Monetary Shocks and Bank Intermediation in a Dynamic Stochastic General Equilibrium Model

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Abstract
Empirical studies have shown that in economies with relatively low inflation rates output growth and money growth are correlated (McCandless & Weber 1995). The purpose of this study is to illustrate how the basic Real Business Cycle (RBC) model can be modified to incorporate money in an attempt to construct monetary business cycle model such that the dynamics of the model also give positive correlation between money shocks and output. This is meaningful since understanding how monetary shocks generate real effects is critical for any normative analysis of monetary policy. It is conjectured that the banking sector plays an important role in the monetary transmission mechanism and money is injected into the model through financial intermediaries. It is observed in this model that a positive monetary shock reduces interest rates and stimulates economic activity, which is called the *liquidity effect*. Furthermore, the statistics generated by the model shows that monetary shocks have significant real impact when money enters through the financial system. Taken together, this implies that how money enters into the model significantly matters for the impact of monetary shocks and such shocks entering through financial intermediaries may be important in determining the cyclical fluctuations of the U.S. economy.
Keywords: Business cycle, money growth shock, monetary transmission mechanism, financial intermediaries, liquidity effect.

1 Introduction

The core of the RBC methodology is the neoclassical growth model that resembles a stable economy, assumed to be following its long-term growth trend (King & Rebelo 1999). When hit by exogenous shocks that affect its environment, the model generates fluctuations that resemble business cycles. The model is termed real because it ignores nominal factors such as money and bonds. It is a dynamic general equilibrium model in that it studies an economy that evolves over time. However, a remarkable feature of the business cycle in many industrialized countries is the striking association between movements in monetary aggregates and aggregate output. In fact, the strength of this association has been sufficiently persuasive in the U.S. that M2 has long been included in the Commerce Department's Index of Leading Economic Indicators (LEI). Although correlation does not imply causality, this coherence is interpreted in the literature as an evidence that monetary forces are important for fluctuations in economic aggregates[1].

The purpose of this study is two-fold. First, it attempts to illustrate how the basic neoclassical business cycle model can be modified to incorporate money in an attempt to construct monetary business cycle models of the US economy. Traditional RBC research have focused on technology shocks calculated from the Solow residuals as the main driver of economic fluctuations. This study, however, explores whether and how monetary forces can be an important cause of business cycle fluctuations over and above technology shocks in a world where agents are assumed to behave rationally. Second, it attempts to show that how money enters an economy matters for the impact of monetary shocks. In this regard, this study offers a quantitative assessment of how the fluctuations and co-movements that we observe in the data

[1] See, for instance, Friedman & Schwartz (1963)

compare with those displayed by the artificial economies that are constructed.

2 Literature review

Almost all economists believe that money is neutral in the long-run as long-run effects of money fall almost entirely on prices with little impact on real variables. However, many also believe that monetary factors can have effects on real variables in the short-run. The most influential evidence that money does matter for business cycle fluctuations is the comprehensive historical research by Friedman & Schwartz (1963).

The neoclassical growth model proposed by Solow (1956) is a non-monetary model. Although transactions take place, there is no medium of exchange and hence no role for money. Employing the neoclassical framework to analyze monetary issues require a role for money to be specified so that agents will wish to hold positive amounts of money in equilibrium. This leads to the fundamental question of how we should model the demand for money.

Sidrauski (1967) introduced money by treating it symmetrically with other goods in assuming that holdings of real cash balances generate a flow of services per unit of time and incorporated real money balances into the utility function. This came to be known as the *money-in-the-utility function* model. In this model the growth rate of money and hence the inflation rate have no effect on steady state values of real variables and the model displays what is called *superneutrality*. Since inflation reduces real money balances, an increase in the rate of monetary expansion generates a welfare loss. In terms of the dynamics of the model, the real variables of the economy are not affected by money growth shocks for the case of log-separable utility function. Modeling money in this fashion, however, implies that there is no clear purpose of money in this model other than giving utility from its possession. For instance, no trade ever takes place and money is never used in model economies with only one good and identical agents.

Clower (1967) identified that the role of money is indistinguishable from that of any other commodity when money is treated symmetrically and argued that a precise distinction between money and non-money commodities is required for a theory of monetary phenomena. He puts forth the role of money as a medium of exchange by requiring explicitly that money be used for certain types of transactions. This idea was later developed formally by Lucas Jr (1980) where each household consists of two members - a shopper and a worker. The shopper spends each day shopping at different stores while the worker works at the same store. A *cash-in-advance* constraint requires households to bring in money from the previous period which they use in the current period to make purchases.

Clower (1967, pp.5) also stated that ‘‘Money buys goods and goods buy money; but goods do not buy goods”. Motivated by this real world phenomenon we intend to model money in this study as a medium of exchange requiring explicitly that money be used for the purchase of consumption goods. The requirement that money be used to purchase goods is simply imposed. Nothing in the model explains why money is used but rather it is a social convention. If, for some reason, everyone else uses money for transactions, then it is in one’s own interest to use money as well.

Early attempts to juxtapose the long-run neutrality of money and the short-run effects of money were made by Friedman (1968) and Lucas Jr (1972). Friedman (1968) distinguished between actual and perceived real wages and argued that actual real wages are important for firms hiring decisions whereas perceived real wages are important for workers labor-supply decisions. Lucas Jr (1972) constructed Friedman’s idea by creating information problems for rational economic agents. He showed that monetary shocks could result in real fluctuations if they created confusion among economic agents as to whether changes in observed prices reflect changes in relative prices or changes in the aggregate price level.

A second way of exploring the effects of monetary shocks on real activity is to introduce nominal rigidities. For instance, Cho & Cooley (1995) examined the quantitative implications of multi-period wage contracts for business cycle fluctuations. First, they showed that monetary shocks, propagated by nominal contracts, are not the major source of business cycle fluctuations. Second, they further showed that monetary shocks combined with technology shocks do not account for business cycle fluctuations as monetary shocks seem too strong in their results.

In stark contrast, Christiano et al. (2005) showed that a model embodying moderate amounts of nominal rigidity accounts well for their estimate of the dynamic response of the U.S. economy to a monetary policy shock. The impulse responses of key macroeconomic variables were estimated using structural vector autoregression (VAR). A key finding is that stickiness in nominal wages is crucial for the model's performance.

It is worthy of notice that the effect of a positive money growth shock results in two opposing effects. One is known as the *liquidity effect* in which the extra money pushes down interest rates and stimulates economic activity. The other is known as the *anticipated inflation effect* in which people expect more increases in money growth and higher inflation in the future. According to Fisherian fundamentals[2], this results in higher nominal interest rates and thus depresses economic activity. A conventional view held by most economists and monetary policymakers is that central banks can reduce short-term nominal interest rates by employing policies that lead to faster growth in the money supply and by doing so can lead to a persistent increase in the level of employment and output.[3]

It is well perceived that the question of why money matters and how monetary shocks generate real effects are critical for any normative analysis of monetary policy since designing good policy requires understanding of how monetary policy affects the real economy. Therefore, it is believed that there is strong motivation to focus research on construction of monetary business cycle models in order to gain deeper understanding about the monetary transmission mechanism. In this regard this study is an addition to research focused on the role of monetary shocks.

3 Data

In order to analyze the performance of our artificial economies, quarterly data is required to represent the equivalent of the variables in the model. The variables are output, consumption, investment, labor, price level, inflation, money supply and nominal interest rate. The data series of this study is from 1960(1) to 2012(2).[4] The data source, except for total hours worked, is FRED data provided by the Federal Reserve Bank of St. Louis. Total hours worked is obtained from Francis-Ramey Hours Data.

3.1 Features of U.S. business cycles

In this section the business cycle facts of the U.S. economy are represented by calculating several statistics and displaying the cyclical components from the HP filtered time series data. I report the amplitude of the fluctuations in aggregate variables in order to assess their relative magnitudes, measure the correlation of aggregate variables with real output to capture the extent to which variables display co-movement, and finally measure the cross-correlation over time to indicate whether there is any evidence that variables lead or lag one another. Table 1 shows the summary statistics.

Table 1: U.S. data

Variable	**Std. Dev.**	**Rel SD.**	**x(-1)**	**x**	**x(+1)**
Output	1.65	1	0.83	1	0.83
Consumption	0.97	0.59	0.75	0.81	0.71
Investment	8.8	5.33	0.67	0.89	0.7
Total hours worked	1.9	1.15	0.43	0.66	0.83
CPI	1.24	0.75	-0.54	-0.41	-0.28
Inflation: $\Delta LN(CPI)$	0.48	0.29	0.2	0.32	0.33
M1	2.6	1.58	0.14	0.09	-0.01
M2	1.7	1.03	0.27	0.16	0.05
3-month T-bill rate	1.23	0.75	0.2	0.37	0.43

From observing the relationship between output (GDP) and other data sets, the following characteristics are regarded as the most significant features of the US business cycle for the period 1960(1) – 2012(2): [5]

[2]Fisher (1930).
[3]See Christiano (1991).
[4]Number in parenthesis refers to the quarter.
[5]Entries in column x are the contemporaneous cross-correlation coefficients between the cyclical component of the series and

- Consumption is less volatile than output and is pro-cyclical.
- Investment is more than five times as volatile as output and is pro-cyclical.
- Total hours worked is slightly more volatile than output and is pro-cyclical.
- Pro-cyclical and leading money: There is a slight contemporaneous positive correlation between the nominal money stock (measured as either M1 or M2) and real output. More importantly, there is also a pronounced phase shift in the correlation between output and money stock. The cross-correlation of output with the monetary aggregates show that output is more highly correlated with lagged values of the aggregates, implying that money peaks before output.
- Counter-cyclical prices: Price level, measured as Consumer Price Index (CPI), shows that prices are counter-cyclical.
- Inflation is positively correlated with output. It also tends to lag the GDP cycle by three quarters.
- There is a positive correlation between output and nominal interest rates (3-month T-bill rate).

These are the primary facts that characterize the business cycle of the US economy. Now I proceed to describe the model used in this study.

4 A DSGE Model with Bank Intermediation

Modern economies are characterized by the presence of financial intermediaries that receive funds from people and firms and use these funds to buy bonds or stocks or to make loans to other people or firms. Financial intermediaries, mainly banks, play an important role in the monetary transmission mechanism and an analysis of the impact of monetary shocks cannot ignore them. This section describes the model where I follow McCandless (2008) and add a financial intermediary in a cash-in-advance framework. This financial intermediary is modeled as a perfectly competitive banking sector which takes deposits of money from households and lends it to firms. Firms need to cover the wage bill before the goods are sold and hence they borrow to pay for labor services. Monetary policy in this model works through the banking sector where the central bank can make lump-sum monetary transfers to or withdrawals from the financial system. What most central banks do, including the Fed, is to set short-term interest rates (for example, federal funds rate in the U.S.) through open market operations. While central banks do not make direct injections of money into the financial system, however, injecting money into the economy in this way is a delicate way of modeling monetary policy. This is because using interest rate rules effectively means that a central bank is changing the amount of money going into the financial system. I intend to show that how money enters an economy matters significantly for its impact on real as well as nominal variables.

4.1 The Structure

The economy in this model has four types of agents: households, firms, financial intermediaries and a monetary authority.

4.1.1 Households

The household maximizes a utility function of the form

$$E_0 \sum_{t=0}^{\infty} \beta^t (ln\ c_t^i + Bh_t^i),$$

subject to a cash-in-advance constraint,

$$P_t c_t^i \leq m_{t-1}^i - N_t^i + \eta w_t h_t^i,$$

the cyclical component of output. Entries in columns x(-1) and x(+1) are the non-contemporaneous cross-correlation coefficients at one lag and one lead respectively.

and a flow budget constraint,

$$c_t^i + k_{t+1}^i + \frac{m_t^i}{P_t} \leq w_t h_t^i + r_t k_t^i + (1-\delta)k_t^i + \frac{m_{t-1}^i}{P_t} - \frac{N_t^i}{P_t} + \frac{r_t^n N_t^i}{P_t},$$

where N_t^i is family i's period t nominal lending to the financial intermediary, r_t^n is the gross interest rate paid by the financial intermediary on deposits, η is the fraction of period t wage income spent or deposited in a financial intermediary by household i. I will consider the case where wages cannot be spent until the next period,i.e.,$\eta = 0$. McCandless (2008) models η by stating that there is a time cost of spending current income in the current period which depends on η. Leisure is then time available minus time spent working and time used to spend wage income quickly. Another important point to note is that the interest rate r_t^n received by households is simultaneously both real and nominal. It is nominal because it is paid in money and at the same time it is real because the deposits are made and paid back during the same period.

4.1.2 Firms

A perfectly competitive representative firm hires labor and rents capital in order to maximize profit in each period and the production function is given by

$$Y_t = \lambda_t K_t^{\theta} H_t^{1-\theta}.$$

Technology evolves exogenously according to

$$ln\lambda_t = (1-\gamma)ln\overline{\lambda} + \gamma ln\lambda_{t-1} + \varepsilon_t^{\lambda},$$

where the error term is independently and identically distributed as $\varepsilon_t^{\lambda} \sim N(0, \sigma_{\varepsilon_\lambda}^2)$, $0 < \gamma < 1$ and the stationary state value of the level of technology is $\overline{\lambda} = 1$.

4.1.3 Financial Intermediaries

I model the financial intermediary as a perfectly competitive banking sector with no operation costs that takes deposits from households and makes risk-less loans to firms. The loans are risk-less because they are made after observing the shocks. Importantly, the monetary authority operates its monetary policy in this model through the financial intermediary as stochastic injections or withdrawals of money from the financial system.

Since the financial intermediary is assumed to be perfectly competitive, all of what it earns on loans is paid out to the depositor and the zero profit condition is

$$r_t^f (N_t + (g_t - 1)M_{t-1}) = r_t^n N_t, \tag{4.1.1}$$

where g_t is the gross growth rate of money in period t and r_t^f is the gross interest rate paid by the firm on the working capital that it borrows from the bank. Again, r_t^f is both real and nominal since the loans are intra-period loans.

The financial market clears in every period which means that all of the funds that households have lent to the financial intermediary plus net financial injections or withdrawals from the monetary authority are lent by the financial intermediary to firms. This market clearing condition is given by

$$(N_t + (g_t - 1)M_{t-1}) = P_t w_t H_t. \tag{4.1.2}$$

4.1.4 Monetary Policy

Monetary authority is assumed to follow a very simple form of monetary policy,

$$M_t = g_t M_{t-1}. \tag{4.1.3}$$

Here g_t is assumed to follow the law of motion,

$$ln\ g_t = (1-\pi) ln\ \overline{g} + \pi ln\ g_{t-1} + \varepsilon_t^g, \quad (4.1.4)$$

where again the error term is independently and identically distributed as $\varepsilon_t^g \sim N(0, \sigma_{\varepsilon_g}^2)$ and $0 < \pi < 1$.

Monetary policy in this model with financial intermediaries might seem strange as it is simply a stochastic process for money growth. Central banks in most industrialized countries today probably follow some form of Taylor rule[6]. In this regard, money growth shocks can be understood as a surprise change in policy.

4.2 Calibration

This section discusses the calibration of the parameter values that are given in Table 2.

Table 2: Parameter Values

Parameter	Value	Description
β	0.98	Household's discount factor
δ	0.025	Depreciation rate of capital
θ	0.336	Capital share in Cobb-Douglas production function
A	1.63	Preference weight on leisure
B	-2.4447	Marginal disutility of labor
γ	0.979	AR(1) coefficient in TFP process
π	0.64	AR(1) coefficient in money growth process
$\sigma_\varepsilon^\lambda$	0.0072	Standard deviation of TFP shock
σ_ε^g	0.0066	Standard deviation of money growth shock

The discount factor (β) and the depreciation rate (δ), following King & Rebelo (1999), are chosen to be 0.98 and 0.025 respectively. Quarterly depreciation rate on capital, δ, is derived in King & Rebelo (1999) from a conventional depreciation rate of 10% per annum. Next, following Gollin (2002), we use a capital share (θ) of 0.336 which implies a labor share $(1-\theta)$ of 0.664.

In order to simulate our models so that we can compare them to the U.S. economy, we need to obtain measures for the technology shocks and money growth shocks that feed into our model. Once the shocks are obtained, we feed them in the recursive equilibrium law of motion. We set all the variables to zero for 1959(4) and feed our first shock in the next quarter, 1960(1). The simulated series are then de-trended by the HP filter to remove any growing trend in the data before it is compared to actual data. Following King & Rebelo (1999), the $AR(1)$ coefficient for technology shock, γ, is chosen to be 0.979 and the standard deviation, $\sigma_\varepsilon^\lambda$, is set to 0.0072.

Next we use data on $M2$ to estimate the $AR(1)$ process for money growth rate and the regression (standard error in parenthesis) over the sample period $1960(1) - 2012(4)$ produces the following equation:

$$\Delta ln(M2)_t = \underset{(0.001004)}{0.006054} + \underset{(0.053371)}{0.638}\ \Delta ln(M2)_{t-1}, \quad \hat{\sigma}_\varepsilon^g = 0.0066.$$

The results of this regression lead us to set π equal to 0.64 and σ_ε^g equal to 0.0066. The implied average growth rate of money, $\overline{g}$, is 1.01697. To ensure that the gross growth rate of money always exceeds the discount factor, as required for the cash-in-advance constraint to bind, we draw money growth shocks from a log normal distribution which implies that $ln(g_t)$ will never become negative.

Following Hansen (1985), the utility function has indivisible labor which implies that the elasticity of substitution between leisure in different periods for the representative agent is infinite. This follows from the assumption that all variation in the labor input reflects adjustment along the extensive margin. B represents the marginal disutility received from working an extra unit of time according to 'Hansen-Rogerson' preferences. Calculation of B is now discussed below.

[6]See Taylor (1993) for an exposition.

With divisible labor model, utility is concave with respect to both consumption and leisure and is given by

$$u(c_t, l_t) = ln(c_t) + Aln(1 - h_t),$$

where A is the preference weight on leisure.

Hansen (1985) shows that with indivisible labor and the employment lottery assumption, the expected utility in period t is equal to

$$u(c_t, \alpha_t) = ln(c_t) + h_t \frac{Aln(1-h_0)}{h_0} + A(1 - \frac{h_t}{h_0})ln(1),$$

where $\frac{h_t}{h_0} = \alpha_t$ is the probability that a particular household will be chosen to provide labor and h_0 is the amount of fixed labor to be provided by a household if chosen to work. This simplifies to

$$u(c_t, h_t) = ln(c_t) + Bh_t,$$

where $B = \frac{Aln(1-h_0)}{h_0}$.

The parameter A is chosen so that households spend one-third of their time working. Hansen (1985) chose a value of $A = 2$ whereas for our choice of parameters, a value of $A = 1.63$ results in about one-third of the available time spent working. The parameter B is then chosen by setting the expression of hours worked in steady state for the divisible and indivisible labor models equal to each other. This gives B equal to -2.4447. [7]

4.3 Impulse Responses for Working Capital Model

The recursive equilibrium laws of motion for examining the models implications to a technology shock and money growth shock are given by

$$x_t = Px_{t-1} + Qz_t,$$
$$y_t = Rx_{t-1} + Sz_t$$

and

$$z_t = Nz_{t-1} + \varepsilon_t$$

where x_t is the vector of state variables, y_t is the vector of control variables and z_t is the vector of exogenous stochastic variables. We define the state variables as $x_t = [\widetilde{K_{t+1}}, \tilde{M}_t, \tilde{P}_t]$, the control variables as $y_t = [\tilde{r}_t, \tilde{w}_t, \tilde{Y}_t, \tilde{C}_t, \tilde{H}_t, \tilde{N}_t, \tilde{r}_t^n, \tilde{r}_t^f]$ and the stochastic variables as $z_t = [\tilde{\lambda}_t, \tilde{g}_t]$.[8] The policy matrices P, Q, R and S are solved using Uhlig's method of log linearization and method of undetermined coefficients. The responses shown by the impulses are to a single positive shock of 1 standard deviation that occurs in period 2.

4.3.1 Response to a technology shock

Figures 1 shows the responses of the model economy to a technology shock for the case when $\eta = 0$. Note that the responses of the real variables to a technology shock are very similar to the basic indivisible labor RBC model. With a positive technology shock, the individual's lifetime income is higher and so his/her lifetime consumption will be higher as well. The individual wants to consume more in every period and this gain in lifetime consumption will be spread out over time due to the assumed concavity of the utility function with respect to consumption which implies that the individual wants to 'smooth' his/her consumption rather than having them wildly fluctuate. This leads to the inter-temporal substitution of

[7] Hours worked in steady state for the economy with divisible labor is given by $\overline{H} = \frac{1}{1+\frac{A}{1-\theta}[1-\frac{\beta\delta\theta}{1-\beta(1-\delta)}]}$ and for the economy with indivisible labor by $\overline{H} = -\frac{1-\theta}{\frac{Aln(1-h_0)}{h_0}[1-\frac{\beta\delta\theta}{1-\beta(1-\delta)}]}$.

[8] A tilde over a variable denotes log deviation from the steady state.

labor. By increasing current output through working harder and smoothing consumption, the individual builds up capital stock so that in the future less labor needs to be used in production and more leisure can be enjoyed. Saving is supported by a rise in the marginal product of capital and the associated rise in real rental on capital. It is worthy of note that the price level goes down after a positive technology shock. This is because a fixed money stock is chasing an increasing amount of goods. This implies that how money enters into the model does not matter for the impact of technology shock on real variables. Furthermore, technology shock has trivial impact on interest rate received by households on bank deposits.

4.3.2 Response to a money growth shock when $\eta = 0$

Figure 2 shows the response of the working capital model to a money growth shock for the case where current period wage income cannot be used for current consumption purchases. Unlike in a simple cash-in-advance model, new issues of money are injected directly into financial intermediaries as additional loanable funds. Hence, a money growth shock generates a wedge between the interest rate received by households and that paid by firms. The intuition for understanding this is straightforward. In order to induce firms to absorb more cash for employment purposes, financial intermediaries must lower the interest rate charged on loans to firms. Lower real borrowing costs for firms increase their demand for labor. Consequently, real wages increase and additional labor is supplied by households which then stimulates economic activity.

Looking at the household sector of the economy, we know that at the beginning of each period households are holding money that they are carrying over from the previous period and they lend some of this money to financial intermediaries. With a positive money growth shock and expansion of lending activity, banks earn a higher revenue. Since banks are assumed to be perfectly competitive, the extra revenue is distributed to households as higher interest rates on their deposits. Consequently, households' opportunity cost of holding cash balances for consumption increases. As such, households hold less money for consumption purposes and put more money into banks. Since current period wage income are not allowed to be used to purchase consumption goods, consumption falls unequivocally as there is no intra-temporal leisure consumption trade-off. Also, with additional labor, the marginal product of capital increases and the capital stock grows until the marginal product of capital again equals $\bar{r}$, its steady state value.

4.4 Assessing the Working Capital Model when $\eta = 0$

In order to evaluate the performance of the working capital model presented in this section, the statistics generated by the model are compared against those observed in the U.S. economy presented in section 3. Table 3 below displays some key summary statistics.

Table 3: Summary Statistics ($\eta = 0$): Actual data vs. Technology shock vs. Both shocks

	Actual data		Technology shock		Both shocks	
Variable	**Std. Dev.**	**Corr. Coef.**	**Std. Dev.**	**Corr. Coef.**	**Std. Dev.**	**Corr. Coef.**
Output	1.65(1)	1	1.6(1)	1	1.88(1)	1
Consumption	0.97(0.59)	0.81	0.55(0.34)	0.862	0.9(0.48)	0.112
Investment	8.8(5.33)	0.89	6.69(4.18)	0.982	10.49(5.58)	0.924
Labor	1.9(1.15)	0.66	1.03(0.64)	0.969	1.78(0.95)	0.889
Price level	1.24(0.75)	-0.41	0.96(0.60)	-0.986	1.79(0.95)	-0.452
Inflation	0.48(0.29)	0.32	0.7(0.44)	-0.447	0.91(0.48)	-0.036
Nominal interest rate	1.23(0.75)	0.37	0.06(0.04)	0.987	0.87(0.46)	0.547
Money	1.7(1.03)	0.16			1.69(0.9)	0.127

It is immediately obvious from looking at Table 3 that injecting money into the model through financial intermediaries enable money growth shocks to have significant real effects. Output, consumption, investment and labor are all more volatile in the second economy where both technology and money growth shocks are operating. This is a major qualification that I would like to point out in this study. How money enters a model matters significantly for its impact on real variables.

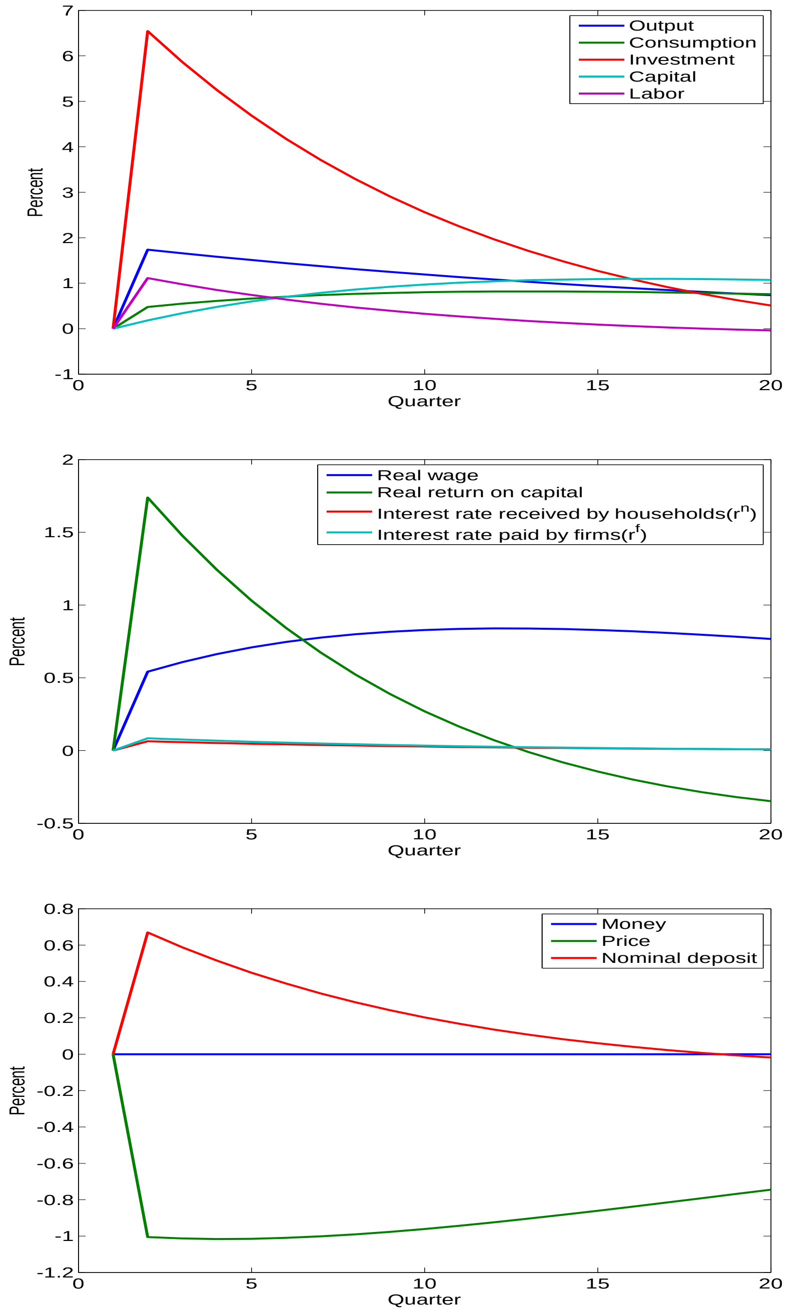

Figure 1: Response of the working capital model to a technology shock ($\eta = 0$)

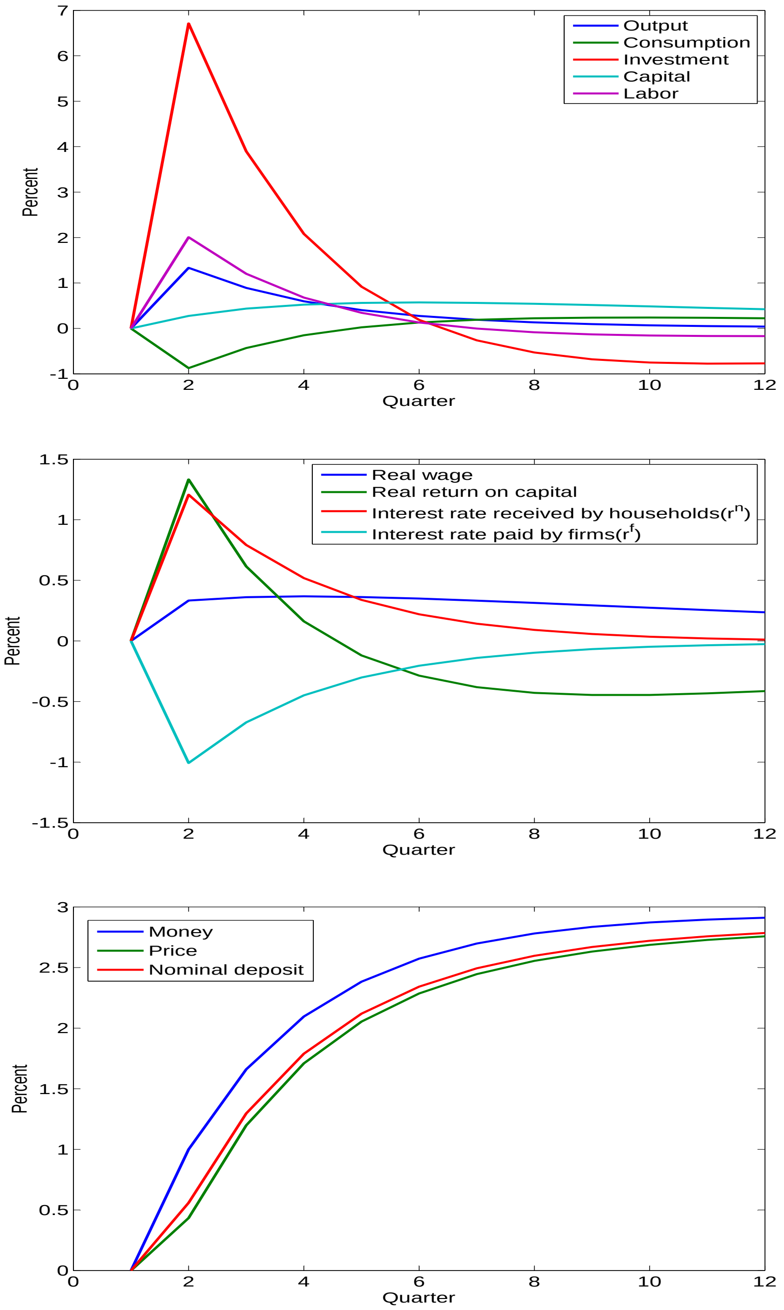

Figure 2: Response of the working capital model to a money growth shock ($\eta = 0$)

The results from comparing the standard deviations of the variables in the model economy with those observed in the U.S. economy shows that with both technology and money growth shocks, the model does a reasonably good job in replicating the variability of output, consumption, investment and labor. The standard deviation of output is 14% larger compared to actual data; that of consumption and labor is 7.2% and 6.3% smaller respectively whereas that of investment is 19% larger than its empirical counterpart. In terms of nominal variables, prices and inflation show higher volatility whereas nominal interest rate shows lower volatility than that of actual data. In fact, inflation shows 90% more volatility which is somewhat disconcerting.

When comparing the contemporaneous correlation of the variables with output, the addition of money growth shock hurts in one dimension but helps in others. Inflation, although not pro-cyclical as in the data, is less negatively correlated and almost acyclical which is a move in the desired direction. Moreover, prices are very highly negatively correlated with only technology shock. With both shocks operating, Table 6 shows that prices are less negatively correlated and almost aligned to what is observed in the data. On the contrary, the contemporaneous correlation of consumption with output deteriorates as it is now less positively correlated than in the data but this might be anticipated given a fall in consumption after a positive money growth shock.

The nominal asset through which agents can transfer wealth inter-temporally in this model is the nominal bank deposit. Since in-period uncertainty is revealed before the loans take place, firms are always assumed to pay back the loans and hence banks never default on its borrowing from households. Nominal deposits are risk-less and hence we compare the nominal interest rate received by households with the 3-month T-bill rate for the U.S. economy. With only technology shocks, nominal interest rates on bank deposits show very little volatility and a very high contemporaneous correlation with output. With both shocks operating volatility increases, although it is still lower than in the data. Moreover, nominal interest rates are now less positively correlated with output and hence more aligned to the data.

Another important characteristic to note is the behavior of the money stock itself in this model. Table 3 shows us that money is slightly positively correlated with current output and this is keeping with what is observed in the data. More importantly, as discussed in Section 3.1, money supply is a leading variable as observed from the phase shift in correlation with output in Table 1. Our model economy with financial intermediaries where monetary shocks enter the economy via this financial sector is well able to replicate this phenomenon.

5 Discussion

In this paper I have illustrated how the basic neoclassical model can be modified to incorporate money in an attempt to replicate the cyclical fluctuations of the U.S. economy. A neoclassical model with stochastic perturbations to technology and money growth rate has been built upon in this regard. Following McCandless (2008), I have studied a model with financial intermediaries where money is injected through the financial system. In this case, a positive money growth shock results in lower lending rates thus persuading firms to borrow more and to expand their scale of operation. Accordingly, hours worked and output both increases with a positive money growth shock illustrating the *liquidity effect* at work.

Next I have assessed the quantitative importance of monetary shocks for business cycle fluctuations in this environment. In doing so, I have added money growth shocks to technology shocks and unconditional moments are then generated to provide a basis for comparison with the empirical counterparts. Traditional monetary policy is thought to follow some sort of interest rate rule which operates through the financial system and involves short term interest rates (e.g. the *federal funds rate* on overnight interbank loans). Motivated by this real world feature, I have added a perfectly competitive banking sector which acts as an intermediary between borrowers (firms) and lenders (households). The results from simulating this model environment shows that monetary shocks have significant real effects at business cycle frequencies. All the real variables are more volatile when monetary shocks are added.

The financial market is frictionless according to the way I have modeled it. Households' decisions about how much to lend to the financial intermediary are made after observing both technology and money growth shocks. After a positive money growth shock we have observed that interest rates received by households increase. Consequently, this induces households to deposit more into banks. As a result banks have an even larger pot of money to lend out to the firms (both the new injections from the monetary authority and higher deposits from households). The assumption that households can continuously revise their consumption and savings decisions is probably too strong when compared to the real world scenario. Presumably, there are costs associated with continual updating. For instance, there are penalties that the intermediaries charge on early withdrawals and interest rates earned in the first period in which new deposits have been made are generally lower. Accordingly, we could modify the working capital model in one of two ways that might help in reducing the impact of monetary shocks and make it more realistic. Either we could assume that households have less-than-perfect flexibility in responding to a monetary shock and assume that portfolio decisions must be made before observing the current period shock. This class of models, called *limited participation* models, have been studied by Christiano (1991), Christiano & Eichenbaum (1992) and Fuerst (1992) among others. In *limited participation* models, with household deposit decisions fixed in the previous period, bank lending of working capital to firms would not expand by as much as in my version after a positive monetary shock. Consequently, lending rates would decline to a lesser extent and hours worked and output would not increase by as much as we have observed. Otherwise, following Cooley & Quadrini (1999), we could assume that households have perfect flexibility but there is an adjustment cost associated with changing portfolio decisions which would similarly help to minimize the impact of monetary shocks.

6 Conclusion

This study has delineated how the basic real business cycle model can be tailored to analyze the role of monetary shocks in business cycles. By developing linear approximations to the models studied, we have been able to show the response of the economy to unanticipated changes in the growth rate of money supply. For the standard values of the model's parameters, the statistics generated by the working capital model shows that it is capable of depicting some of the business cycle features of the U.S. economy. This indicates that money growth shocks may be important in determining the cyclical fluctuations at business cycle frequencies. However, as discussed in the previous section, the relatively stronger impact of monetary shocks in my model environment implies that inclusion of the basic mechanism alone does not provide the perfect representation.

The framework of the working capital model can be adopted to study a range of different monetary policy issues. The analysis of this paper has dealt with only a closed economy. Once the interdependencies of an economy that engages in substantial international trade with the rest of the world are recognized, monetary policy can have additional effects. For instance, domestic output and prices will depend on exchange rates which, in turn, may depend on monetary policy.

Finally, I conclude by reemphasizing that the question of how monetary shocks generate real effects are critical for any normative analysis of monetary policy and as such monetary versions of real business cycle models have huge potential. Most central banks today follow some kind of Taylor rule by which they set the short-term interest rate following a feedback from output gap and inflation. Having constructed a model where monetary shocks can have positive effects on real variables, this study provides future opportunities for further research about what would be the best policy option for a central bank to follow. Furthermore, in future research I also wish to incorporate financial friction into the model in an effort to understand the role played by credit market imperfections such as asymmetric information.

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