal{I}(1)$ series.

4.2 Causality Test Results

Results from both standard Granger causality tests as well as Sims lagged dependent variable tests reveal little connection between the marginal predictive content of a monetary aggregate and its potential for improving policy outcomes. Each causality test is conducted on simulated data from our DSGE model. We simulate a random time-series of length 200 periods from the model with an initial burn-in period of 1000 periods. All VAR models include 4 lags, consistent with typical rules of thumb for quarterly data.⁸ For each causality test, we repeat this exercise 500 times to account for sampling uncertainty and report the median p-value for the F-test that all lags or leads of a particular variable are zero.

Table 7 reports the results from these exercises for Granger Causality tests. The second column reports p-values for the test whether the interest rate or a measure of money Granger Causes real GDP, whereas the fourth column examines whether these variables Granger Cause the price level. These bivariate tests find overwhelmingly that the interest rate Granger Causes both output and prices. Furthermore, each measure of money causes real GDP, while the monetary base and simple sum money each cause the price level. The Divisia measure of money fails to cause prices. Interestingly, in this bivariate Granger Causality comparison, the policy instrument that best stabilizes inflation around the central banks target (See for example Table 5) offers no marginal predictive content for prices.

We would also like to know if adding the interest rate affects money's ability to cause important macroeconomic variables. The third and fifth columns in Table 7 perform the F-test on lags of money for output and the price level, respectively, when the regression also conditions on lags of the interest rate on one-period bonds (corresponding to 3-month T-bill

⁸Using information criteria or other tests to determine lag length for each of the thousands of VARs we estimate would be too onerous. We report results with 4 lags in the paper, however, we have repeated the exercise with 3 lags and 5 lags, respectively, to determine if there is any sensitivity to lag length. Conclusions with bivariate causality tests are unaffected. In fact, p-values are almost unchanged when using the lagged dependent variable version of the Sims test. The only sensitivity we observe is with trivariate Granger Causality tests. We find that the Divisia aggregate and the simple sum aggregate Granger cause output when 3 lags are in the model. This result may obtain because 3 lags of output and the interest rate are insufficient to explain output, leaving a predictive role for money.

rates in the U.S.). For all three money measures, there is no causal effect on either output nor the price level. This evidence that money loses predictive power when the interest rate is included in a regression (and possibly other variables) has been found in real world data by Bernanke and Blinder (1992) amongst others and suggests another dimension along which our calibrated model is able to match key features of post-war U.S. economic data.

One factor that seems important to Granger Causality test results is the way to account for possible stochastic trends in the series. One common approach is to first difference the data. However, Christiano and Ljungqvist (1988) argue that typical Granger causality tests have low power on first differenced data. Hence, the Sims lagged dependent variable test may be preferable since the asymptotic distribution for this test is the same whether or not there are unit roots.

Results for these bivariate Sims lagged dependent variable tests are found in Table 8. Qualitatively, they are the same as we obtained with Granger Causality tests.⁹ The only substantial difference is that when we use the test procedure that properly accounts for integrated regressors the evidence that simple sum money causes real output is weaker - significant at the 10% level instead of the 5% level obtained using Granger's test. Again, the Divisia measure of money is the only variable that fails to cause the price level, while each variable causes real GDP. Thus, our main result is robust to this alternative test of causality. The variable that offers the most welfare improvement to a central bank contemplating a new policy instrument has the weakest causal relationship with two key macroeconomic variables.

5 Conclusion

Despite interest rates having the strongest marginal predictive content for both output and prices, a constant Divisia money growth rule outperforms the interest rate rule. This results emerges despite Divisia money's poor ability to offer any marginal predictive content for prices in both a Granger causality and Sims causality sense. The welfare results also clash with the causality results for the other monetary aggregates. The monetary base Granger causes output and prices with a high level of significance, but is outperformed in a welfare sense by the interest rate rule. Perhaps most contrasting are the results for the simple sum monetary aggregate. Despite simple-sum money Granger causing both output and prices, it induces indeterminacy and so fails to even register a welfare value.

⁹Thus, in this example integrated series didn't have much effect on our inferences.

In an influential paper on money’s ability to cause output, Christiano and Ljungqvist (1988) assert that Eichenbaum and Singleton (1986) “conjecture that it would be difficult to construct a business cycle model which (a) assigns an important role to monetary factors, (b) is empirically plausible and (c) has the implication that money fails to Granger-cause output.” This claim is reasonable, and at one time that may have been widely believed. Interestingly, our sticky price model satisfies point (a) in that paths for output, prices, and interest rates can’t be determined without reference to money. Furthermore, our model satisfies point (b) insofar as it matches the persistence and volatility of U.S. time series data. However, our model also satisfies point (c) when the interest rate is included in the VAR. Also, our model is consistent with another finding in the literature that money causes economic activity in the bivariate relationship, but not when lags of interest rates are added to the regression (Bernanke and Blinder, 1992). While the results in this paper are established for a particular model and calibration, we conclude that it is feasible to write down a variant of a commonly used structural model that is able to match key features of the data while assigning an important role to money, but offers policy prescriptions that are at odds with the results of causality tests.

Our results advocate further development of structural models of the U.S. economy with realistic modeling of monetary aggregates. Such models are able to shed light on complex and multi-layered policy questions such as the optimal monetary policy instrument. The structural models developed by Belongia and Ireland (2014, 2015) offer important advancements in this direction, but there likely is scope for extending their framework or developing new frameworks which seriously model environments with multiple monetary assets, or similarly, model the creation of liabilities by the financial sector. This paper argues that work along these directions, as opposed to reduced-form tests for causality, are where questions concerning the usefulness of alternative monetary policy instruments and indicators are more likely to be settled.

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Table 1: Calibrated Model Parameters

Description	Parameter	Value
Discount Factor	β	0.99
Inflation Target	Π	$1.02^{\frac{1}{4}}$
Technology Growth Rate	$exp(z)$	$1.02^{\frac{1}{4}}$
Reserves Ratio	$exp(\tau)$	0.03
Deposit Creation Cost	$exp(x)$	0.01
Money Demand Shock	$exp(v)$	2.65
Utility Function Constant	η	16.61
Monetary Aggregate Weight	ν	0.275
Monetary Aggregate CES	ω	0.5
Goods Aggregate CES	θ	6
Price Adjustment Cost	ϕ	50
External Habits	b	0.85
Taylor Rule Smoothing	ρ_r	0.79
Taylor Rule Inflation Response	ρ_π	2.15
Taylor Rule Gap Response	ρ_g	0.93

Table 2: Estimated Model Parameters

Description	Parameter	Value
Preference Shock Persistence	ρ_a	0.3981
Preference Shock Volatility	σ_a	0.0433
Money-Demand Shock Persistence	ρ_v	0.3701
Money-Demand Shock Volatility	σ_v	0.0014
Technology Shock Volatility	σ_z	0.0086
Reserves Demand Shock Persistence	ρ_τ	0.8557
Reserves Demand Shock Volatility	σ_τ	0.0526
Deposit Cost Shock Persistence	ρ_x	0.7430
Deposit Cost Shock Volatility	σ_x	0.0031
Monetary Policy Shock Volatility	σ_r	0.0015
Shopping-Time Function Curvature	χ	27

Table 3: Model Fit: Moment Matching Results^a

Variable		Data Moment	Model Moment
Real GDP Growth	ρ	0.320	0.312
	σ	0.008	0.006
Inflation	ρ	0.983	0.861
	σ	0.006	0.006
Federal Funds Rate	ρ	0.962	0.879
	σ	0.010	0.006
Divisia M2 Growth	ρ	0.481	0.481
	σ	0.009	0.011
Divisia M2 User Cost	ρ	0.915	0.879
	σ	0.100	0.123
Monetary Base Growth	ρ	0.336	0.338
	σ	0.039	0.040

^a For each variable ρ denotes the first order auto correlation and σ denotes the standard deviation.

Table 4: Welfare Comparison of Alternative Monetary Policy Instruments

Alternative Policy Instrument	Welfare Cost Relative to Interest Rate Rule ^a
Constant Divisia Growth Rule	-0.71
Constant Simple-Sum Growth Rule	Indeterminate
Constant Monetary Base Growth Rule	0.57

^a Negative values imply welfare is higher under the alternative policy regime than under the interest rate rule. Welfare costs are expressed as the percentage of steady-state consumption households would be willing to pay to live under the calibrated interest rate rule instead of the alternative policy regime.

Table 5: Stochastic Means and Standard Deviations

Variable	Preference and Technology Shocks			
	Taylor Rule		Constant Divisia Growth	
	Mean	Std. Dev.	Mean	Std. Dev.
$\ln(R_t)$	0.0192	0.0061	0.0195	0.0129
$\ln(\Pi_t)$	0.0045	0.0059	0.0050	0.0031
$\ln(C_t/\exp(z_{t-1}))$	-1.1183	0.0107	-1.1186	0.0144
$\ln(Y_t/\exp(z_{t-1}))$	-1.0934	0.0112	-1.0944	0.0155
$\ln(H_t)$	-1.0983	0.0126	-1.0993	0.0173
$\ln(M_t/\exp(z_{t-1}))$	0.0112	0.0100	0.0122	0.0132
$\ln(N_t/\exp(z_{t-1}))$	-1.4721	0.0967	-1.4147	0.2061
$\ln(D_t/\exp(z_{t-1}))$	-0.2231	0.0510	-0.2391	0.1037

Table 6: Stochastic Means and Standard Deviations

Variable	Money Demand and Financial Sector Shocks			
	Taylor Rule		Constant Divisia Growth	
	Mean	Std. Dev.	Mean	Std. Dev.
$\ln(R_t)$	0.0200	0.0000	0.0199	0.0018
$\ln(\Pi_t)$	0.0050	0.0000	0.0050	0.0001
$\ln(C_t/\exp(z_{t-1}))$	-1.1181	0.0000	-1.1181	0.0001
$\ln(Y_t/\exp(z_{t-1}))$	-1.0937	0.0001	-1.0937	0.0003
$\ln(H_t)$	-1.0986	0.0001	-1.0986	0.0003
$\ln(M_t/\exp(z_{t-1}))$	0.0105	0.0015	0.0106	0.0001
$\ln(N_t/\exp(z_{t-1}))$	-1.5024	0.0025	-1.5007	0.0290
$\ln(D_t/\exp(z_{t-1}))$	-0.2121	0.0020	-0.2126	0.0153

Table 7: Granger Causality Test

Causal Variable	Real GDP		Price Level	
Interest Rate	0.000		0.000	
Divisia	0.008	0.108	0.116	0.427
Simple-Sum	0.018	0.105	0.000	0.435
Monetary Base	0.000	0.294	0.000	0.449

^a p-values

^b The second and fourth columns are for Granger Causality of real output and the price level, respectively, in the bivariate VAR.

^c The third and fifth columns are the test for money causing real output and the price level, respectively, when the interest rate is included in the trivariate VAR.

Table 8: Lagged-Dependent Variable Version of Sims Test for Causality

Causal Variable	Real GDP	Price Level
Divisia	0.001	0.363
Simple-Sum	0.064	0.000
Monetary Base	0.000	0.000
Interest Rate	0.000	0.000

^a p-values

^b This bivariate causality test was developed by Geweke, Meese, and Dent (1983).