Monetary Aggregates and Output

Authors	Scott Freeman, and Finn E. Kydland
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Abstract

This paper offers a general equilibrium model that explains how the observed correlations of money and output fluctuations may come about through endogenously determined fluctuations in the money multiplier. The model is calibrated to meet long run features of the U.S. economy (including monetary features) and then subjected to shocks to the Solow residual following a random process like that observed in U.S. data. The model's predicted business-cycle frequency correlations, of both real and nominal variables, share the following features with U.S. data: i) $M1$ is positively correlated with real output; ii) the money multiplier and deposit-to-currency ratio are positively correlated with real output; iii) the price level is negatively correlated with output [in spite of (i) and (ii)]; iv) the correlation of $M1$ with contemporaneous prices is substantially weaker than the correlation of M1 with real output; v) correlations among real variables are essentially unchanged under different monetary policy regimes; and vi) real money balances are smoother than money demand equations would predict. Although features (i) and (iv) may have been considered support for a causal influence of money on output, the paper demonstrates that they are consistent with an economy in which money has no such causal influence.

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Scott Freeman
Professor of Economics
Department of Economics
University of Texas
Austin, TX 78712
freeman@eco.utexas.edu

Finn E. Kydland
Visiting Scholar
Federal Reserve Bank of St. Louis
Professor of Economics
Graduate School of Industrial Admin.
Carnegie Mellon University
Pittsburgh, PA 15213

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1. Introduction

The business cycle observation that motivates our work is the procyclical movement of the nominal money stock, reported most influentially by Friedman and Schwartz (1963a,b). This correlation between money and output is cited by a wide range of economists as a compelling suggestion, or even a central macroeconomic fact, that monetary factors play a causal role in output fluctuations.

Consider a recent roundtable on the core of macroeconomics: While all carefully assert long run monetary neutrality, Taylor (1997) nominates a short-run trade-off between inflation and unemployment as a principle of macroeconomics; Eichenbaum (1997), while otherwise minimizing the importance of monetary fluctuations, nevertheless asserts that "monetary policy is not neutral in the short run. As an empirical matter, the classic Keynesian and vintage RBC view about the cyclical ineffectiveness of monetary policy has been buried;" Blinder (1997) places a reliable Phillips curve in a prominent place in the core; and Blanchard (1997) asserts that "in the short run, higher money growth can increase output."[1] Elsewhere, Ball and Mankiw (1994) go so far as to divide the profession into irreconcilable "traditionalists" and "heretics" by one's beliefs in

[1]The remaining panel member, Solow (1997), emphasizes aggregate demand as the source of output fluctuations but does not mention monetary factors.

(their sticky-price explanation for) money's causal effect on output.

We are not as confident that the existence of a money/output correlation proves the effectiveness of monetary policy. Other studies into the nature of the money/output correlation lead one to question whether we should interpret this correlation as evidence that changes in the money stock *cause* changes in output. First, the vector autoregressions [Sims (1972)] that seemed to establish money's predictive power for output have proven very fragile. Vector autoregressions that include interest rates along with money and output find that interest rates [Sims (1980) using nominal interest, Litterman and Weiss (1985) using real rates] help to predict both money and output, leaving monetary innovations with little remaining predictive power for output.[2]

Second, fluctuations in output are observed to be more strongly linked to fluctuations in inside money – that part of the money stock consisting of deposits at financial intermediaries – than to innovations in the monetary base – the part of the money stock actually controlled by the central bank. [See Cagan (1965), Sims (1972), King and Plosser (1984), Coleman (1996), and Leeper,

[2]Stock and Watson (1989) find that detrending the money data restores much of the predictive content of monetary data. See Stock and Watson for a summary of investigations into the money/output correlation. See Cooley and LeRoy (1985) for a general critique of making causal inferences from unrestricted vector autoregressions. Barsky and Miron (1989) find a seasonal money/output link that, given the exogenous and predictable Christmas and summer, argues for the endogenity of the money stock.

Sims, and Zha (1996). This is especially true before 1980, the period of the greatest money/output correlation.] Movements in broad monetary aggregates like $M1$ are more tightly linked to real output than are movements in the base because of the money multiplier's tighter links. The money multiplier is an endogenous variable determined by the public's relative preference for deposits and currency. Like most other economic choices, the public's choice of the composition of its money balances is likely to be affected by any number of factors that fluctuate at business cycle frequencies. Building on the Sargent and Wallace (1982) view of an endogenously fluctuating money stock, Freeman (1986) and Freeman and Huffman (1991) show how correlations of money and output fluctuations may come about through endogenously determined fluctuations in the money multiplier.[3]

In this paper we ask whether the endogenous nature of monetary aggregates may account in a quantitatively plausible way for the observed correlation of money and output and other features of the data. To this end we adapt the endogenous money multiplier model of Freeman and Huffman (1991) into an

[3]Tobin (1970) also argues that the precedence of the changes in money did not imply that money changes caused the output changes. His reasoning is that a forward-looking, activist central bank might cause the money/output correlation by changing the money base to affect some targeted fluctuating variable that leads the cycle. While our explanation shares the spirit of Tobin's argument, we concentrate on the endogeneity of the money multiplier because its links to output fluctuations seem stronger.

otherwise standard model of a business cycle set off by real disturbances. In deliberate contrast to monetary models that create a money/output link using sticky prices or fixed money holdings, all prices and quantities are assumed to be fully flexible.[4] Following the style of business cycle analysis in Kydland and Prescott (1982), the model will be calibrated to meet long run features of the U.S. economy (but now including also monetary features) and then subjected to shocks to the technology level following a random process like that observed in U.S. data. The model's predicted business-cycle frequency correlations, of both real and nominal variables, is then compared to those of the U.S. data. We find that the model's predicted business-cycle frequency correlations share the following features with U.S. data: i) $M1$ is positively correlated with real output; ii) the money multiplier and deposit-to-currency ratio are positively correlated with real output; iii) the price level is negatively correlated with output [in spite of (i) and (ii)]; iv) the correlation of $M1$ with contemporaneous prices is substantially weaker than the correlation of $M1$ with real output; v) correlations among real variables are essentially unchanged under different monetary

[4]Examples of the "sticky" price approach include models assuming long-term fixed nominal contracts [following Fischer (1977) and Taylor (1979)] or "menu" costs of price adjustments [following Mankiw (1985)]. Examples of the second approach, often called "limited participation" models, assume that some economic agents are temporarily unable to alter their money balances at will [following Lucas (1990), Fuerst (1992), and Christiano and Eichenbaum (1992)].

policy regimes; and vi) real money balances are smoother than money demand equations would predict.

Others, notably Chari, Christiano, and Eichenbaum (1995), have considered an endogenous money multiplier in calibrated models of the business cycle. Their computational experiments differ from ours in one distinct way. In their model, the endogenous money multiplier is introduced into a model that already features links between money and real output generated by some stickiness or incompleteness in markets (specifically, the assumption that households cannot immediately adjust their money balances). As a result, while of interest for other reasons, their model cannot be used to explore fully the task we have set for ourselves – to generate the money/output correlation in a model without resorting to stickiness in prices or economic decisions.

Coleman (1996) takes an approach closer to our philosophy. He employs a model featuring an endogenous money multiplier in which he postulates separate transactions costs for consumption and investment purchases. The model contains 28 parameters of which 12 are calibrated and 16, including nine transaction-cost parameters, are estimated for the period 1959Q1-1994Q2 using simulated moments estimation. While his approach produces interesting insights on the sources of money-output association, including lead-lag relationships, and on the extent to which they can be reconciled with the model, the model's complexity reduces the transparency of its findings.

In this paper, we take a decidedly more parsimonious approach. We assume that consumption goods can be purchased using either currency or bank deposits. Only the minimal number (two) of transaction costs are assumed. One is a Baumol (1952)-Tobin (1956) cost of acquiring money balances, necessary to determine the demand for money and make endogenous the velocity of money. Specifically, we assume that money balances can be replenished during each period at a cost of leisure time for each instance such a transaction takes place. The other is a fixed cost of using deposits, necessary to determine the division of money balances into currency and deposits. In equilibrium, deposits, being backed by capital, offer a better rate of return than currency. Therefore the fixed cost of using deposits allows a demand for currency despite its low rate of return. Smaller purchases are made with currency and the larger ones with deposits. Facing these two costs and other factors that may vary over the business cycle, households make decisions that determine the velocity of money and the money multiplier.

In the next section, we outline our model environment, derive the stationary equilibrium, and discuss the model's calibration. In Section 3, we describe the model's properties when subjected to production technology shocks under a fixed growth rate of fiat money and then two alternative stochastic processes for money growth.

2. The theoretical framework

2.1. The environment:

Each of a large number of infinitely lived identical households is endowed with a stock of capital in the initial period (period 0) and one unit of time in each period $t \geq 0$. Time can be used for leisure, labor, or the conducting of transactions.

There is a continuum of good types indexed by j with $0 \leq j \leq 1$. The utility of the representative household is the following function of its consumption of goods of each type $[c_t(j)]$ and of leisure (d_t) in each period $t \geq 0$:

$$E \sum_{t=0}^{\infty} \beta^t u \left[\min \left(\frac{c_t(j)}{2j} \right), d_t \right] \tag{2.1}$$

The function $u(.,.)$ is assumed to satisfy the Inada conditions and to be increasing in each argument, quasi-concave, and twice continuously differentiable.

A single production process produces capital and consumption goods of every type j. Output at t is a constant-returns-to-scale function of the two inputs to production at t – capital (k_t) and labor (l_t): $z_t f(k_t, l_t)$, where z_t denotes the technology level. In every period fraction δ of the existing capital stock depreciates after production ($0 < \delta < 1$). The capital per household available for production in period t therefore equals the sum of capital created in period $t-1$ (i_{t-1}) and that part of the previous period's capital stock which has not depreciated: .

$$k_t = i_{t-1} + (1-\delta)k_{t-1}. \tag{2.2}$$

The technology level evolves according to

$$z_t = \rho z_{t-1} + \varepsilon_t, \tag{2.3}$$

where the ε's are normally distributed with positive mean and standard deviation σ.

In addition to capital, two other assets are available to households – fiat money and bank deposits. Fiat money, uniquely issued by the government, is unbacked, intrinsically useless, and costless to exchange. The stock of fiat money (in units called dollars) at the end of any period t is M_t, with $M_t = \xi_t M_{t-1}$. Changes in the stock of fiat money are financed by lump sum subsidies of x_t

units of fiat money to each household. The government budget constraint is

$$x_t = (\xi_t - 1) M_{t-1}. \tag{2.4}$$

Bank deposits are loans to competitive financial intermediaries that use the proceeds to invest in capital and reserves of fiat money. The government requires that financial intermediaries hold reserves of at least θ dollars worth of fiat money for each dollar held in deposits. The use of deposits to make a purchase incurs a fixed cost of γ goods for each type of good purchased using deposits.[5] (This might be thought of as a check-clearing cost or a cost of verifying the identity of the person writing a check or making a withdrawal.) Deposits made in period t pay competitively determined interest in period $t + 1$.

The consumption of each household must be purchased with money balances chosen at the beginning of the period. Any combination of deposits and fiat money may be chosen to satisfy this requirement, but the ratio of deposits to currency chosen at the beginning of the period must be maintained throughout the period. If these money balances are replenished n_t times in period t, then n_t

[5]The assumption of a fixed cost of deposits is taken from Prescott (1987) and has been used to endogenize currency demand in Freeman and Huffman (1991) and Schreft (1992). In a growing economy the assumption that the cost is fixed in goods implies a gradual shift from currency to deposits (as observed domestically) over time.

dollars worth of consumption goods can be purchased for each dollar of balances held. The replenishment of money balances (a trip to the asset market) uses ϕ units of time so that the total time spent on transactions equals ϕn_t. A household begins each period with the money balances it chose in the previous period. Essentially this transactions technology is that introduced by Baumol (1952) and Tobin (1956) but with a transaction cost payable in time as proposed by Karni (1973).

The requirement that consumption be purchased using money functions like the commonly assumed "cash-in-advance" constraint in that the level of consumption determines the demand for money balances, but with three differences worth noting. First, current consumption is purchased by *current* money balances, not the money balances acquired in the previous period. Second, the velocity of money, as represented by n_t, is not fixed but is determined endogenously. Third, bank deposits as well as fiat money may be used to purchase consumption, and the ratio of deposits to fiat money is freely chosen.

2.2. Equilibrium:

An equilibrium consists of the following: i) households choose consumption, labor, and asset holdings taking as given prices and rates of return; ii) firms maximize profits taking factor prices as given; iii) firms and banks earn zero profits; and iv) markets clear.

Let us examine household choices in several steps, starting with the choices of the composition of consumption and money balances. For a given desired level of total period t consumption c_t^*, the Leontief-type instantaneous utility function, $u\left[\min\left(\frac{c_t(j)}{2j}\right), d_t\right]$, induces agents to distribute consumption over the various goods types according to the optimizing rule

$$c_t(j) = 2jc_t^*. \tag{2.5}$$

Integrating (2.5) from $j = 0$ to 1 will verify that total consumption equals c_t^*.

Substitution of this optimal rule (2.5) into the household's utility function (2.1) yields a more standard objective function

$$\sum_{t=0}^{\infty} \beta^t u\left(c_t^*, d_t\right). \tag{2.6}$$

Consider next the household's choice of the composition of money balances for a given c_t^*. For each type of good purchased, a household must decide whether deposits or fiat money offer the more attractive rate of return, net of transaction costs. Deposits, however, have a fixed cost of use so that, defining $\tilde{r}_{t+1}$ as the real gross rate of return paid by banks in period $t+1$ on deposits made in period t and r_{t+1} as the real gross rate of return on nonintermediated assets acquired at t, the real rate of return net of transaction costs for n_t purchases of size $c_t(j)$ is

$$\tilde{r}_{t+1} - \frac{\gamma r_{t+1} n_t}{c_t(j)}, \tag{2.7}$$

an increasing function of the size of the purchase (an increasing function of j). Because of the fixed cost of using deposits, the deposit rate of return net of transaction costs goes to negative infinity as j goes to zero; i.e., deposits become less desirable as the purchase size decreases. In contrast, the nominal gross rate of return of fiat money is always unity no matter how many units are purchased because it incurs no fixed cost per transaction. This implies that there exists some j^* below which currency is preferred to deposits. In the case of perfect foresight (or certainty equivalence) this j^* is given by the value of j at which currency and deposits offer the same rate of return:

$$\tilde{r}_{t+1} - \frac{\gamma r_{t+1} n_t}{2jc_t^*} = \frac{p_t}{p_{t+1}}. \tag{2.8}$$

We will concentrate on the interesting case in which both currency and deposits are used as money ($j^* < 1$).

INSERT FIGURE

Recall that money balances are replenished n_t times each period. Then, denoting nominal household deposits by h_t and nominal fiat money balances by m_t, we can use j^* to express the demand for each type of money as the values of h_t and m_t satisfying

$$n_t \frac{h_t}{p_t} = \int_{j^*}^{1} c_t(j) dj = \int_{j^*}^{1} 2 j c_t^* dj = \left(1 - j^{*2}\right) c_t^*, \tag{2.9}$$

$$n_t \frac{m_t}{p_t} = \int_{0}^{j^*} c_t(j) dj = \int_{0}^{j^*} 2 j c_t^* dj = j^{*2} c_t^*. \tag{2.10}$$

Let us now turn to the constraints on the household's decision. The time constraint is

$$1 = l_t + d_t + n_t \phi, \tag{2.11}$$

which divides the available time into labor (l_t), leisure (d_t), and the number of trips to the bank (n_t). Let us define w_t as the (real) wage paid to a unit of labor, and a_t as the level of nonmonetary assets acquired by the end of period t. We can now write the agent's goods budget constraint:

$$w_t l_t + r_t a_{t-1} + \frac{\tilde{r}_t h_{t-1}}{p_{t-1}} + \frac{m_{t-1} + x_t}{p_t} = c_t^* + a_t + \frac{h_t}{p_t} + \frac{m_t}{p_t} + \gamma(1 - j_t^*), \qquad (2.12)$$

which states that wages plus the return from the household's (nonmonetary and monetary) assets must equal its consumption, its new asset holdings, and its transaction costs.

We can now express the agent's perfect foresight problem as the maximization of (2.6) subject to the constraints (2.9)-(2.12). After using 2.12 and 2.11 to substitute for c_t^* and d_t, the household's constrained problem may be expressed as the choice of a_t, h_t, m_t, j_t^*, n_t, and l_t to maximize

$$\sum_{t=0}^{\infty} \beta^t u \left[w_t l_t + r_t a_{t-1} + \frac{\tilde{r}_t h_{t-1}}{p_{t-1}} + \frac{m_{t-1} + x_t}{p_t} - c_t^* - a_t - \frac{h_t}{p_t} - \frac{m_t}{p_t} - \gamma(1 - j_t^*), 1 - l_t - n_t \phi \right] \qquad (2.13)$$

$$+ \sum_{t=0}^{\infty} \eta_t \left[n_t \frac{h_t}{p_t} - \left(1 - j^{*2}\right) c_t^* \right]$$

$$+ \sum_{t=0}^{\infty} \mu_t \left[n_t \frac{m_t}{p_t} - j^{*2} c_t^* \right].$$

We'll denote its derivatives with respect to the first and second arguments as u_c and u_d, respectively. The first order conditions resulting from the choice of a_t, h_t, m_t, j_t^*, n_t,and l_t are respectively

$$r_{t+1} = \frac{u_c\left(c_t^*, d_t\right)}{\beta u_c\left(c_{t+1}^*, d_{t+1}\right)}, \tag{2.14}$$

$$\frac{u_c\left(c_t^*, d_t\right)}{\beta u_c\left(c_{t+1}^*, d_{t+1}\right)} = \tilde{r}_{t+1} + \frac{\eta_t n_t}{\beta^{t+1} u_c\left(c_{t+1}^*, d_{t+1}\right)}, \tag{2.15}$$

$$\frac{u_c\left(c_t^*, d_t\right)}{\beta u_c\left(c_{t+1}^*, d_{t+1}\right)} = \frac{p_t}{p_{t+1}} + \frac{\mu_t n_t}{\beta^{t+1} u_c\left(c_{t+1}^*, d_{t+1}\right)}, \tag{2.16}$$

$$\mu_t = \eta_t + \frac{\gamma \beta^t u_c\left(c_t^*, d_t\right)}{2 j_t^* c_t^*}, \tag{2.17}$$

$$\mu_t \frac{m_t}{p_t} + \eta_t \frac{h_t}{p_t} = \beta^t u_d\left(c_t^*, d_t\right), \tag{2.18}$$

$$w_t u_c\left(c_t^*, d_t\right) = u_d\left(c_t^*, d_t\right). \tag{2.19}$$

It immediately follows from (2.14)-(2.17) that in an equilibrium in which all assets are held, the assets with the lowest transaction costs must have the lowest equilibrium returns; i.e.,

$$r_{t+1} > \tilde{r}_{t+1} > \frac{p_t}{p_{t+1}}. \tag{2.20}$$

The bank's problem is easy to describe. Banks accept deposits, investing them in a portfolio of capital and fiat money reserves. In equilibrium, capital's rate of return exceeds that of fiat money ($r_{t+1} > \frac{p_t}{p_{t+1}}$), ensuring that banks will not hold more than the legal minimum requirement of reserves (θ for each dollar of deposits). Free-entry among zero-cost, zero-net-worth banks requires that depositors are offered the rate of return received by the banks' assets:

$$\tilde{r}_{t+1} = (1-\theta)r_{t+1} + \theta\frac{p_t}{p_{t+1}}. \tag{2.21}$$

The firm's problem is entirely standard. Profit maximization by competitive firms operating under constant returns to scale induces a representative firm to use capital k_t and labor l_t until the marginal product of each equals the competitively determined rental rate of that input (respectively, π_t and w_t):

$$z_t f_k(k_t, l_t) = \pi_t, \tag{2.22}$$

$$z_t f_l(k_t, l_t) = w_t. \tag{2.23}$$

These conditions also ensure that constant-returns-to-scale firms earn no economic profits. The effective gross real rate of return on capital, r_t , is therefore

$$r_t = \pi_t + (1-\delta), \tag{2.24}$$

The clearing of the asset market for capital requires that the capital stock per household must equal the sum of capital held directly by each household and capital held by banks on behalf of each household:

$$k_{t+1} = a_t + (1-\theta)\frac{h_t}{p_t}. \tag{2.25}$$

The clearing of the market for fiat money requires that the stock of fiat money equal the combined stocks of currency and reserves:

$$M_t = m_t + \theta h_t. \tag{2.26}$$

The total money stock, the sum of nominal deposits and currency, is

$$M1_t = m_t + h_t, \tag{2.27}$$

which, using (2.26) can be written as the product of the monetary base and the money multiplier

$$M1_t = M_t\left[1 + \frac{h_t(1-\theta)}{m_t + \theta h_t}\right]. \tag{2.28}$$

The money multiplier is closely related to the deposit-to-currency ratio, h_t/m_t, but with an adjustment for that part of the base that serves as reserves.

2.3. The behavior of money over the cycle

Let us illustrate the workings of the model by describing the response of monetary variables to a positive technology shock. The increased output from a positive technology shock leads to an increased desire for consumption. In response the household wishes to increase both real money balances, which depresses the price level, and trips to the bank to refresh money balances, which increases the velocity of money, other things equal. The positive technology shock has the added effect of increasing the marginal product of labor and thus the opportunity cost of the time spent on transactions. This further increases the demand for real money balances but reduces trips to the bank.

A positive technology shock affects also the composition of money balances. The resulting increase in desired consumption increases the size of all purchases. Because the deposits are preferred for larger purchases, households increase the ratio of deposits to currency.[6] This increases the money multiplier and thus $M1$. To the extent that it reduces the demand for currency, this switch in the composition of money balances also increases the price level, other things

[6] One might loosely think of these large purchases as purchases of durable goods, which are generally large and thus purchased using deposits.

equal. Any increase in the nominal interest rate will further encourage household preferences for deposits over currency.

2.4. Steady State

At this point let us look for an equilibrium that is stationary in c_t^*, $\frac{h_t}{p_t}$, $\frac{m_t}{p_t}$, j_t^*, n_t, and l_t, starting with the rates of return. From (2.14), the rate of return on unintermediated capital in steady state requires

$$r_t = \frac{1}{\beta}. \tag{2.29}$$

From the budget constraint (2.12) and the clearing of the market for fiat money (2.26), the steady-state rate of return of fiat money is

$$\frac{p_t}{p_{t+1}} = \frac{1}{\xi}. \tag{2.30}$$

It follows directly from these two rates of return and (2.21) that the real gross rate of return on deposits is

$$\tilde{r}_{t+1} = (1-\theta)\frac{1}{\beta} + \theta\frac{1}{\xi}. \tag{2.31}$$

Defining the following stationary transformations of the Lagrange multipliers

$$\mu^* \equiv \mu_t \beta^t, \tag{2.32}$$

$$\eta^* \equiv \eta_t \beta^t, \tag{2.33}$$

we can express the first-order conditions (2.15)-(2.18) in steady state as

$$\frac{1}{\beta} = \tilde{r} + \frac{\eta^* n}{u_c(c^*, d)\,\beta}, \tag{2.34}$$

$$\frac{1}{\beta} = \frac{1}{\xi} + \frac{\mu^* n}{u_c(c^*, d)\,\beta}, \tag{2.35}$$

$$\eta^* = \mu^* + \frac{\gamma u_c(c^*, d)}{2j^* c^*}, \tag{2.36}$$

$$\eta^* + \mu^* = u_d(c^*, d). \tag{2.37}$$

These conditions, together with the stationary versions of (2.4), (2.12), (2.19), and (2.22)–(2.26), define the steady state.

3. Quantitative Analysis

When values have been assigned to the model's parameters, a computational experiment proceeds by computing from the model many independent time paths, each of the same length as those for the data period for the United States with which the model is contrasted. As is also done for the data, the model's time series, except for interest rates, are detrended using the Hodrick-Prescott filter. We refer to each variable's deviation from the trend as the cyclical component. The model's cyclical behavior can then be summarized in the form of a set of statistics, such as standard deviations and correlation coefficients.

3.1. Model Calibration

The parameters of preferences and productive technology are calibrated to satisfy certain steady-state relations. In the steady state, investment is one-quarter of output, so that, with a depreciation rate of 0.025, the ratio of capital to annual output is 2.5. The production-function is assumed to have a Cobb-Douglas form $z_t k_t^{\alpha} l_t^{1-\alpha}$. The parameter α is calibrated so that the labor share of national income is 0.64. The autocorrelation coefficient ρ in the technology level process is set equal to 0.95 with a standard deviation σ of its innovations of 0.0076. The utility function is assumed to have the form $\frac{1}{1-\nu}\left[(c_t^*)^{\varsigma}(d_t)^{1-\varsigma}\right]^{1-\nu}$, with $0 < \varsigma < 1$, $\nu > 0$. Setting the average allocation of households' time (net of sleep and personal care) to market activity equal to 0.30 restricts the value of the utility function's share parameter, ς, to be 0.33. We choose $\nu = 2$. The reserve-requirement ratio, θ, is set equal to 0.10.

We make no attempt here to obtain independent values of the key parameters γ and ϕ. Instead, we calibrate them to steady-state values of the deposit/currency ratio and the share of capital that is intermediated. In determining the deposit/currency ratio, we exclude a rough estimate of the currency held abroad or associated with unlawful activities. Estimates of the former currently range from two-thirds to three-quarters. An indication is that high-denomination currency (100- and 50-dollar bills) by 1995 had risen to over 70 percent of the outstanding currency. If we divide the deposits portion of $M1$ by one-third of currency, the resulting figures range from about 12 early in our sample to about 7 late in the sample. The figure one-third used in that calculation surely is too low for the early period but probably too high for recent years. As a compromise, we selected a deposit/currency ratio of 9 for our computational experiments. Dividing the nonreserve portion of $M1$ by the capital stock (about 2.5 times annual GDP) yields values ranging from about four to six percent. We chose 0.05 as our steady-state value. The resulting parameter values are

$\gamma = 0.0060$ and $\varphi = 0.00076$. In our computational experiments, the average aggregate resource use associated with the fixed cost γ works out to be 0.41 percent of the model's GDP. The time per replenishment implied by the value of ϕ is approximately one hour. (Note that ϕ represents not the cost of going to the ATM machine but the cost of replenishing all deposit and cash balances from nonmonetary assets.)

3.2. Quantitative Findings

We start by examining the model's behavior under two simple monetary policies, each with an average annual inflation rate of 3 percent. Under the first, policy A, the growth rate of fiat money is fixed at 3% in every period. Under the second, policy B, serially uncorrelated shocks have been added to the supply of fiat money, with a standard deviation of 0.5 percent.

The model displays interesting comovements among its variables. Table 1 presents contemporaneous correlations with output.

	$M1$	P	$M1/M0$	$M1/P$	$PY/M1$	R_{nom}	C	I	L
Policy A	1	-.49	1	.98	.52	-0.06	.96	.99	.99
Policy B	.87	-.13	1	.98	.52	-0.06	.95	.99	.99

Table 1: Contemporaneous correlations with output

for two serially uncorrelated monetary policies.

Notice first that $M1$ is positively correlated with real output. Under Policy A in which there is no randomness in the growth rate of fiat money, it is obvious that the movement of $M1$ comes from the reaction of the deposit-to-currency ratio to the technology shock. A positive technology shock encourages the use of deposits because it increases both the return to the capital backing deposits and the size of consumption purchases. Because technology shocks are assumed to be the only source of randomness, the correlation is very high. Under Policy B, with randomness in the monetary base, $M1$ and the price level are less tightly correlated with real output, although output's correlations with the money multiplier and real sector variables are essentially unchanged.

A second interesting pattern is the countercyclical behavior of prices. Although a pro-cyclical increase in the money multiplier implies a decrease in the demand for fiat money which, other things equal, implies a higher price level, the increase in desired consumption from a positive technology shock increases the demand for both forms of money, decreasing the price level. In these computational experiments as in the actual data [see Kydland and Prescott (1990) and Cooley and Ohanian (1991)], this second effect dominates.

In Table 2 we present correlations between $M1$ and other endogenous variables for policy B, with serially uncorrelated randomness in the growth rate of the monetary base.

	GDP	P	C	I	$M1/M0$	R_{nom}
Policy B	.87	.34	.87	.85	.87	-.07

Table 2: Contemporaneous correlations with $M1$

for a random but serially uncorrelated monetary policy.

Several patterns observed here are consistent with a business cycle driven by monetary fluctuations. Nominal money balances are positively correlated with contemporaneous consumption and investment as well as labor and future capital. Notice too that the correlation of $M1$ with contemporaneous prices (.34) is substantially weaker than the correlation of $M1$ with real output (.87). Looking at these correlations without knowing the underlying economic structure, one might be tempted to imagine that they come from an economy in which monetary shocks are not offset by price level changes but have a causal effect on output. These correlations, however, are found in a model driven by technology shocks featuring complete flexibility in prices and money balances.

Consider now the more realistic assumption that shocks to the growth rate of the monetary base are serially correlated. Consider in particular a first-order autoregressive process with an autoregression parameter of 0.7 and a standard deviation of .2, which we will call policy C. In this case, positive innovations to the current rate of growth of the monetary base signal an increased probability of high growth in next period's monetary base. As a result agents will anticipate a high rate of inflation, inducing them to switch some of their money balances from currency to capital-backed deposits, stimulating output.[7] This stimulus is negligible, however. The standard deviation of output is the same (1.33) under both policies. Comparing policies B and C in Table 3 we do not find much of a difference in the correlations with output of real variables, despite some differences in the correlations of nominal variables.

[7]This effect of serially correlated monetary expansions was proposed by Lacker (1988) and Freeman and Huffman (1991).

	$M1$	P	$\frac{M1}{M0}$	$\frac{M1}{P}$	$\frac{PY}{M1}$	R_{nom}	C	I	L
Policy B	.87	-.13	1	.98	.52	-0.06	.95	.99	.99
Policy C	.81	-.1	.92	.98	.52	-0.05	.94	.99	.99

Table 3: Correlations with output,

with and without serial correlation in monetary base growth.

In Tables 4 and 5 we compare the model's correlations with output and with $M1$ respectively to those of the U.S. before and after 1980.[8]

	$M1$	P	$\frac{M1}{P}$	$\frac{PY}{M1}$	$M0$	$\frac{M1}{M0}$	C	I	L	R_{nom}
Policy C	.81	-.1	.98	.52	.01	.92	.94	.99	.99	-0.05
U.S. 59:1-79:3	.70	-.78	.81	.45	.46	.46	.89	.90	.86	.29
U.S. 79:4-95:4	.09	-.56	.26	.51	.34	.02	.89	.89	.91	.48

Table 4: correlations with output

[8]The correlations are calculated from Citibase data. Labor, L, is hours from the establishment survey. The price level, P, is the GNP deflator. Consumption, C, is total consumption and investment, I, is total investment. A case could be made that, to be consistent with our calibration, high-denomination currency should be subtracted from $M1$. As its movements are largely uncorrelated with the U.S. business cycle, however, and our focus is on correlations between money and output, we made no attempt to do so. Our sample period starting in 1959:I is based on availability of quarterly monetary aggregates.

	C	I	P	$\frac{M1}{M0}$	R
Policy C	.82	.78	.47	.91	.12
U.S. data 59:1-79:3	.63	.66	-.50	.67	.37
U.S. data 79:4-95:4	.27	.13	-.42	.94	-.48

Table 5: correlations with $M1$

Our simple model generally matches the signs of these correlations of the real data. In particular, we see in Table 4 that output is positively correlated with output and real balances even though prices are countercyclical.

The model also displays a correlation of $M1$ with contemporaneous prices that is substantially weaker than the correlation of $M1$ with real output. The model does not go as far as the actual data, however, which displays in Table 5 a negative correlation between $M1$ and the price level. A negative correlation is a possibility consistent with the mechanics of our theory: positive output shocks can drive $M1$ up (through an increase in the money multiplier) while it drives the price level down (through an increased demand for money). As calibrated, however, our simple model displays a price level that is not sufficiently countercyclical for this outcome (see Table 4).

From Table 4 we see that the correlation of output and the money multiplier is much greater in the model than in the data. An assumption of the model made for tractability is that the same number of purchases are made regardless of the desired level of consumption. When more consumption is desired, a household simply makes larger purchases, increasing the use of deposits and the money multiplier. The response of the money multiplier (and thus the price level) to output fluctuations would therefore be less (more like the data) if agents increased both the size and quantity of purchases when consumption increases.[9]

The model's correlations (and, we believe, its assumptions about monetary structures) are much closer in magnitude to those in the real U.S. economy before 1980 (the period of much of the empirical work on money-output correlations) than to those after 1980. The financial deregulation of the 1980's brought large changes in what could be used as money and a major change in monetary policy. Most relevant to our story about the money multiplier are the large and fluctuating flows of U.S. currency to foreign countries, especially the former Soviet Union, in this period.[10] As Gavin and Kydland (1996) point out, the various monetary changes in the post-1980 era led to dramatic changes in

[9]We did not redesign our model to allow for a variable number of purchases because it would add complexity to the choice of the composition of money balances in a way that we cannot imagine how to calibrate.

[10]See Porter and Judson (1996) for evidence concerning the flows of currency to the former Soviet Union. We thank Philip Jefferson for bringing this to our attention.

the variance and correlations of $M1$ and other monetary variables (though not to real behavior). Explaining the changes brought by the 1980's is an important project for future work by monetary economists of all persuasions but beyond the scope of a model with only a single type of intermediated asset, a monetary policy without targeting, and no foreign demand for dollars.

Another area for exploration is the possible endogeneity of the monetary base. It is clear from Table 4 that even in the period before 1980 the correlation of the monetary base and output is stronger in the data than in our experimental economy with its exogenous random monetary base (although in both the pre-1980 data and the model it is weaker than the correlation of $M1$ and output). A policy by the Federal Reserve of changing the monetary base in reaction to economic events (for example, a policy of stabilizing the price level) might account for this correlation. We wish, however, to keep the focus of this present paper squarely on the endogeneity of the money multiplier.

3.3. The excessive smoothness of real money balances

A puzzle for monetary theory is the observed persistence of money holdings in the face of fluctuations in income and nominal interest rates. Lucas (1994) presents the puzzle in the following way. He first shows that unitary income elasticity accounts well for the trend of $M1$ since 1900. Plotting the money-income ratio versus a nominal interest rate, he finds that an interest elasticity of -0.5 fits the data better that either -0.3 or -0.7. Using time series data on nominal output and interest rates, Lucas then calculates predicted $M1$ from the relation $m/p = Ayr^{-1/2}$, where m, p, y , r and A represent respectively nominal money balances ($M1$), the price level, real output, the nominal interest rate and a scale parameter. Lucas finds that the actual time series of $M1$ is much smoother than the predicted time series.

For our economy under policy C, the average percentage standard deviation of cyclical real $M1$ is 1.36, while that predicted by the relation used by Lucas is 1.21.[11] The artificial time series generated by our model thus display more smoothness than would be predicted by a conventional money demand function. This apparent "stickiness" of money demand is observed even though money balances are completely flexible in the model. What looks like stickiness of money demand comes from the endogeneity of $M1$ through the money multiplier. Using the Lucas notation, m/py fails to fluctuate as much as would be predicted from long run behavior because endogenous changes in the total money supply

[11]Under policies A and B, the difference between predicted and "actual" standard deviations is of the same magnitude.

(m) offset fluctuations in nominal income (py) at the business cycle frequency.

4. Conclusion

As its name suggests, much of the research in the real business cycle tradition has left aside monetary factors when studying sources and effects of macroeconomic fluctuations. Attention to monetary phenomena, however, is now increasing.

Motivated by observed correlations between real output and nominal variables like the total money supply, efforts have been made to model monetary innovations as a source of real fluctuations at the frequency of the business cycle. To get nominal variables to matter for real output, two lines of work have been developed that deviate from the cornerstone of classical economics and the real business cycle approach: the assumption that relative prices and the decisions of rational economic agents can react to any exogenous disturbance. Instead, these two lines of work assume that either nominal prices or nominal money balances are assumed to be unchangeable for some period.

In this paper we attempt to address the observed correlations of nominal money balances and real output while imposing no rigidity in prices or agent choices. This intentionally simple equilibrium model demonstrates that one may observe correlations between nominal monetary aggregates and real output even in economies in which rigidities are not imposed.

Money in the model has no causal effect on the decisions that affect real output. The key to the monetary correlations displayed by the model lies in the endogeneity of the money supply that results from the households' choices of the composition of their money balances in response to variables that fluctuate over the business cycle. These endogenous monetary responses yield not only the sought-after money/output correlation but also the sticky prices and money balances that other models of money and output impose by assumption.

We do not offer this analysis as a definitive affirmation of complete monetary neutrality. Indeed, in our model economy, shocks to required reserves or serially correlated shocks to the monetary base have an influence on output. Other real effects of monetary policies are certainly conceivable. We offer a rather tractable way in which an endogenous money multiplier can be introduced into models considering a variety monetary phenomena, policies, or links to the real sector.

Our purposes in this exercise are two. First we demonstrate that the endogeneity of the money stock may significantly contribute to the observed correlations between nominal and real variables and therefore must be taken into account. Only after allowing for the endogeneity of the money stock can one begin to make a case for the effectiveness of monetary policy.

Second, we show with our example that restrictions on the flexibility of agent choices or prices are not required to generate a money/output correlation. Assumptions of inflexible prices and decisions pre-judge the effectiveness and desirability of policy by allowing the monetary authority to make the nominal adjustments that agents are assumed unable to make. Recent efforts to model monetary phenomena often seem to have granted themselves an exemption on the grounds of necessity from the classical standard of adjustable prices and quantities. Our work demonstrates that this exemption is not necessary to address the monetary data. We hope that those who disagree with us as to the source of these monetary phenomena will return to the debate with explicit models in which the necessity of government intervention is not built into constraints on agent behavior.

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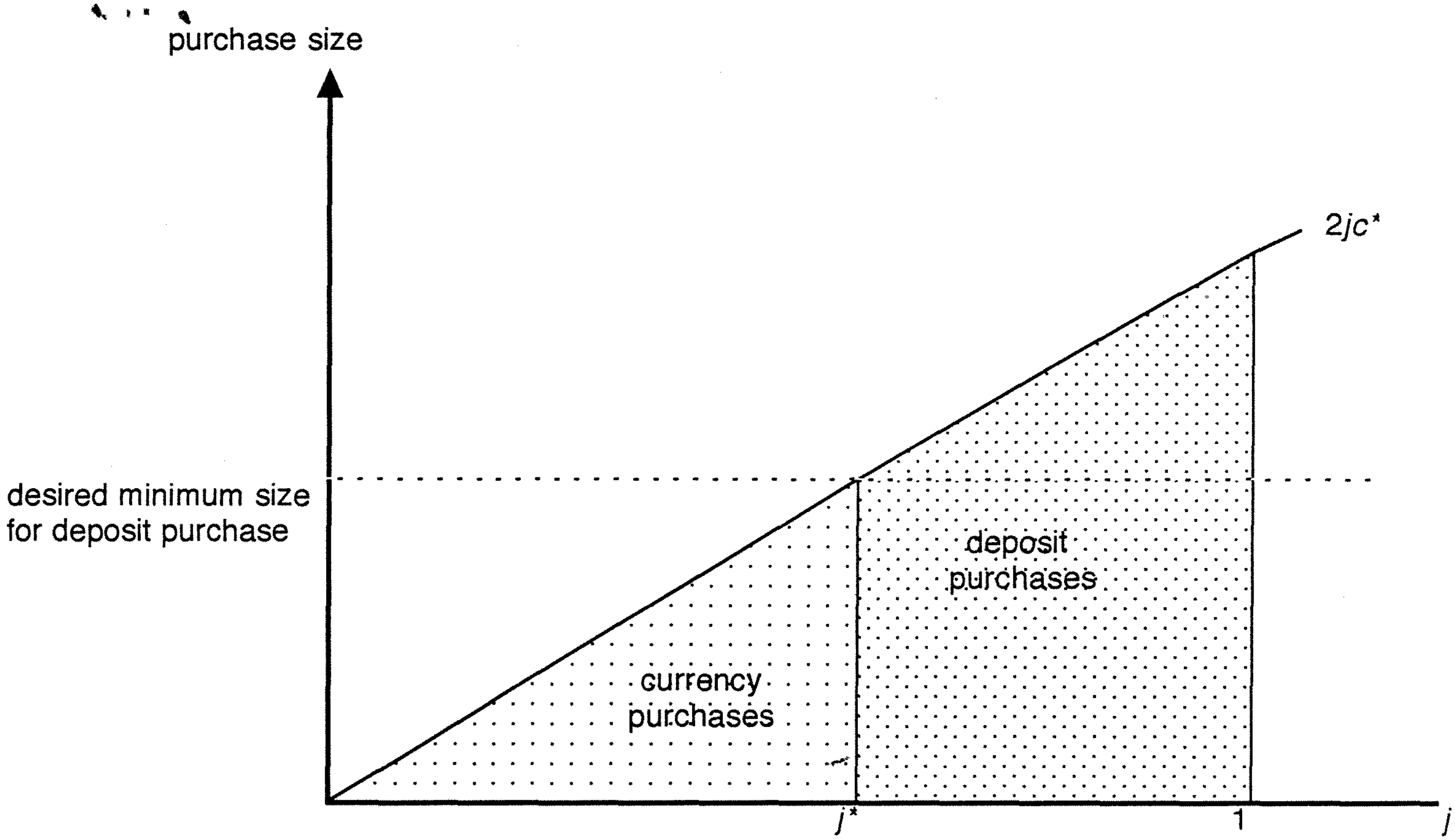

Figure: The composition of money balances