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Does Money Matter?

by

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ABSTRACT

This thesis attempts to analyze the effects monetary policy has had on the level of output in the United States, in order to determine if money matters in the determination of output. The Real Business Cycle model is presented as an alternative to the standard Keynesian model, because unlike the Keynesian model, the Real Business Cycle model argues that money is neutral. The combined effect of anticipated and unanticipated effects is studied using 3 different causality tests. A simple bivariate Granger causality test, Holmes and Hutton (1990a) Rank causality test, and the Stock and Watson (1989) causality test. However, some authors argue that only unanticipated money matters. The testing of unanticipated effects follows Cover (1992) who separates the unanticipated shocks into positive and negative shocks. As well, following Belongia (1995), the robustness of the results is tested by using 12 different monetary aggregates.

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To my Parents and Brother

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CHAPTER I: INTRODUCTION

Does money matter? It appears to be a harmless enough question to ask, but what exactly does it mean? In this case, what is meant by asking the question does money matter, is can the central bank, such as the Federal Reserve System in the United States, manipulate the fluctuations in the level of output by altering the money supply?

Not that long ago, this question would not have been that interesting, because the Keynesian IS-LM framework stated that changes in the money supply caused changes in the level of output, and this framework was well supported by empirical evidence. Thus, the central bank was able to manipulate the fluctuations in the level of output by altering the money supply, and this implied that money did matter.

However, in the 1970's. there were a number of adverse aggregate supply shocks, such as the OPEC oil price increases. As a result, the empirical results that favored Keynesian IS-LM models had changed, and it now appeared that the fluctuations in output were being driven by aggregate supply shocks, such as the OPEC oil price shock, rather than by aggregate demand shocks, such as changes in the money supply.

In an attempt to explain these findings, a new class of models was introduced called Real Business Cycle models. These models argued that the fluctuations in output were caused by random technology shocks, which then caused changes in the aggregate supply.

A review of Real Business Cycle models is presented in chapter II. Chapter II discusses why Real Business Cycle models were developed and presents a basic Real

Business Cycle model. Chapter II also discusses how more complex models are calibrated and solved, and also presents three main extensions to the basic Real Business Cycle model. Finally, chapter II discusses some of the major criticisms that have been leveled against the Real Business Cycle framework.

The next chapter empirically tests the implications stated by Real Business Cycle models. Since we are interested in the role money plays in determining the future levels of output, we want to test the Real Business Cycle model's hypothesis concerning money. With respect to money, Real Business Cycle models argue that money is neutral, or that there may exist reverse causality between money and output. If money is neutral, then changes in the level of output are independent of changes in the money supply. If there is reverse causality, then changes in the money supply are caused by changes in the level of output. However, both of these results are in contrast to the Keynesian and Monetarist's point of view, that changes in the money supply cause changes in the level of output.

Chapter III studies the causal relationship between money and output, in an attempt to discriminate between the competing modeling frameworks. The analysis in chapter III expands on the work of Serletis (1988), and Belongia (1995). Both authors argue that empirical testing of monetary effects must be done using different monetary aggregates, since some aggregates are theoretically superior to others. Therefore, the causality tests performed in this analysis studies 12 different monetary aggregates. 5 simple sum, 5 Divisia, and 2 FFDM aggregates. As well, unlike Belongia (1995), a number of different simple sum and Divisia monetary aggregates are used, and unlike Serletis (1988), the sample period is expanded to include the late 1980s and early 1990s.

As a result, chapter III provides an explanation concerning the differences between simple sum and Divisia monetary aggregates.

However, there have been a number of criticisms leveled against causality tests. These criticisms include arguments against the use of ad hoc lag length determination, the dependence of the causality results on the functional form used, the assumption of normally distributed error terms, and the fact that different causality results cannot be directly compared because different causality tests tend to study different sample periods.

As a result, unlike previous studies concerning the causal relationship between money and output, this analysis uses 3 different causality tests on the same United States monthly data from 1960:1 to 1993:4. The 3 causality tests are a bivariate Granger causality model, the Stock and Watson (1989) causality formulation, and the Holmes and Hutton (1990a) causality framework, which has never been applied to money-output causality tests. The benefits of the Holmes and Hutton (1990a) causality framework are, that it is a causality test that does not depend on a specific functional form or on the assumption of normally distributed error terms, unlike previous causality test formulations. Chapter III discusses each of these causality tests and presents their results.

The criticism concerning the ad hoc lag structures is resolved by using Schwarz's (1978) criterion to determine the optimal lag structure for each causality test. Also, in order to determine the correct prefiltering procedure, chapter III analyzes the trend properties of the data for both unit roots and cointegration.

Chapter III determined the relationship between the level of output and the combined anticipated and unanticipated money supply. However, it has been argued by some authors such as Lucas (1972, 1973), Sargent and Wallace (1975), Barro (1977, 1978), Barro and Rush (1980), and Mishkin (1982), that only the unanticipated changes in the money supply have any effect on the level of output.

As a result, chapter IV follows Cover (1992), and separates the money supply shocks into anticipated and unanticipated money supply shocks, and then separates the unanticipated money supply shocks into positive and negative unanticipated money supply shocks. In doing this, Cover (1992), uses three different money supply processes to separate money supply shocks into anticipated and unanticipated shocks. The analysis performed in chapter IV, uses those three money supply processes, as well as a money supply process that is determined optimally using the Schwarz criterion.

Then like Cover (1992), the unanticipated money supply shocks are tested for a causal relationship with the level of output. This causal relationship is tested in such a way, that the positive and negative shocks can be analyzed for asymmetric effects. That is, does a positive unanticipated money supply shock have a greater affect on output than a negative unanticipated money supply shock, or is it the other way around. In order to test the robustness of these results, I follow Cover (1992), and use three different output supply processes.

Once again, expanding on the work of Belongia (1995), the asymmetric tests are performed using 12 different monetary aggregates.

Finally, chapter V concludes by analyzing the results of the previous chapters, and states possible policy implications. As well, chapter V suggests possible extensions in this area of research.

CHAPTER II: REAL BUSINESS CYCLE THEORY: A LITERATURE REVIEW

II.1. INTRODUCTION

There was a point in the 1960s when modern macroeconomics became relatively uninteresting. The Keynesian IS-LM framework appeared to give all of the correct answers, and macroeconomists felt that they had finally unlocked the mystery of how the aggregate macroeconomy functioned. However, in the 1970s there were a number of adverse aggregate supply shocks, such as the OPEC oil price increases, and as a result, the trade off between inflation and unemployment was no longer as easily observed.

The trade off between inflation and output is explained by the basic Phillips Curve. A.W. Phillips in 1958, argued that labor services should behave in the same way as any other commodity. Therefore, the nominal wage rate, or the price of labor services, will increase when there is excess demand, and will decrease when there is excess supply. This implies that there exists an inverse relationship between the nominal wage rate and the unemployment rate. When the unemployment rate is low (high demand for labor services), the nominal wage rate is high, and when the unemployment rate is high (low demand for labor services), the nominal wage rate is low.

The decline in the empirical power of the Keynesian model reawakened the macroeconomic community to some of the weaknesses of the Keynesian models. The weakness that many economists focused on was the lack of strong theoretical foundations. These economists felt that macroeconomic models should use microeconomic theory in order to strengthen the models theoretical foundations. In other words, they felt that macroeconomic models should incorporate household utility maximization problems within the model's framework. In an economy with optimizing agents, Milton Friedman and Edmund Phelps argued that the long run Phillips Curve will be vertical rather than downward sloping. This implies that any level of inflation is compatible with any level of real demand (or supply) of goods.

Friedman and Phelps stated that what firms and individuals are interested in, is the real wage rate, rather than the nominal wage rate. Thus, it is the real wage rate that increases when there is excess demand for labor, and decreases when there is excess supply. McCallum (1989a) explains this relationship in the following way:

$$(2.1.1) \qquad \Delta \log\left(\frac{W_t}{P_t}\right) = f(UN_{t-1})$$

which implies

$$(2.1.2) \qquad \Delta w_t - \Delta p_t = f(UN_{t-1})$$

where W is the nominal wage rate, P is the price level, UN is the unemployment rate, and the lower case means the variable is in logarithm form. This relationship shows that the wage rate is determined on information from the past (the previous period, t-1), and thus, firms and individuals do not know what the current values are when making their decisions. The firms and individuals can only form expectations of the current values in the previous period. Let Δp_t^e be the expectation Δp_t in period t-1 which will be realized in period t. Substituting and rearranging equation (2.1.2) yields:

$$(2.1.3) \qquad \Delta w_t = f(UN_{t-1}) + \Delta p_t^e.$$

In the steady state, the values of the variables will remain constant through time, as long as they are achieved once, which implies that once the steady-state equilibrium has been obtained, the growth rate of the variables will be constant. Therefore, the variable can be changing over time, but the rate of change will be constant.

Combining the steady-state result with the classical notion that there exists a one to one relationship between the money supply growth rate and the inflation rate, we expect that the level of inflation will be the same as the money supply growth rate, and the growth rates to be constant through time. As individuals realize that the price of goods has increased, the nominal wage rate will have to be higher at every level of work effort in order to compensate for the increase in prices. Therefore, there exists a one to one relationship between the money supply growth rate, the inflation rate and the growth in the nominal wage rate. However, including technological progress, the growth rate of the nominal wage rate will exceed the inflation rate by the amount of technological progress. As McCallum (1989a) shows, the relationship between the nominal wage rate and the inflation rate now becomes:

(2.1.4) $$\Delta w_t = \Delta p_t + \lambda$$

where λ measures the rate of technological progress. Substituting equation (2.1.4) into equation (2.1.3) yields:

(2.1.5) $$\Delta p_t + \lambda = f(UN_{t-1}) + \Delta p_t^e.$$

Finally, remembering that in the steady-state, the rate of change in the variable is constant through time, the actual inflation rate will be equal to the expected value of inflation. This implies that equation (2.1.5) now becomes:

(2.1.6) $$\lambda = f(UN).$$

Equation (2.1.6) shows that there is no relationship between the inflation rate, and the unemployment rate. Therefore, the long run Phillips Curve is vertical.

As well as the lack of empirical evidence, and strong theoretical foundations, the Keynesian model is a static model which focuses on determining output at a specific point in time. However, business cycles tend to be discussed in terms of how the cycle changes through time. In an attempt to incorporate dynamics, Keynesian models began including accelerator mechanisms for investment and inventories, as well as equations that allow for price and wage adjustments through time. The problem was that these equations lacked any kind of theoretical foundation, and thus, any specification of these equations would work. In the end, the dynamic adjustment equation that was used, was the one that fit the data best.

These problems implied that there was a need for a modeling framework which has strong theoretic foundations, is able to incorporate theoretically correct dynamics, and is empirically robust. Real Business Cycle (RBC) models take the first steps in developing such a framework. By expanding on earlier work on growth theory, RBC models develop small scale dynamic general equilibrium models in order to study how aggregate macroeconomic variables change in response to changes in the economic environment.

In section 2, a basic RBC model is discussed. Section 3 discusses the calibration and solution procedure used to solve more complex RBC models. Section 4 discusses the Hodrick and Prescott filter. Section 5 analyzes three extensions of RBC models, and though these three extensions study specific problems, they also represent examples of broader extensions. Specifically, the indivisible labor model of Hansen (1985) looks at the role of non-convexities in individual preferences, Cooley and Hansen (1989) try to determine if there is a specific role for money within the RBC framework, and McGratten (1994b) looks at how the inclusion of demand side shocks alters the characteristics of RBC models. Section 6 describes some of the criticisms of RBC models, and section 7 concludes.

II.2 A BASIC REAL BUSINESS CYCLE MODEL

Plosser (1989, p.35) states:

> "...when we think of business cycles, we frequently think about notions of persistence or serial correlation in economic aggregates; comovement among economic activities; leading or lagging variables relative to output; and different amplitudes or volatilities of various series. The objective of any model of the business cycle is to generate a coherent understanding of how and why these characteristics arise."

Snowdon, Vane, Wynarczyk (1994) provide the following characteristics that most RBC models have in common. RBC models show that business cycles can be generated by the decisions of optimizing agents to real disturbances in a frictionless, perfectly competitive economy. RBC models all have the following characteristics. The first is that individuals maximize their utility subject to resource constraints. Second, there exists perfect price flexibility which implies continuous market clearing, and that an equilibrium will always be obtained. A third characteristic of RBC models is that expectations are formed rationally, so all individuals and firms face identical and complete information. Finally, unlike previous business cycle theories, the cycle is not being driven by monetary or demand side shocks, but rather by supply side shocks in the form of random technology shocks.

These technology shocks are random fluctuations in the rate of technological progress. These supply side shocks alter the production function causing rational individuals to make a new choice concerning their level of consumption and labor supply. The changes in these choices generate fluctuations in aggregate macroeconomic variables. Therefore, business cycles are driven by real rather than monetary forces.

The technological shocks can take a number of different forms. Some examples of technological shocks are natural disasters that reduce agricultural output, the OPEC oil price increases of 1973 and 1979, government regulation and import quotas, and changes in the quality of the capital and labor inputs.

In order to determine the equilibrium process, we use the result that in the absence of externalites, competitive equilibria are Pareto optima. This means that in equilibrium, no individual can be made better off without making any other individual worse off. The Pareto optimum is the one which maximizes the welfare of the representative agent subject to technology constraints and the information structure. A simple RBC model from McCallum (1989b), gives a general idea about what RBC models are trying to accomplish.

First of all, McCallum (1989b) considers an economy composed of similar, infinitely lived households which solve the following maximization problem:

$$\text{(2.2.1)} \qquad \text{MAX}\{E_t[\sum_{j=0}^{\infty}\beta^j U(c_{t+j}, 1-n_{t+j})]\}$$

subject to the budget constraint

$$\text{(2.2.2)} \qquad c_t + k_{t+1} \leq z_t f(n_t^d, k_t^d) + (1-\delta)k_t - w_t(n_t^d - n_t) - q_t(k_t^d - k_t)$$

where E is the expectations operator, β is the discount factor, c is the level of consumption, n is the amount of labor supplied by the individual, n^d is the amount of labor demanded by firms, k is the amount of capital owned by individuals, k^d is the amount of capital demanded by firms, δ is the depreciation rate, w is the nominal wage rate, q is the nominal rate of return on capital, f is the production function, U is the utility function, and z is the random technology shock. Equation (2.2.1) states that individuals attempt to maximize the expected discounted utility over an infinite time horizon, and the level of utility is increasing in consumption and decreasing in the amount of labor supplied. The resource constraint given by equation (2.2.2) states that the amount consumed this period plus the amount of capital that individuals would like next period, can never exceed the total amount produced by the economy plus what remains of the capital stock after depreciation minus what is paid for labor services and capital rental.

In order for this model to be solved without resorting to the more complicated procedures presented later, McCallum (1989b) states that three simplifying assumptions must hold. These assumptions are that the production function is Cobb-Douglas, preferences are log-linear, and there is complete depreciation of capital within a single period so δ = 1. This implies that:

$$U(c_t, 1-n_t) = \theta \log c_t + (1-\theta)\log(1-n_t), \quad 0 < \theta < 1$$

and

$$z_t f(n_t, k_t) = z_t n_t^{\alpha} k_t^{1-\alpha}.$$

Therefore, the maximization problem becomes:

(2.2.1') $$\text{MAX}\{E_t[\textstyle\sum_{j=0}^{\infty} \beta^j (\theta \log c_{t+j} + (1-\theta)\log(1-n_{t+j}))]\}$$

subject to

(2.2.2') $$c_t + k_{t+1} = z_t n_t^{\alpha} k_t^{1-\alpha} - w_t(n_t^d - n_t) - q_t(k_t^d - k_t).$$

However, for a market equilibrium to exist, the labor and capital markets must clear which implies $\Sigma n_t^d = \Sigma n_t$, and $\Sigma k_t^d = \Sigma k_t$. Since all households are the same and face the same stochastic process z, then $n_t^d = n_t$ and $k_t^d = k_t$.

Therefore, the problem becomes:

(2.2.2'') $$\text{MAX}\{E_t[\textstyle\sum_{j=0}^{\infty} \beta^j (\theta \log c_{t+j} + (1-\theta)\log(1-n_{t+j}))]\}$$

subject to

(2.2.2") $\quad c_t + k_{t+1} = z_t n_t^{\alpha} k_t^{1-\alpha}$.

The household then solves the maximization problem with respect to c_t, n_t, k_{t+1}.

The Lagrange formulation of the problem becomes:

$$L = E_t[\sum_{j=0}^{\infty}\beta^j(\theta \log c_{t+j} + (1-\theta)\log(1-n_{t+j}))] + E_t[\sum_{j=0}^{\infty}\beta^j\lambda_{t+j}(z_t n_{t+j}^{\alpha} k_{t+j}^{1-\alpha} - c_{t+j} - k_{t+1+j})]$$

and the partial derivatives are:

(2.2.3) $$\frac{\partial L}{\partial c_t} = \frac{\theta}{c_t} - \lambda_t = 0$$

(2.2.4) $$\frac{\partial L}{\partial n_t} = -\frac{(1-\theta)}{(1-n_t)} + \alpha z_t n_t^{\alpha-1} k_t^{1-\alpha}\lambda_t = 0$$

(2.2.5) $$\frac{\partial L}{\partial k_{t+1}} = -\lambda_t + E_t[\beta\lambda_{t+1}(1-\alpha) z_{t+1} n_{t+1}^{\alpha} k_{t+1}^{-\alpha} = 0$$

(2.2.6) $$\frac{\partial L}{\partial \lambda_t} = z_t n_t^{\alpha} k_t^{1-\alpha} - c_t - k_{t+1} = 0$$

where λ is the standard Lagrange multiplier, and E is dropped for all variables in time t, and for k_{t+1}, since these values are known with certainty.

McCallum (1989b) then argues that with a log-linear utility function and complete depreciation, the income and substitution effects of a wage rate change will just offset each other, which leaves the labor supply choice unaffected. Therefore, n will be constant over time so $n_t = n$.

The next step is to determine how z_t and k_t enter the production function. McCallum (1989b) does this by conjecturing the solution that c_t and k_{t+1} are proportional to $z_t k_t^{1-\alpha}$. Since the amount of labor supplied is constant, then it seems logical to assume that the amount of consumption and capital required next period will depend on the variable part of production.

This conjectured solution yields the following two expressions:

(a) $$c_t = \pi_{10} z_t k_t^{1-\alpha}$$

(b) $$k_{t+1} = \pi_{20} z_t k_t^{1-\alpha}$$

and the problem now becomes solving for π_{10} and π_{20}.

McCallum (1989b) uses equation (2.2.3) to eliminate λ_t and from equation (2.2.5) yields:

(2.2.5') $$\frac{\theta}{c_t} = E_t\beta[\frac{\theta}{c_{t+1}}(1-\alpha) z_{t+1} n^{\alpha} k_{t+1}^{-\alpha}].$$

Substituting equations (a) and (b) into equation (2.2.5') to eliminate c_t and k_{t+1} gives:

$$\frac{\theta}{\pi_{10} z_t k_t^{1-\alpha}} = E_t\beta(1-\alpha)[\frac{\theta z_{t+1} n^{\alpha} k_{t+1}^{-\alpha}}{\pi_{10} z_{t+1} k_{t+1}^{1-\alpha}}]$$

(2.2.7) $$\frac{\theta}{\pi_{10} z_t k_t^{1-\alpha}} = \frac{(1-\alpha)\beta\theta n^{\alpha}}{\pi_{10}(\pi_{20} z_{t+1} k_{t+1}^{1-\alpha})}.$$

Equation (2.2.7) implies:

$$\pi_{20} = (1-\alpha)\beta n^{\alpha}.$$

In order to solve for π_{10}, substitute equations (a) and (b) into equation (2.2.6) to get:

$$z_t n^{\alpha} k_t^{1-\alpha} = \pi_{10} z_t k_t^{1-\alpha} + \pi_{20} z_t k_t^{1-\alpha}$$

$$n^{\alpha} = \pi_{10} + \pi_{20}$$

$$n^{\alpha} = \pi_{10} + (1-\alpha)\beta n^{\alpha}.$$

Thus, solving for π_{10}, c_t, and k_{t+1} yields:

$$\pi_{10} = [1-(1-\alpha)\beta] n^{\alpha}$$

$$c_t = [1-(1-\alpha)\beta] n^{\alpha} z_t k_t^{1-\alpha}$$

$$k_{t+1} = (1-\alpha)\beta n^{\alpha} z_t k_t^{1-\alpha}.$$

In order to prove that the assumption of constant labor supply is correct, substitute equation (2.2.3) into equation (2.2.4), and then insert the values of consumption and capital.

The amount of labor supplied each period then becomes:

$$\frac{(1-\theta)}{(1-n)} = \frac{\alpha z_t n^{\alpha-1} k_t^{1-\alpha}\theta}{c_t}$$

$$\frac{(1-\theta)}{(1-n)} = \frac{\alpha z_t n^{\alpha-1} k_t^{1-\alpha}\theta}{[1-(1-\alpha)\beta] n^{\alpha} z_t k_t^{1-\alpha}}$$

$$\frac{(1-\theta)}{(1-n)} = \frac{\alpha\theta}{[1-(1-\alpha)\beta] n}$$

$$(1-\theta)[1-(1-\alpha)\beta] = \frac{\alpha\theta}{n}(1-n)$$

$$(1-\theta)[1-(1-\alpha)\beta] = \frac{\alpha\theta}{n} - \alpha\theta$$

$$n = \frac{\alpha\theta}{(1-\theta)[1-(1-\alpha)\beta] + \alpha\theta}$$

which is constant. Therefore, it was correct to state that the income and substitution effects of a wage rate change offset each other, and that the amount of labor supplied is constant over time.

As these equations show, the level of consumption and the amount of capital desired next period, will vary depending on how the level of production changes, but the amount of labor supplied each period will be the same. However, these equations do not provide a very thorough explanation about what kind of choices the individual households are making.

Barro (1993), provides the intuition behind the equations. Suppose that there is a positive temporary shock to the production function. This means that the value z is positive and greater than one, but only remains this way for a finite number of periods. Thus, after the finite periods have passed, the level of production falls to the level it was before the technology shock happened.

In analyzing the reaction of households, we examine the wealth effects and the substitution effects. The wealth effect concerns the overall scale of opportunities. That is, if a change allows people to obtain more of the commodities that provide utility, then there is a positive wealth effect. A substitution effect refers to the relative costs households incur to obtain various items that provide utility. For example, a change may occur in the possibilities for transforming more work into more consumption. In other words, the change alters the relative costs between leisure and consumption.

Now assume that the technology shock increases the marginal product of labor as well as increasing overall production. The increase in the marginal product of labor means that at the current level of work effort, individuals are able to produce more good. Therefore, there is an incentive for individuals to work harder now and rest later. This is the substitution effect because consumption is cheaper relative to leisure, so the rational maximizing individual substitutes to the lower cost commodity, which in this case, is consumption.

The wealth effect is caused by the fact that the increase in overall production allows individuals to work less because they can increase their level of consumption while decreasing their amount of work effort. As equation (2.2.2) shows, an increase in the amount produced in the economy allows individuals to consume more goods.

This result is the same as the one that was obtained from the solution of the basic RBC model. It was shown that when there is an increase in the overall level of production, the level of production increases. However, in the basic RBC model, it was necessary to assume that the wealth and substitution effects canceled out. Therefore, the desire to work more due to the increase in the marginal product of labor, is offset exactly by the desire to work less because of the increase in overall production.

McCallum (1989b) states that there is another interesting result that can be obtained from the basic RBC model presented earlier. Returning to the solution for k_{t+1}, and taking the logarithm yields:

$$\log k_{t+1} = \Phi_0 + (1-\alpha)\log k_t + \log z_t \tag{2.2.8}$$

which follows a stochastic process due to the shock term z, and where Φ_0 contains all constants. Now make the standard assumption that the shock term is autoregressive of order 1 (AR(1)), or follows a Markov process. This means that the shock is based on the previous period's shock plus a random variable that is independently and identically distributed (i.i.d). Therefore, z has the following equation of motion:

(2.2.9) $$\log z_t = \rho \log z_{t-1} + \varepsilon_t$$

where ε is i.i.d.

McCallum (1989b) substitutes equation (2.2.9) into equation (2.2.8) to obtain:

(2.2.10) $$\log k_{t+1} = \Phi_0 + (1-\alpha)\log k_t + \rho \log z_{t-1} + \varepsilon_t.$$

However, we know from equation (2.2.8) that:

$$\log z_{t-1} = \log k_t - \Phi_0 - (1-\alpha)\log k_{t-1}$$

and when substituted into equation (2.2.10) implies:

$$\log k_{t+1} = \Phi_0 + (1-\alpha)\log k_t + \rho[\log k_t - \Phi_0 - (1-\alpha)\log k_{t-1}]$$

(2.2.11) $$\log k_{t+1} = (1-\rho)\Phi_0 + (1-\alpha+\rho)\log k_t - (1-\alpha)\rho \log k_{t-1}$$

and thus, capital evolves around an AR(2) process, because k_{t+1} is dependent on the two previous periods.

The same analysis can be done for consumption. Taking the logs of the solution for consumption gives:

(2.2.12) $$\log c_t = \Phi_1 + (1-\alpha)\log k_t + \log z_t.$$

Once again, Φ_1 contains all of the constants. McCallum (1989b) rewrites equation (2.2.10) as:

$$\log k_t = \Phi_0 + (1-\alpha)\log k_{t-1} + \log z_{t-1}$$

$$\log k_t - (1-\alpha)\log k_{t-1} = \Phi_0 + \log z_{t-1}$$

$$(1-(1-\alpha)L)\log k_t = \Phi_0 + \log z_{t-1}$$

(2.2.10') $$\log k_t = \frac{\Phi_0 + \log z_{t-1}}{(1-(1-\alpha)L)}$$

where L is the lag operator, such that L^i means that the variable has been lagged i times. Thus, if i = 1, then the variable is lagged once.

Substituting equation (2.2.10') into (2.2.12) gives:

(2.2.12') $$\log c_t = \Phi_1 + (1-\alpha)[1-(1-\alpha)L]^{-1}\Phi_0 + \log z_t + (1-\alpha)[1-(1-\alpha)L]^{-1}\log z_{t-1}.$$

Multiplying through by [1-(1-α)L] yields:

$$1-(1-\alpha)L]\log c_t = [1-(1-\alpha)L]\Phi_1 + (1-\alpha)\Phi_0 + [1-(1-\alpha)L]\log z_t + (1-\alpha)\log z_{t-1}$$

(2.2.12") $$\log c_t - (1-\alpha)\log c_{t-1} = [1-(1-\alpha)L]\Phi_1 + (1-\alpha)\Phi_0 + \log z_t - (1-\alpha)\log z_{t-1} + (1-\alpha)\log z_{t-1}.$$

Remembering that z follows a Markov process, we have

$$\log z_t = \rho\log z_{t-1} + \varepsilon_t$$

$$\log z_t - \rho\log z_{t-1} = \varepsilon_t$$

$$(1-\rho L)\log z_t = \varepsilon_t$$

$$\log z_t = (1-\rho L)^{-1}\varepsilon_t$$

which when substituted into equation (2.2.12") gives:

$$\log c_t - (1-\alpha)\log c_{t-1} = [1-(1-\alpha)L]\Phi_1 + (1-\alpha)\Phi_0 + (1-\rho L)^{-1}\varepsilon_t$$

and multiplying through by (1-ρL) gives:

$$(1-\rho L)(\log c_t - (1-\alpha)\log c_{t-1}) = (1-\rho L)[1-(1-\alpha)L]\Phi_1 + (1-\rho L)(1-\alpha)\Phi_0 + \varepsilon_t$$

$$\log c_t - \rho\log c_{t-1} - (1-\alpha)\log c_{t-1} + \rho(1-\alpha)\log c_{t-2} = 1-(1-\alpha)L - \rho L + \rho(1-\alpha)L^2]\Phi_1 + [1-\rho L - \alpha + \alpha\rho L]\Phi_0 + \varepsilon_t.$$

Note that the lag operator has no effects on the constants Φ_0 and Φ_1. Therefore, the equation for consumption becomes:

(2.2.12"') $$\log c_t = (1-\alpha-\rho)\log c_{t-1} - \rho(1-\alpha)\log c_{t-2} + (\alpha-\rho\alpha)\Phi_1 + (1-\alpha)(1-\rho)\Phi_0 + \varepsilon_t$$

which follows an AR(2) process.

The reason that these results are so important, is that the detrended time series of most macroeconomic variables are well described by an AR(2) process for U.S. data.

As well, studies such as Cochrane (1988), and Campbell and Mankiw (1987), have shown that both quarterly and annual U.S. GNP is well approximated by an AR(2) model.

II.3. CALIBRATION AND SOLUTION PROCEDURES

In most cases, RBC models are not as simple as the one that was presented in the previous section, and therefore cannot be solved that easily. These complicated RBC models are solved using a successive approximation dynamic programming technique.

In the most basic sense, RBC models are intertemporal optimization problems. They contain an objective function (the representative agent's utility), state variables which are variables that are beyond the control of the maximizing agent (the stochastic shock variable z), choice variables (consumption, labor, and the capital stock), and transition equations which connect the state variables with the control variables (the budget constraint). The solution to the intertemporal optimization problem is to maximize the objective function with respect to the choice variables and subject to the transition equations. These problems can be solved in the same manner as the previous section. However, if the number of variables and transition equations are large enough, the simultaneous solution for the choice variables may be computationally difficult, and there may exist an easier way of solving the problem.

Hansen and Prescott (1995) describe a procedure which solves the social-planning problem given in the RBC models. This procedure involves solving a dynamic programming problem by successive approximations. Going through this procedure is important because the majority of all RBC models are solved using this method, or some slight deviation of it.

The dynamic programming problem has the following form:

(2.3.1) $$V(z,s) = MAX\{U(z,s,d) + \beta E[V(z',s')|z,s]\}$$

subject to

(2.3.2) $$z' = A(z) + \varepsilon'$$

(2.3.3) $$s' = B(z,s,d)$$

where z is a vector of exogenous state variables, s is a vector of endogenous state variables, and d is a vector of choice variables. U is the utility function, E is the expectations operator, β is the discount factor, V(z,s) is the optimal value function, and the primes indicate next period values. Equations (2.3.2) and (2.3.3) are the laws of motion for the state variables z and s respectively. ε is i.i.d., and A(z) and B(z,s,d) are both linear functions.

This solution technique is only valid if the preferences are quadratic and the constants are linear. Therefore, it is necessary to linearize the constraints by substituting the nonlinear constraints into the objective function and then transforming the objective function so that it is quadratic.

In order to derive a quadratic estimate of the objective function, Hansen and Prescott (1995) use a Taylor series expansion at the steady state values of z, s, and d. Let y be the stacked vector of (z, s, d), $y = [z \quad s \quad d]$, and the superscript T denote the transpose of the vector. Let $\bar{y}$ be the steady-state values of y, such that $\bar{y} = (\bar{z}, \bar{s}, \bar{d})$, where $\bar{z} = A(\bar{z})$, and $\bar{s} = B(\bar{z}, \bar{s}, \bar{d})$ because in the steady-state, the values are known with certainty. The Taylor series expansion of U(y) at the steady-state $\bar{y}$ is:

$$\tilde{U}(y) = U(\bar{y}) + DU(\bar{y})^T(y - \bar{y}) + (½)(y - \bar{y})^T D^2U(\bar{y})(y - \bar{y})$$

where $DU(\bar{y})$ is a vector of first partial derivatives of U:

$$DU(\bar{y}) = [D_1U(\bar{y}) \quad \cdots \quad D_{\eta(y)}U(\bar{y})].$$

Following Hansen and Prescott (1995), let $\eta(y)$ be the number of elements in the stacked vector y, and $D^2U(\bar{y})$ be a matrix of second partial derivatives of U:

$$D^2U(\bar{y}) = \begin{matrix} D_{11}U(\bar{y}) & \cdots & D_{1\eta(y)}U(\bar{y}) \\ \vdots & \ddots & \vdots \\ D_{\eta(y)1}U(\bar{y}) & \cdots & D_{\eta(y)\eta(y)}U(\bar{y}) \end{matrix}$$

and is $\eta(y) \times \eta(y)$, because there are $\eta(y)$ elements in the stacked vector y.

Now let h^i be a vector where all of the elements are 0 except for the ith component h^i_i, which is equal to a small positive number $\tilde{h}$:

$$h^i = [0 \ \cdots \ \tilde{h} \ \cdots \ 0].$$

Hansen and Prescott (1995), then use the following formulas to derive the numerical approximations of the components $DU(\bar{y})$ and $D^2U(\bar{y})$:

$$D_iU(\bar{y}) = \frac{[U(\bar{y}+h^i) - U(\bar{y}-h^i)]}{2\tilde{h}}$$

$$D^2_{ii}U(\bar{y}) = \frac{[U(\bar{y}+h^i) - U(\bar{y}-h^i) - 2U(\bar{y})]}{\tilde{h}^2}$$

$$D^2_{ij}U(\bar{y}) = \frac{[U(\bar{y}+h^i+h^j) - U(\bar{y}+h^i-h^j) - U(\bar{y}-h^i+h^j) + U(\bar{y}-h^i-h^j)]}{4\tilde{h}^2}$$

for $i \neq j (i, j = 2 \ldots n)$.

Since the first component of y is equal to 1, the Taylor series expansion can be rearranged such that $\tilde{U}(\bar{y}) = y^TQy$, where Q is an $\eta(y) \times \eta(y)$ symmetric matrix. The individual elements of Q are:

$$Q_{1i} = Q_{i1} = \frac{[D_iU(\bar{y}) - \sum_{ij}^{\eta(y)}(D^2_{ij}U(\bar{y})\bar{y}_j)]}{2} \qquad \text{for } i = 2 \ldots \eta(y)$$

$$Q_{ij} = Q_{ji} = (\tfrac{1}{2})D^2_{ij}U(\bar{y}) \qquad \text{for } i, j = 2 \ldots \eta(y)$$

$$Q_{11} = U(\bar{y}) - \sum_{i=2}^{\eta(y)} D_iU(\bar{y})\bar{y}_i + (\tfrac{1}{2})\sum_{i=2}^{\eta(y)}\sum_{j=2}^{\eta(y)} D^2_{ij}U(\bar{y})\bar{y}_i\bar{y}_j.$$

The linear-quadratic dynamic programming problem becomes:

$$(2.3.4) \qquad V(z,s) = \mathrm{MAX}\{y^TQy + \beta E[V(z',s')|z]\}$$

subject to

(2.3.2) $$z' = A(z) + \varepsilon'$$

(2.3.3) $$s' = B(z, s, d).$$

By following the method of successive approximations, a sequence of approximations for V is generated, and well-behaved problems will converge to the optimal value function. To solve this problem, Hansen and Prescott (1995) use an initial quadratic approximation for the value function, V^0, and given the nth element, the n + 1st element is obtained by:

(2.3.5) $$V^{n+1}(z, s) = \mathrm{MAX}\{y^T Q y + \beta[V^n(z', s')]\}$$

subject to

(2.3.6) $$z', s']_i = \sum_{j \le \eta(y)} B_{ij} y_j \qquad \text{for } i = 1 \ldots \eta(z, s)$$

where B_{ij}'s are taken from equations (2.3.2) and (2.3.3) and $\eta(z,s)$ is the dimension of the stacked vector (z,s).

In order to obtain V^{n+1}, equation (2.3.6) is substituted into equation (2.3.5), in order to eliminate z' and s'. The problem is then defined in (z, s, d), since both B and y are functions of (z, s, d). The first-order conditions are then used to solve for d as a linear function of the state variables z and s. After substituting d into equation (2.3.6), the next approximation can be formulated. Hansen and Prescott (1995) then describe this procedure in a more detailed fashion by formulating a seven step procedure.

The first step in the Hansen and Prescott (1995) procedure is to define an arbitrary negative semi-definite matrix for V^0, which is $\eta(z,s) \times \eta(z,s)$. An example would be a matrix where the diagonal is composed of small negative numbers and the off-diagonal elements are zero. As well, the first $\eta(z)$ columns of V^0 contain coefficients corresponding to the elements of the exogenous state variables z. The last $\eta(s)$ columns of V^0 contain coefficients corresponding to the elements of the endogenous state variables

s. $\eta(z)$ and $\eta(s)$ are the number of exogenous and endogenous state variables respectively.

The next step in the procedure is to define x as a stacked vector, $x = [z \quad s \quad d \quad z' \quad s']$. Then construct a matrix $R^{[\eta(x)]}$, which has the dimension $\eta(x) \times \eta(x)$, and contains the matrix Q in the upper left corner, and the matrix βV^n in the lower right corner. $\eta(x)$ is the number of variables in the stacked vector x. The rest of he elements in $R^{[\eta(x)]}$ are set equal to zero.

The expression $y^TQy + \beta V(z', s')$ from equation (2.3.5) can then be written as a single quadratic form, $x^TR^{[\eta(x)]}x$. As described earlier, the next step is to compute $V^{n+1}(z,s)$ by eliminating the variables z', s', and d from $x^TR^{[\eta(x)]}x$, using equation (2.3.6) and the first-order conditions. Hansen and Prescott (1995) define this procedure in the following way. Suppose, that after some substitutions, the quadratic form becomes $x^TR^{(j)}x$, where $j > \eta(z,s)$. Then the jth component can then be eliminated by using one of the constraints or first-order conditions. It now becomes possible to express x_j in terms of x_i, where $i < j$. Therefore, x_j becomes:

(2.3.7) $$x_j = \sum_{i<j} \gamma_i x_i .$$

Now substitute equation (2.3.7) into the objective function $x^TR^{(j)}x$. The new objective function is $x^TR^{(j-1)}x$, where the elements in the first j - 1 rows and columns $R^{(j-1)}$ are:

(2.3.8) $$R^{(j-1)}_{ih} = R^{(j)}_{ih} + R^{(j)}_{ji}\gamma_h + R^{(j)}_{jj}\gamma_i\gamma_h \qquad \text{for } i,h = 1,\ldots,j-$$

and the remaining elements are equal to zero.

Substituting the constraints, equation (2.3.6), into the objective function in order to eliminate z' and s'. The constraints for the exogenous and endogenous state variables, which determine the last $\eta(z,s)$ elements of x, are given by:

$$x_i = \sum_{j<J} B_{ij} x_j$$

$$i = \eta(z,s,d) + 1, \ldots, \eta(x)$$

$$J = \eta(z,s,d)$$

where $\eta(z,s,d)$ is equal to the number of variables in the stacked vector (z, s, d).

The first element eliminated out of x, is the last element in s'. Therefore, equation (2.3.8) gives the matrix $R^{[\eta(x)-1]}$, where the γ's are replaced with the coefficients from $B_{\eta(x),j}$. The matrix $R^{[\eta(x)-1]}$ contains all elements in $R^{[\eta(x)]}$, except for the last element of s'.

Once all of the elements of s' and z' have been eliminated from $R^{[\eta(x)]}$, the quadratic objective function becomes $x^T R^{[\eta(z,s,d)]} x$. The dimensions of the matrix $R^{[\eta(z,s,d)]}$ are still conformable with x, because the elements of s' and z' have been replaced by zeros.

The next step in the Hansen and Prescott (1995) procedure, is to eliminate the choice variables d, by using the first-order condition with respect to the jth component of x, assuming that all components of x with an index greater than j have been eliminated, is given by:

$$x_j = -\sum_{i=1}^{j-1}\left(\frac{R_{ji}^{(j)}}{R_{jj}^{(j)}}\right)x_i, \quad j = \eta(z,s)+1,\ldots,\eta(z,s,d). \tag{2.3.9}$$

If $R_{jj}^{(j)}$ is not less than zero, then there have been some errors made, or there is a failure of this method to find the optimal value function.

Now remove all of the decision variables by using equation (2.3.8), until $R^{[\eta(z,s,d)]}$ is reduced to the matrix $R^{[\eta(z,s)]}$, and the objective function becomes $x^T R^{[\eta(z,s)]} x$.

Finally, set V^{n+1} equal to the matrix formed by the first $\eta(z,s)$ rows and columns of $R^{[\eta(z,s)]}$. If the elements are sufficiently close to the elements of V^n, (for example the largest difference is less than 0.00001), then the iteration can stop, otherwise, repeat the procedure with V^{n+1} in the place of V^n.

It is now possible to rewrite equation (2.3.9) in order to solve for the equilibrium policy functions of the choice variables. Therefore, equation (2.3.9) becomes:

$$d_j = \sum_{j<K} C_{ij} x_i, \quad j = 1,\ldots,\eta(d) \tag{2.3.10}$$

where

$$C_{ij} = \frac{-R_{Ki}^{(K)}}{R_{KK}^{(K)}}$$

and

$$K = \eta(z, s) + j.$$

Since the policy function is a function of the choice variables with indices 1 to j - 1, as well as the state variables z and s, it is necessary to write the policy function in terms of just the state variables. Hansen and Prescott (1995) then define the equilibrium policy function as:

$$d_j = \sum_{i=1}^{\eta(z,s)} D_{ij} x_i , \tag{2.3.11}$$

where for each i,

$$D_{i1} = C_{i1}$$

$$D_{i2} = C_{i2} + C_{\eta(z,s)+1,2} D_{i1}$$

$$D_{ij} = C_{ij} + \sum_{h<j} [C_{\eta(z,s)+h,j} D_{ih}], \quad j = 3, \ldots, \eta(d).$$

In order to double check the solution, Hansen and Prescott (1995) state that the steady state solution from the original planner's problem, $\overline{z}$ and $\overline{s}$ should be substituted into the right hand side of equation (2.3.11). If equation (2.3.11) gives the same choices as $\overline{d}$, then the solution is correct.

Now that the decision rules have been obtained, the next step is to choose parameter values from growth observations and from studies using microeconomic data. Given the set of parameter values, the artificial economy is then simulated for the same number of periods as the actual economy's data sample. However, before the standard deviations and the correlations with output are calculated, both the actual and the simulated data is logged and detrended using the Hodrick-Prescott filter.

II.4. THE HODRICK AND PRESCOTT FILTER

Hodrick and Prescott (1980), develop the Hodrick and Prescott (HP) filtering procedure, which decomposes the time series into growth and business cycle components. Let the series that is being filtered be denoted by y, and the trend of that series be τ. The mean squared deviation from trend becomes:

(2.4.1) $$MSE = \sum_{t=1}^{T} (y_t - \tau_t)^2 .$$

The least-squares time trend is found by minimizing (2.4.1) subject to a constraint. In this case, Prescott uses the following constraint:

(2.4.2) $$\sum_{t=2}^{T-1} [(\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1})]^2 \leq \alpha .$$

Equation (2.4.1)defines the cyclical component of the series and equation (2.4.2) is the penalty for variation in the second difference of the trend component. As α increases, the penalty is reduced and the trend line has more variation, and thus, resembles the original series more closely.

Equations (2.4.1) and (2.4.2) imply the following minimization problem:

(2.4.3) $$\mathrm{MIN}\{\sum_{t=1}^{T} (y_t - \tau_t)^2 + \mu[\sum_{t=2}^{T-1} ((\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1}))^2 - \alpha]\}$$

where μ is the Lagrange multiplier of the constraint, and controls the smoothness of the trend component. As μ increases, the trend component becomes smoother, and in the limit, the minimization problem yields a linear deterministic trend.

The first-order condition with respect to τ_t is:

$$-2(y_t - \tau_t) - 4\mu(\tau_{t+1} - 2\tau_t + \tau_{t-1}) + 2\mu(\tau_t - 2\tau_{t-1} + \tau_{t-2}) + 2\mu(\tau_{t+2} - 2\tau_{t+1} + \tau_t) = 0$$

which reduces to

(2.4.4) $$y_t = \mu[(1/\mu) + 6\tau_t - 4\tau_{t+1} - 4\tau_{t-1} + \tau_{t+2} + \tau_{t-2}].$$

Therefore, y = Aτ, where

$$A = \mu \begin{array}{ccccccccc} (1+\frac{1}{\mu}) & -2 & 1 & 0 & \cdots & \cdots & \cdots & 0 & \tau_1 \\ -2 & (5+\frac{1}{\mu}) & -4 & 1 & 0 & \cdots & \cdots & 0 & \tau_2 \\ 1 & -4 & (6+\frac{1}{\mu}) & -4 & 1 & 0 & \cdots & 0 & \tau_3 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \vdots \\ 0 & \cdots & 0 & 1 & -4 & (6+\frac{1}{\mu}) & -4 & 1 & \tau_{T-2} \\ 0 & \cdots & \cdots & 0 & 1 & -4 & (5+\frac{1}{\mu}) & -2 & \tau_{T-1} \\ 0 & \cdots & \cdots & \cdots & 0 & 1 & -2 & (1+\frac{1}{\mu}) & \tau_T \end{array}$$

and equation (2.4.4) corresponds to rows 3 and 5. The other rows occur because we cannot go back two periods for rows 1 and 2, and we cannot go forward two periods for rows 6 and 7.

We can then solve for τ:

$$\tau = A^{-1}(y/\mu)$$

and for annual series $\mu = 400$, for quarterly series $\mu = 1600$, and for monthly series $\mu = 14400$.

The artificial economy is then simulated numerous times. Fro example, Cooley and Hansen (1989) simulate it 50 times, and then the averages of the standard deviations and correlations are reported and compared with actual time series.

As tables 2.1 and 2.2 show, the basic model from section 2 simulates the actual economy rather well, considering how simple it is. Table 2.1 reports the standard deviations of percentage departures from trend. The actual economy shows that consumption, capital stock, hours worked, productivity and the price level are less volatile than output, and that investment is a lot more volatile than output.

Table 2.2 presents the contemporaneous correlations with output. For the actual U.S. economy, consumption, investment, and hours worked are highly correlated with output and are procyclical. Productivity, is mildly correlated with output and is procyclical. The capital stock does not appear to be correlated with output and therefore, is acyclical. Finally, the price level is negatively correlated with output and is countercyclical.

In all cases, the basic model results give roughly the same results, but the volatility of the variables is under stated, and the correlations with output are overstated.

II.5. EXTENSIONS

II.5.A. INDIVISIBLE LABOR

In the basic RBC model, people make a choice of how many hours they work in equilibrium. Combining this result with the assumption that all markets clear, means that any unemployment in the economy is completely voluntary, and that the volatility in aggregate hours worked is due to individuals adjusting the number of hours they work each day. However, Hansen (1985) argues that the variability in aggregate hours is due to individuals working full-time or not working full-time, rather than adjusting the number of hours worked while employed. Thus, the role of indivisible labor arises from the fact that individuals tend to work some number of hours, or not at all, and unlike other RBC models, a type of non-convexity is introduced.

Most RBC models depend on the intertemporal substitution of leisure to account for the fluctuations in hours worked. The intertemporal substitution of leisure means that individuals are making choices about whether to work today, and have more leisure next period, or to have more leisure today and work next period. However, in order to fit the stylized facts of small procyclical variations in the real wage being associated with large procyclical variations of employment, the elasticity of intertemporal substitution of leisure needs to be large (which makes the labor supply curve flatter). The indivisible labor model of Hansen (1985) allows this to occur. In that model, the elasticity of intertemporal substitution of leisure is infinite, which implies a horizontal labor supply curve.

The fact that people tend to work full time or not at all would suggest that non-convexities may be present in individual preferences. This implies that there is decreasing marginal utility of leisure at low levels of leisure, and increasing marginal utility at higher levels of leisure. These types of preferences reflect the indirect preferences on the costs associated with working each period. Thus, the fixed costs of getting dressed and driving to work may be large enough to offset any benefits of working any amount less than full-time. In this case, individuals choose not to work at all.

However, the non-convexity of the model means that the representative agent's problem may not support a competitive equilibrium. In order to bypass this problem, individuals choose lotteries rather than hours worked. This means that the new commodity that is being traded is a contract between the firm and the individual that requires the individual to work h_0 hours full time with the probability α_t. Thus, individuals choose the probability of working α_t, and a competitive equilibrium can be derived by solving the now concave dynamic programming problem.

Hansen (1985) states that if unemployment insurance is available then individuals will choose to insure themselves fully, so the individual gets paid whether they work or not. Thus, consumption is the same regardless of whether or not the individual is employed.

The expected utility in period t is:

$$U(c_t, \alpha_t) = \alpha_t(\log c_t + A\log(1-h_0)) + (1-\alpha_t)(\log c_t + A\log 1)$$

(2.5.1.1) $$U(c_t, \alpha_t) = \log c_t + A\alpha_t \log(1-h_0)$$

where c is consumption and A is a positive parameter. Only α_t of the population has to work h_0 hours full-time which implies that per capita hours worked in period t becomes:

(2.5.1.2) $$h_t = \alpha_t h_0$$

Solving equation (2.5.1.2) for α_t and substituting into equation (2.5.1.1) yields:

(2.5.1.3) $$U(c_t, \alpha_t) = \log c_t + h_t A \frac{\log(1-h_0)}{h_0}$$

Letting $h_t = 1 - l_t$ and substituting into equation (2.5.1.3) gives:

$$U(c_t, l_t) = \log c_t + A\frac{\log(1-h_0)}{h_0} - l_t A\frac{\log(1-h_0)}{h_0}$$

and therefore,

$$\frac{\partial U}{\partial l_t} = -A\frac{\log(1-h_0)}{h_0}$$

which is constant. Thus, since utility is linear in leisure, the elasticity of substitution between leisure in different periods is infinite and the model is able to generate small procyclical variations in the wage rate and still have large variations in hours worked.

The representative agent's problem becomes:

(2.5.1.4) $\quad \text{MAX}\{E_t[\sum_{t=0}^{\infty}\beta^t(\log c_t + A\alpha_t \log(1-h_0)]\}$

subject to

(2.5.1.5) $\quad c_t + i_t \le \lambda_t k_t^{\theta} h_t^{1-\theta}$

(2.5.1.6) $\quad k_{t+1} = (1-\delta)k_t + i_t$

(2.5.1.7) $\quad \lambda_{t+1} = \gamma\lambda_t + \varepsilon_{t+1}$

(2.5.1.8) $\quad h_t = \alpha_t h_0$

where β is the discount factor, i is investment, k is capital, δ is the depreciation rate, λ is the stochastic shock, and ε is and i.i.d. random variable. Equation (2.5.1.5) states that the amount consumed and invested in the current period, cannot exceed the total amount produced in the economy. Equation (2.5.1.6) is the equation of motion for the capital stock, and states that the amount of capital next period consists of what is left of the capital stock in the current period after depreciation plus the amount invested in replenishing the capital stock. The random stochastic shock follows a standard Markov process as shown by equation (2.5.1.7). Finally, equation (2.5.1.8) states that the total hours worked is the percentage of the population that has to work h_0 hours full-time. This problem is then calibrated and solved according to the techniques described in section 3.

As table 2.1 shows, the indivisible labor economy tends to generate significantly larger fluctuations in total hours than an economy with divisible labor. However, the variability tends to larger in the actual economy than in either of the simulated economies. As well, the indivisible labor model exhibits large fluctuations in hours worked relative to fluctuations in productivity, which is more in line with what the actual economy displays. Therefore, it seems that the indivisible labor economy is able to resemble actual facts better than previous RBC models, and that by including non-convexities such as indivisible labor, business cycle theories will not have to depend solely on technology shocks in order to generate fluctuations in aggregate macroeconomic variables.

II.B. MONEY

As we have seen so far, there does not appear to be an explicit role for money within the RBC framework. What is surprising, is that RBC models have been able to replicate the characteristics of aggregate macroeconomic variables while abstracting for the role of money, even though the correlation between money is a statistical fact.

Cooley and Hansen (1989), study the quantitative importance of money by analyzing the effects of money on real variables via the effects of anticipated inflation. Money is introduced into the model by using a cash-in-advance constraint. This means that some goods can only be purchased using cash, while other goods can be purchased using credit. Thus, excess demand for credit can be financed with loans, while the total consumption of cash goods can only be paid from existing money balances. In this model only consumption goods need to be paid for in cash which means that the cash-in-advance constraint only applies to consumption, and therefore, leisure and investment are the credit goods.

In this case, money can have important real effects. An increase in the money supply causes an increase in the level of anticipated inflation, and due to the cash-in-advance constraint, the only way households can reduce their cash holdings in order to counter the effects of the price increase, is to reduce their consumption. Therefore, the increase in prices causes households to substitute away from activities which require cash, such as consumption, into activities which do not require cash, such as leisure.

This model looks at two different money supply processes. The first is that money is supplied according to a constant growth rate rule and the second money supply process follows an autoregressive form which has the same characteristics as historical experience. The labor supply aspect of this model uses Hansen's (1985) approach of indivisible labor which was discussed earlier.

In order to incorporate money explicitly, Cooley and Hansen (1989), assume that households enter period t with nominal money balances M_{t-1} which has been carried over from the previous period. These nominal money balances are then increased by a lump-sum transfer equal to $(\mu_t - 1)M_{t-1}$ where μ_t is the growth rate of money and M_t is the per capita money supply.

As stated earlier, there are two money supply processes being studied. The first is a constant growth rate of the money supply, and the second is that the log of the gross growth rate evolves according to the following autoregressive form:

$$\log(\mu_{t+1}) = \alpha \log(\mu_t) + \xi_{t+1}$$

where ξ_{t+1} is i.i.d..

Since consumption goods can only be purchased using cash, the household must satisfy the following constraint:

$$p_t c_t \leq m_{t-1} + (\mu_t - 1)M_{t-1}$$

where p is the price level, c is consumption, the lower case values are the values for the individual household, and the upper case values are the per capita values. The above constraint states that current period consumption must be less than or equal to the household's current period nominal money holdings. It should be noted that a sufficient condition for this constraint to be binding is that the growth rate in money must exceed the discount factor. By imposing this condition, the model becomes easier to solve because corner solutions are ruled out. Also, this assumption is not unreasonable since in reality the gross growth rate of the money supply process tends to be greater than the discount rate.

Incorporating the above constraint into the indivisible labor model implies that the representative agent solves the following maximization problem:

(2.5.2.1) $$\text{MAX}\{E_t[\sum_{t=0}^{\infty}\beta^t(\log c_t + h_t A\frac{\log(1-h_0)}{h_0})]\}$$

subject to

(2.5.2.2) $$c_t + i_t + \frac{m_t}{p_t} \le w_t h_t + r_t k_t + \frac{(m_{t-1} + (\mu_t - 1)M_{t-1})}{p_t}$$

(2.5.2.3) $$c_t \le \frac{m_{t-1} + (\mu_t - 1)M_{t-1}}{p_t}$$

(2.5.2.4) $$Y = \exp(z_t)K_t^{\theta}H_t^{1-\theta}$$

(2.5.2.5) $$K_{t+1} = (1-\delta)K_t + I_t$$

(2.5.2.6) $$k_{t+1} = (1-\delta)k_t + i_t$$

(2.5.2.7) $$w_t = (1-\theta)\exp(z_t)K_t^{\theta}H_t^{-\theta}$$

(2.5.2.8) $$r_t = \theta\exp(z_t)K_t^{\theta-1}H_t^{1-\theta}$$

(2.5.2.9) $$z_{t+1} = \gamma z_t + \varepsilon_{t+1}$$

(2.5.2.10) $$\mu_{t+1} = \mu_t \qquad \text{or} \qquad \log(\mu_{t+1}) = \alpha\log(\mu_t) + \xi_{t+1}$$

where β is the discount factor, h_t is aggregate hours worked, h_0 is the predetermined full-time hours worked, i is investment, w is the nominal wage rate, r is the rental rent on capital, δ is the depreciation rate, and z is the stochastic shock. Equation (2.5.2.1) is the same utility function as the one defined in Hansen's indivisible labor model discussed earlier. Equation (2.5.2.2) states that everything consumed, invested or held as real money balances, cannot exceed the amount received from working, from capital and from the lump-sum money transfer. The cash-in-advance constraint is given by equation

(2.5.2.3). The standard Cobb-Douglas production function is defined by equation (2.5.2.4). Equations (2.5.2.5) and (2.5.2.6) both describe how next periods capital stock is obtained, where (2.5.2.5) is the per capita capital stock and (2.5.2.6) is the individual capital stock. Equations (2.5.2.7) and (2.5.2.8) are derived from the firm's profit maximization problem. Equation (2.5.2.7) states that the nominal wage rate is equal to the marginal product of labor, and equation (2.5.2.8) states that the rental rate of capital is equal to the marginal product of capital. The standard assumption of the technology shock following a Markov process is given by equation (2.5.2.9) and ξ is i.i.d.. Finally, equation (2.5.2.10) shows that the money supply either follows a constant growth rate rule, or an autoregressive formulation, depending on what process is being analyzed.

Once again. the model is solved and calibrated according to the techniques discussed in section 3, and the results are presented in tables 2.1 and 2.2. What these results show is that when money is supplied optimally (constant growth rate), the artificial economy has the characteristics as the indivisible labor economy which does not include the cash-in-advance constraint. The constant growth rate rule implies positive nominal interest rates causing individuals to substitute leisure for consumption because leisure is a credit good and thus, an increase in the interest rate increases the cost of leisure relative to consumption. As well, investment will also decline, and the steady state capital stock will be lower. Therefore, the results show that when money is supplied optimally, the characteristics of the business cycle remain unchanged.

In the case of the autoregressive money supply process, there is little change in the cyclical behavior of the real variables. In this case, table 2.1 shows that consumption becomes more variable relative to output and the price level becomes more volatile. As well, table 2.2 shows that the correlation between consumption and the price level with output becomes smaller in absolute values.

However, it should be noted that unexpected inflation plays no role in this economy. Since the results show that accounting for anticipated inflation does not have a significant affect on the characteristics of the artificial economy, Cooley and Hansen (1989) argue that the influence of money in the short-run fluctuations is going to be the result of the monetary authority's behavior having significant informational consequences for private agents. This means that only surprise monetary shocks may have an affect on real variables. The effect the surprise monetary shock has on short-run fluctuations will be due to the influence of the money supply process has on the expectations of the relative prices, as suggested by the natural rate literature. The natural rate literature argues that individuals first form expectations about the price level, and then individuals realize the actual price level. If the actual price level is greater than expected, firms increase production in order to capture the benefits of the higher price, which then causes output, employment and consumption to increase. If the actual price level is less than expected, firms decrease production, which then causes output, employment and consumption to decrease.

II.5.C. GOVERNMENT

As was stated earlier, RBC models are driven by technology shocks. Support for this assumption is provided by Prescott (1986) who estimated that technology shocks account for 75% of the fluctuations in the post war U.S. economy. McGratten (1994b), then asks the following questions: what accounts for the remaining 25% ? if other disturbances are introduced, will the technology shocks still account for the 75% of the fluctuations? and will including these additional disturbances allow the model to replicate the actual U.S. economy better than previous models?

McGratten (1994b), introduces fiscal disturbances such as innovations in government expenditures, labor tax rates, and capital tax rates. The role of government in this model is to levy taxes on capital and labor and then spend this revenue on government consumption and lump-sum transfers. These fiscal policies are set exogenously.

The changes in the tax rates imply that there exists a negative correlation between wages and hours. The increase in the tax rates mean that the revenue received from capital and labor decreases, which then causes consumption to decrease. In order to offset the decrease in consumption, individuals need to increase the number of hours worked. Combining this result with the high positive correlation between wages and hours that occurs when only technology shocks drive the cycle, the overall effect of both shocks should drive the correlation between wages and hours close to zero, which is what is observed in the actual U.S. time series.

In this model, individuals will also have preferences over public goods which are provided by the government, as well as the usual preferences over private consumption and leisure. The utility function in this case becomes:

(2.5.3.1) $$E_0 \sum_{t=0}^{\infty} \beta^t U(c_{p,t} + \pi g_t, a(L) l_t)$$

where β is the discount factor, expectations are conditional on the information the household has at time 0, and utility is increasing in both arguments. $c_{p,t}$ is the current consumption of private goods, g_t is current consumption of public goods, and $a(L)l_t$ means that utility depends on past hours of leisure $l_t, l_{t-1}, l_{t-2}, \ldots$ π measures how government expenditures affects individual utility. If $\pi > 0$, then increases in government expenditures on public goods increase utility and the marginal utility of consumption decreases. If $\pi < 0$, then increases in government expenditures on public goods decreases utility, and the marginal utility of consumption increases.

The specific functional form that McGratten (1994b) uses for the utility function is:

(2.5.3.2) $$U(c_t, l_t) = \frac{(c_t^{\gamma} l_t^{1-\gamma})^{\alpha}}{\alpha}$$

and

$$c_t = c_{p,t} + \pi g_t$$

$$l_t = a(L) l_t, \quad a(L) = (1-\eta)^{j-1} a_1.$$

Turning to the leisure equation, if $a(L) = \sum_{j=0}^{\infty} a_j L^j$, $a(1) = 1$, and L is the lag operator, then one hour of leisure at time t gives a_j hours of leisure at time $t + j$. Now assume that the effects of leisure services declines geometrically over time which means $a(L) = (1 - \eta)^{j-1} a_1$, $0 < \eta < 1$. If the fluctuation a is constrained to have $a_0 = 1$, then utility is time-separable.

The total hours of work at time t is given by:

$$n_t = H - l_t$$

where H is the total hours allotted to leisure and work. this implies:

$$a(L)l_t = H - a_0 n_t - \eta(1 - a_0)h_t$$

$$h_{t+1} = (1 - \eta)h_t + n_t$$

where $h_t = \sum_{j=1}^{\infty} (1 - \eta)^{j-1} n_{t-j}$ is the weighted sum of past hours worked.

The representative agent now solves the following maximization problem:

(2.5.3.3) $$E_0 \sum_{t=0}^{\infty} \beta^t U(c_{p,t} + \pi g_t, a(L)l_t)$$

subject to

(2.5.3.4) $$U(c_t, l_t) = \frac{(c_t^{\gamma} l_t^{1-\gamma})^{\alpha}}{\alpha}$$

(2.5.3.5) $$c_t = c_{p,t} + \pi g_t$$

(2.5.3.6) $$l_t = a(L)l_t, \quad a(L) = (1 - \eta)^{j-1} a_1$$

(2.5.3.7) $$i_t = \sum_{j=0}^{N-1} \phi_{N-j} s_{t-j}, \quad \phi_j \geq 0, \quad \sum_{j=1}^{N} \phi_j = 1$$

(2.5.3.8) $$c_{p,t} + i_t \leq (1 - \tau_t) r_t k_t + (1 - \varphi_t) w_t n_t + \delta \tau_t k_t + \xi_t$$

(2.5.3.9) $$k_{t+1} = (1 - \delta)k_t + s_{t-N+1}$$

(2.5.3.10) $$y_t = \lambda_t k_t^{\theta} n_t^{1-\theta}$$

(2.5.3.11) $$v_t = b_0 + b(L)v_{t-1} + b_{\varepsilon}\varepsilon_t, \quad v_t = [\lambda_t, g_t, \tau_t, \phi_t]$$

Equation (2.5.3.7) is the budget constraint faced by the individual households. In this case, i is the level of investment, k is the capital stock, r is the rental rate of capital, n is the number of hours worked, w is the nominal wage rate, τ is the capital tax rate, φ is the tax rate on labor, δ is the depreciation rate, and ξ is a lump-sum transfer payment from the government in period t. The budget constraint states that private consumption and investment cannot exceed the after tax rate revenue received from labor services and capital rental plus what is received in the form of government transfers. The nominal wage rate, and the rental rate of capital are both determined by solving the firm's profit maximization problem. Government transfers are defined as any revenue that is not used to finance current government consumption. Thus, the real transfers to individuals at time t is:

$$\xi_t = \tau_t r_t k_t + \phi_t w_t n_t - \delta \tau_t k_t - g_t$$

which shows that government transfers equals the revenue received from taxes on capital and labor minus tax revenue lost to depreciation, minus the revenue spent on government consumption.

Equation (2.5.3.8) follows Kydland and Prescott (1982), by stating that capital takes time to build. It is assumed that it takes N periods to build capital. If s_t is the investment that starts at time t and the parameters ϕ_j denote the fraction of resources allocated to projects which are j periods from completion, then equation (2.5.3.8) is the sum of all projects that are currently being funded, or in other words, total investment.

Instead of total investment being added to the capital stock, only the projects that will add to the capital stock at the end of the period are included. These are the projects which are started in period t - N + 1. Therefore, equation (2.5.3.9) states that the amount of capital stock next period is equal to the level of capital stock this period after depreciation, plus the capital projects which will be finished at the end of the period.

Equation (2.5.3.10) states that output is defined as a standard Cobb-Douglas production function, and equation (2.5.3.11) states that the technology shock, government consumption, the labor tax rate and the capital tax rate all introduce disturbances into the model through a stationary vector autoregression.

Once the problem has been placed in a quadratic-linear form using the techniques described earlier, McGratten (1994b) does not use the solution procedure described in section 3, which is the way most RBC models are solved, but uses a noniterative algorithm described in McGratten (1994a).

It has been argued that one reason for some discrepancy between actual and simulated results may be due to measurement error for output, investment, government consumption, capital stock, hours worked, capital tax rate and the labor tax rate. As table 2.3 shows, by accounting for measurement errors and having the estimation procedure attempt to fit all frequencies in the data, rather than just the cyclical behavior, the predicted model matches the actual data very well. The main differences of the two models occur in the standard deviations. The standard deviations for investment and hours worked is overpredicted, and the standard deviation of government consumption is underpredicted.

Also, McGratten (1994b) now finds that technology shocks account for only 41% of the variation in output, and government consumption, labor tax rates and capital tax rates account for the other 28%, 27%, and 4% of the variation in output respectively. Therefore, the inclusion of demand-side disturbances into the RBC framework improves the performance of the models as well as reducing the dependence on large technology shocks to drive the cycle.

II.6. CRITICISMS

This section discusses some of the major criticisms that have been leveled against the RBC framework. The first criticism of RBC models is their reliance on unobservable technology shocks. There are doubts that the technology shocks are large and frequent enough in order to generate business cycles. However, models like Hansen (1985) and McGratten (1994b) show that RBC models do not need large technology shocks to generate business cycles. By including non-convexities into preferences, and including other types of disturbances, the technology shock does no have to be large or frequent in order to generate business cycles.

Another criticism of technology shocks is how they are introduced into the model. The way technology shocks are currently included, implies that the technology shocks affect all sectors of the economy equally and they affect the productivity of all factors of production equally, regardless of the age of the capital stock and the skill level of the workers.

As well, Prescott uses variations in the Solow residual as evidence of significant technology shocks. The Solow residual measures the part of the change in aggregate output which cannot be explained by changes in the measurable quantities of capital and labor inputs. However, some economists have argued that the variations in the Solow residual can be explained by labor hoarding. Labor hoarding occurs when firms retain more workers than they require because the costs associated with removing and then replacing the work force may be greater than the short-term costs of retaining excess workers. Thus, it pays firms to smooth labor over the cycle. As a result, labor hoarding will cause the percentage reduction in output to exceed the percentage reduction in labor during recessions, and for the percentage increase in output to exceed the percentage increase in labor when the economy recovers.

The second criticism concerns output dynamics. Nelson and Plosser (1982) provide evidence for supply-side shocks by showing that aggregate output does not tend to be trend-reverting. This means that any shocks to output will cause permanent rather than temporary changes in output. A temporary shock would mean that once the shock dissipated, the level of output would return to its trend level. Therefore, if shocks tended to be temporary, then output would tend to be trend-reverting.

In most models, supply-side shocks tend to be permanent, while demand-side shocks tend to be temporary. Thus, the evidence that shocks are permanent, means that variations in output tend to be caused by supply-side shocks. However, it has been shown by Durlauff (1989), that in the presence of coordination failures, permanent shocks can be the result of aggregate demand shocks. As well, changes on the supply-side of the economy may not be independent of changes on the demand-side. If technological progress is dependent upon demand conditions, research and development expenditures, or 'learning-by-doing' effects, then changes in aggregate demand can induce technological changes on the supply-side, which would then have permanent effects on the level of output.

The third criterion concerns recessions. In an RBC model, recessions can be described as periods where technology declines. The argument is that how can the economy loose previous knowledge? The level of knowledge and thus technology may not increase, but it cannot possibly decrease. However, the definition of adverse technology shocks can be enlarged to include items such as changes to the legal and institutional framework, which can alter the incentives to adopt new technology.

As well, Corriveau (1994), shows that recessions do not need to be periods of declining technology. He states that recessions can be caused by an increase in the allocations of resources to research and development when there is an increased opportunity to succeed ex ante, but fails to materialize ex post. This leaves fewer resources allocated for production which uses the previous period's unchanged technology.

The representative agent framework has also come under attack by critics of RBC models. In order to overcome any aggregation problems, RBC models use a representative agent to mimic the behavior of millions of individual agents in the economy. This collapses the entire economy into a single utility function and single production function. Now suppose that all individuals have the same preferences, but they differ only by the amount of income they receive. In this case, the representative agent does not have to be well behaved, and the economy can generate a large number of unstable equilibria.

The preferences and reactions of individuals are not necessarily the same as the representative agent. In fact, it has been shown that even if every individual in the economy prefers situation a to situation b, the representative agent may prefer situation b to situation a. An example of this result occurring is given by Kirman (1992). In an economy with two individuals with preferences similar to Cobb-Douglas and fixed shares of total income, Kirman (1992) shows that both individuals will choose situation a to b, but that the representative agent or the aggregate results of the two individual choices will choose situation b to situation a. As well, the required well behaved aggregate relationships can occur in an economy where agents have bounded rationality, or agents follow simple rules of thumb.

Finally, the last major criticism of RBC models concerns unemployment. Many critics of RBC models argue that one of the biggest weaknesses of RBC models is the fact that unemployment is voluntary. As an example, critics talk about the Great Depression as a period where the large amount of unemployment cannot possibly be explained by intertemporal substitution and productivity shocks.

II.7. CONCLUSION

In terms of modeling frameworks, RBC theory is still relatively new, but it is still evident that the economy can be explained relatively well by a model of a competitive market economy, in which an aggregate technology shock affects the quantity of output produced from capital and labor inputs, which then causes fluctuations in the per-capita quantities of aggregate macroeconomic variables.

As Hansen (1985) and McGratten (1994b) show, the basic model of a competitive market economy, in which an aggregate technology shock generates fluctuations in aggregate macroeconomic variables can be improved by the addition of non-convex preferences, or demand-side shocks.

Another interesting aspect of RBC models, as pointed out by Cooley and Hansen(1989), is that there is no explicit role for money in influencing the fluctuations in output. In order to determine if this result occurs in U.S. data, the following chapter tests the implication that fluctuations in money have no effects on the fluctuations in output.

However, there still exists a number of criticisms that RBC theory must over come. Some of these criticisms are that RBC models rely on unobservable technology shocks, the evidence of permanent shocks in output as evidence of supply-side shocks, the use of the representative agent framework, and finally, the result that all unemployment is voluntary.

The greatest benefit of RBC models, is that they have caused many economists to reevaluate previous models of the economy and as a result, macroeconomics is once again a dynamic area of study.

TABLE 2.1
STANDARD DEVIATIONS OF PERCENTAGE DEPARTURES FROM TREND

Variable	U.S. Economy[a]	Basic Model[a]	Hansen Model[b]	Cooley-Hansen Model[c] Constant Growth Rate	Cooley-Hansen Model[d] AR Growth Rate
OUTPUT	1.76	1.76[e]	1.76[e]	1.76[e]	1.74[e]
CONSUMPTION	1.29	0.55	0.51	0.51	0.65
INVESTMENT	8.60	5.53	5.71	5.71	5.69
CAPITAL STOCK	0.63	0.47	0.47	0.48	0.48
HOURS	1.66	0.91	1.35	1.34	1.33
PRODUCTIVITY	1.18	0.89	0.50	0.51	0.50
PRICE LEVEL	CPI = 1.59 GNP Deflator = 0.98	N/A	N/A	0.51	1.93

NOTES: a: These results are from Table 1.1 in McCallum (1989), page 26.
b: These results are from Table 1 in Hansen (1985)
c: These results are from Table 1 in Cooley and Hansen (1989). The money supply grows at a constant rate ($\bar{g} = 0.99 - 1.15$).
d: These results are from Table 1 in Cooley and Hansen (1989). The money supply follows an autoregressive growth rate ($\bar{g} = 1.15$).
e: Shock variance set to provide match of output variation with actual data.

TABLE 2.2
CONTEMPORANEOUS CORRELATIONS WITH OUTPUT (DEPARTURES FROM TREND)

Variable	U.S. Economy[a]	Basic Model[a]	Hansen Model[b]	Cooley-Hansen Model[c] Constant Growth Rate	Cooley-Hansen Model[d] AR Growth Rate
OUTPUT	1.00	1.00	1.00	1.00	1.00
CONSUMPTION	0.85	0.89	0.87	0.87	0.70
INVESTMENT	0.92	0.99	0.99	0.99	0.97
CAPITAL STOCK	0.04	0.06	0.05	0.07	0.06
HOURS	0.76	0.98	0.98	0.98	0.98
PRODUCTIVITY	0.42	0.98	0.87	0.87	0.87
PRICE LEVEL	CPI = -0.48 GNP Deflator = -0.53	N/A	N/A	-0.87	-0.25

NOTES: a: These results are from Table 1.1 in McCallum (1989), page 26.
b: These results are from Table 1 in Hansen (1985)
c: These results are from Table 1 in Cooley and Hansen (1989). The money supply grows at a constant rate ($\bar{g} = 0.99 - 1.15$).
d: These results are from Table 1 in Cooley and Hansen (1989). The money supply follows an autoregressive growth rate ($\bar{g} = 1.15$).

TABLE 2.3
MEANS AND STANDARD DEVIATIONS OF PREDICTED AND U.S. TIME SERIES[a]

Variable	U.S. TIME SERIES		PREDICTED TIME SERIES	
	Mean	Standard Deviation	Mean	Standard Deviation
OUTPUT	2590	210	2600	208
INVESTMENT	591	42.1	603	67.2
GOVT. CONSUMPTION	598	117	609	87.1
CAPITAL STOCK	21400	831	21500	81.3
HOURS	301	9.28	297	10.2
CAPITAL TAX RATE	0.507	0.0388	0.505	0.0382
LABOUR TAX RATE	0.229	0.0277	0.240	0.0200

NOTES: a: These results are from Table 4 of McGratten (1994), page 591.

CHAPTER III: THE CAUSAL RELATIONSHIP BETWEEN MONEY AND OUTPUT

III.1. INTRODUCTION

As Cooley and Hansen (1989) argue, anticipated monetary shocks play no role in RBC models. Therefore, they argue that anticipated monetary shocks are neutral. That is, the changes in the money supply do not cause changes in output. However, this is in contrast to the Keynesian and Monetarist schools of thought, who argue that changes in the money supply do cause changes in output. Thus, from the Keynesian and Monetarist's point of view, money is not neutral in the short run.

In support of their argument, the Keynesian and Monetarist schools of thought turn to the accepted business cycle stylized fact that money and output are positively correlated, with money leading output. They view this result as evidence that changes in the money supply cause changes in the level of output.

RBC models in contrast, argue that the positive correlation between money and output indicates that the money supply is responding to economic activity, rather than the other way around. In this case, expected changes in output cause changes in the money supply. King and Plosser (1984, p.363), argue that within a RBC model "...monetary services are privately produced intermediate goods whose quantities rise and fall with real economic developments.".

As well, King and Plosser (1984) state that the financial industry provides accounting services which facilitate the market transactions which occur within the economy. The fact that changes in the money supply tend to lead the changes in the level of output is because financial services can be produced quicker than other goods in the economy, and thus changes in financial services will occur before changes in the level of output.

In an attempt to discriminate between competing models, I use three different causality tests in order to determine if changes in the money supply cause changes in the level of output (which is consistent with Keynesian and Monetarist models), or if changes in the level of output cause changes in the money supply, or if there is no relationship between the changes in the level of output and changes in the money supply (which are consistent with RBC models).

However, after the seminal article by Sims (1972), there has been a vast number of papers studying the causal relationship between money and output. The problem with this line of research is that the different studies of the same relationship offer differing and conflicting results with one another. Feige and Pearce (1979, p.522), then point out the following problem:

> " Such findings suggest that substantive economic results may not be robust with respect to the different empirical procedures employed. The reader is thus left to puzzle whether these differences are due to the particular causality test chosen, or when the causality framework is the same, to the particular choices made concerning time period of analysis, seasonal adjustment procedure, pre-filtering technique or the particular truncation chosen for the lag distribution."

In this particular analysis, I expand on a number of previous papers in order to address the issues raised by Feige and Pearce (1979). In particular, this analysis follows Thorten and Batten (1985), who argued that the causality test is dependent on the lag structure chosen. Therefore, the Schwarz criterion is used to statistically determine the lag structure. The issue of the particular causality test chosen is addressed by using three different causality tests, and the trend properties of the data are examined in order to determine the correct pre-filtering technique used.

For all three causality tests, causality is interpreted according to the criterion developed by C.W.J. Granger. For example, money Granger causes output if in a regression with the level of output as the dependent variable and distributed lags of the money supply as the independent variable, the distributed lags of the money supply are jointly statistically significant.

The first causality test analyzes a basic bivariate relationship between money and output. However, the results from this test may be misleading since the conclusions from parametric causality tests are sensitive to the functional form specification and the homoscedasticity and the normality of the errors.

The second causality test follows Holmes and Hutton (1990a), who develop a nonparametric causality test which uses the rank orderings of the variables. Holmes and Hutton (1988, 1990a), show that Granger causality conclusions achieved using the rank orderings are robust over alternative distributions of the error structure, and invariant to monotonic transformations of the variables. Also, if the parametric tests using the original variables satisfy the assumptions of correct functional form, homoscedasticity and normality of the errors, the results obtained using the nonparametric multiple rank F test are similar to the parametric results. Otherwise, the multiple rank F test has considerable power advantages over the conventional F test.

The final causality result applies the statistical approach used by Stock and Watson (1989) in their study of U.S. money - output causality. In this case, the conclusions obtained on whether changes in the money supply cause changes in output, are examined to see if the results hold when the price level and short term interest rates are included in the regression, and when explicit attention is paid to the trend specification of the data.

In the spirit of Belognia (1995), and Serletis and King (1994), who argue that any conclusions obtained are sensitive to the monetary aggregate used, the three causality tests are performed using twelve different monetary aggregates. The 12 monetary aggregates consist of 5 simple sum, 5 Divisia, and 2 FFDM monetary aggregates.

Section 2 gives a brief discussion of simple sum and Divisia monetary aggregates. The trend properties of the data are presented in Section 3. Section 4 presents the results from the basic bivariate relationship. Section 5 discusses the results obtained from the

Holmes and Hutton multiple rank F test, and the Stock and Watson causality tests are presented in section 6. Section 7 concludes.

III.2. DIVISIA AND SIMPLE SUM MONETARY AGGREGATES

The discussion in this section, of the difference between simple sum and Divisia monetary aggregates, is obtained from the work of Barnett, Fisher, and Serletis (1992), and King (1990).

The importance of differentiating between simple sum and Divisia monetary aggregates, is that simple sum aggregates are flawed index numbers and the theoretically correct Divisia monetary aggregate advocated by Barnett (1980) would be a better representation of the effects of monetary policy.

Through simple observation, individuals within the economy hold positive amounts of money and thus, these agents must be able to include the quantity of money as a meaningful single good within their decisions. This idea is brought out in Barnett's (1980, p.13) argument that

> " (i)f the concept of money has meaning then it follows that an aggregate of monetary assets must exist which is treated by the economy as if it were a single good, which we thereby can call 'money'. Such an aggregate is a function (of its component monetary quantities) which is separable from the economy's structure. That concept of money is the subject of aggregation theory and is the concept relevant to policy, since both aggregation theory and policy postulate the appearance of a monetary aggregate as a meaningful stably defined variable in the economy's structure."

The monetary aggregate used by central banks, and the monetary aggregate used in most empirical studies of monetary behavior, is the simple sum monetary aggregate.

The simple sum index is given by:

$$(3.2.1) \qquad Q = \sum_{i=1}^{N} x_i$$

where x_i is the ith monetary component. In this case, there is unitary weighting on each monetary component in the formation of the monetary aggregate. This implies that each monetary component yields exactly the same monetary services. For example, in the case of the M2 monetary aggregate, the monetary component personal fixed term deposits at banks has the same degree of "moneyness" or liquidity, and yields the same monetary services as another monetary component such as demand deposits at banks. Thus, in the simple sum index, personal fixed term deposits at banks would be a perfect substitute for demand deposits.

In order to measure money correctly, the monetary aggregate should be able to reflect the varying degrees of liquidity that the different monetary components have. Thus, a monetary component which is perfectly liquid, such as currency, would have a weighting of one, and a monetary component which is very illiquid, such as fixed term deposits, would have a weighting less than one. In an attempt to define such an aggregate, an economic approach to aggregation is combined to a statistical approach to aggregation.

The economic approach to monetary aggregation uses utility maximizing agents who face a two-stage optimization problem. In the first stage, the agent allocates expenditures over a broad range of categories, such as consumption, leisure, and monetary services. In the second stage, the agent allocates expenditures within each category.

Once again, suppose there exists an economy with identical agents with the same preferences over consumption, leisure and monetary services. The utility function becomes:

$$(3.2.2) \qquad u = u(c, l, x)$$

where c is a vector of consumption goods, l is time allocated to leisure, and x is a vector of monetary services.

The budget constraint states that the purchase of consumption goods, monetary services and leisure time; cannot exceed total income. Thus the budget constraint becomes:

(3.2.3) $$q'c + p'x + wl = y$$

where y is total income, q is a vector of consumption prices, p is a vector of prices for monetary services, w is the opportunity cost of leisure which is equal to the wage rate, and the primes indicate the transpose.

To be more specific, p is the user costs associated with the services of monetary assets and abstracting from any transaction costs, it can be defined as the discounted present value of the foregone interest by using the services of a particular asset. Thus, the price of the ith asset is:

(3.2.4) $$p_i = \frac{(R - r_i)}{(1+R)}$$

where R is the benchmark rate of return, and r_i is the rate of return on asset i.

In order to obtain a solution to this problem, it is assumed that the utility function satisfies the weak seperability condition in the services of monetary assets, which means:

(3.2.5) $$\frac{\partial[(\partial u/\partial x_i)/(\partial u/\partial x_j)]}{\partial \Omega} = 0 \qquad \text{where } \Omega = c, l \text{ and } i \neq j.$$

Thus condition states that the marginal rate of substitution between any two monetary assets is independent of the values of consumption and leisure.

The weak seperability condition implies that the utility function can be written as:

(3.2.6) $$u = u(c, l, f(x))$$

and the second stage optimization problem becomes:

(3.2.7) $$\underset{x}{\text{MAX}}\, f(x)$$

subject to

$$p'x = m$$

where m is the expenditure on the services of monetary assets as a proportion of total income.

In this case, $f(x)$ is the aggregator function for the monetary services problem defined by equation (3.2.7). Then using a specific and differentiable functional form for $f(x)$ and solving the second stage of the optimization problem, an inverse and/or a direct demand-function system can be obtained. Once these solution functions have been determined, specific monetary data can be used to eliminate and replace the unknown parameters of the aggregator function. The estimated function is then called an economic (or functional) monetary index and the calculated value at any point is an economic monetary-quantity index number.

An example of a specific and differentiable aggregator function is a weighted linear function of the form:

(3.2.8) $$f(x) = \sum_{i=1}^{N} a_i x_i .$$

In this case, if $a_i = 1$ for all i, then the weighted linear function collapses down to the simple sum aggregate. However, as stated earlier, the simple sum aggregate does not allow for differing degrees of monetary services.

The preferred specification for the aggregator function would have a flexible functional form. The benefits of flexible functional forms are stated by Barnett, Fisher, and Serletis (1992, p.2096):

> " Flexible functional forms - such as the translog - can locally approximate to the second order any unknown functional form for the monetary services aggregator function, and even higher quality approximations are available."

The translog, or transcendental logarithmic aggregator function is a second order Taylor series expansion of the following form:

(3.2.9) $$f(x) = a_0 + \sum_{i=1}^{N} a_i \ln x_i + \tfrac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} \beta_{ij} \ln x_i \ln x_j$$

where $\beta_{ij} = \beta_{ji}$ for all $i \neq j$.

However, the problem with flexible functional forms is that it is necessary for the unknown parameters to be estimated and the aggregate which is developed in this manner is dependent upon the specification and estimation procedures used. These problems can be circumvented through the use of statistical index number theory which allows a parameter free approximation of the aggregator function.

The preferred statistical index is the Divisia index because unlike the Layspeyres (Consumer Price Index and real GNP), or the Paasche index (Implicit GNP Deflator), the Divisia index captures all of the relevant information when there is a price and quantity change between the base year and the endpoint. The discrete time formula of the Divisia quantity index in growth rates is:

$$\ln Q_t^D - \ln Q_{t-1}^D = \sum_{i=1}^{N} s_{it}^*(\ln x_{it} - \ln x_{i,t-1}) \tag{3.2.10}$$

where Q_t^D is the Divisia quantity index at time t, s_{it}^* is the weighting of the monetary asset x_t at time t, and is equal to:

$$s_{it}^* = \tfrac{1}{2}(s_{it} + s_{i,t-1})$$

and

$$s_{it} = \frac{p_{it}x_{it}}{\sum p_{it}x_{it}}$$

where s_{it} is the expenditure share of monetary asset i during period t.

The connection between the aggregator function and the statistical index is provided by Diewert (1976,1978). The contribution by Diewert is attaching economic properties to the statistical indices. These properties depend on the assumption of utility maximizing economic agents and they relate to the statistical indices' effectiveness in tracking a particular functional form for the unknown aggregator function.

The statistical indices are termed exact if the specific aggregator function is linked to a particular statistical index, and if the aggregator function is a flexible functional form, then the statistical indices are termed superlative. Diewert (1976), has shown that the Divisia index is exact to the linearly homogeneous translog flexible functional form. Thus, the Divisia index is a superlative index number which is consistent with economic aggregation theory of utility maximization and statistical index number theory.

Therefore, unlike the simple sum monetary aggregate, the Divisia monetary aggregate allows for varying degrees of liquidity across monetary assets, and is also well grounded in economic theory.

Figures 3.1 to 3.4 show all 12 monetary aggregates between 1960 and 1993. The aggregates have been normalized to 100 in the base year of 1960. Except for M1, there appears to be a significant difference between the Divisia and simple sum aggregates, and that around 1970, this divergence begins to take place. Appendix I gives a detailed description of what is included in each monetary aggregate.

The two new monetary aggregates introduced by Fleissig, Fisher and Serletis (1995), consists of testing the raw data for consistency with the General Axiom of Revealed Preference, using the NONPAR procedure of Varian (1982). For the groups of data that pass such tests, the issue of weak seperability of one group from another is tested in order to establish relevant groupings. Once the relevant groupings have been determined, the elements of the group are aggregated using the Divisia index, because the Divisia index maintains the microeconomic characteristics of the data.

The new aggregate FFDM1 is aggregated from currency, consumer demand deposits, other checkable deposits, and small NOW accounts at thrifts and commercial banks. The new monetary aggregate FFDM2 consists of FFDM1 plus savings deposits at commercial banks and Savings and Loans, and small time deposits at commercial banks and thrifts.

III.3. TREND PROPERTIES OF THE DATA

The data used in the causality analysis, consists of monthly data from 1960:1 to 1993:4 for the United States. The series used are industrial production, consumer price index, Treasury bill rate, commercial paper rate, simple sum and Divisia indices for M1A, M1, M2, M3, and L. As well the monetary aggregates FFDM1 and FFDM2 are also studied.

In order for the causality tests to be interpreted correctly, the variables used in the tests must be stationary. The following summary of stationarity, unit roots and cointegration is based on chapter 5 of Cuthberson, Hall, and Taylor (1992).

A stationary series will have a constant mean, and a constant, finite variance. In other words, the mean is independent of time, and the variance is bounded by some finite number and does not vary systematically with time. Therefore, after a random shock has disturbed the series, the series will tend to return to its mean and the fluctuations around the mean will approximately have a constant amplitude.

The simplest representation of a nonstationary process, is a random walk without drift:

(3.3.1) $$x_t = x_{t-1} + \varepsilon_t$$

where ε_t is a white noise error term with zero mean and constant variance δ^2. The variance of x is:

(3.3.2) $$\mathrm{Var}(x_t) = t\delta^2$$

and becomes infinitely large as t tends to infinity. Thus x_t is a nonstationary series since the variance is not finite.

The series can be made stationary by first differencing. By taking the first difference of the series, equation (3.3.1) becomes:

(3.3.3) $$x_t - x_{t-1} = \varepsilon_t$$

which has a constant mean, and finite variance δ^2. Thus, x is described as a difference stationary series.

There are a number of ways to test for a stationary series. The most widely used, and the one used here, is the Augmented Dickey-Fuller test [see Dickey and Fuller (1981)]. The Augmented Dickey-Fuller (ADF) test, tests for a random walk process in the series, and has the form:

(3.3.4) $$z_t = \alpha_0 + \alpha_1 t + \alpha_2 z_{t-1} + \sum_{j=1}^{k} \beta_j \Delta z_{t-j} + \varepsilon_t$$

where z is the logarithm of the series, and k is chosen such that the residuals are white noise. We then test the null hypothesis of $\hat{\alpha}_2 = 1$, and if the null hypothesis cannot be rejected, then the series is nonstationary. Since we are testing $\hat{\alpha}_2 = 1$, these stationarity tests are also referred to as unit root tests, and if the null hypothesis cannot be rejected, then the series contains at least one unit root.

In order to determine the exact order of integration, higher orders of differencing are performed and the ADF tests are reapplied. This procedure is performed until the ADF test rejects the null hypothesis of $\hat{\alpha}_2 = 1$. For example, if the ADF test on the second differences of the series rejects the null hypothesis of $\hat{\alpha}_2 = 1$, then the series would contain a single unit root, and the series would be integrated of order 1 or I(1) [in the terminology of Engle and Granger (1987)]. In general, a series which is differenced d times in order to be stationary, is integrated of order d and is denoted as I(d).

In this analysis, the ADF tests are performed with a lag structure of 7. This follows Said and Dickey (1984), who determine the number of lags by taking the total number of observations and raising it to the power of one third.

The test statistic $\hat{\alpha}_2$ does not follow the typical Student's t-distribution, because the distribution relies on the assumption of stationarity, but rather, it uses the critical values which are generated using Monte Carlo experiments by Dickey and Fuller (1981).

As tables 3.1 and 3.2 show, based on the "with trend" version of the ADF test, the null hypothesis of a unit root in levels cannot be rejected for all series, while the null hypothesis of a second unit root is rejected, except for Sum M3, Sum L, and the price level which appear to be integrated of order 2, or I(2).

The only exception to only using stationary series in the causality tests is if the series being studied are cointegrated. In the case of cointegrating variables, the stochastic trend components of two or more variables exactly offset each other to give a stationary linear combination. Thus, in the long run, if two or more series move closely together, so that even though the series may be trended, the difference between them is stationary.

Since the difference between the variables is stationary, the error term in a regression will have well defined first and second moments. Thus, if the variables are cointegrated, the causality tests can be run with the non-stationary variables.

As with the unit root tests, there are a number of different cointegration tests that can be used. Since this analysis is only interested in determining the appropriate form of the causality tests, and not the specific cointegrating vector, the Engle and Granger (1987) cointegration test is used.

The first step of the Engle and Granger (1987) cointegration test is to run the regression:

$$\text{(3.3.5)} \qquad Y_t = \beta_0 + \beta_1 X_t + \varepsilon_t$$

where Y and X are two nonstationary variables with the same order of integration. The next step is test to test to see if the residuals are stationary by running an ADF test on the residuals of the form:

$$\text{(3.3.6)} \qquad \Delta\hat{\varepsilon}_t = \alpha\hat{\varepsilon}_{t-1} + \sum_{i=1}^{b} \phi_i \hat{\varepsilon}_{t-i} + \xi_t .$$

If we reject the null hypothesis that $\hat{\alpha} = 0$, then the residuals are stationary, and the variables Y and X are cointegrated.

The Engle-Granger cointegration test is performed using SHAZAM 7.0. As with the unit root tests, a special critical value must be used because the OLS estimator chooses the residuals in the cointegrating regression to have as small a sample variance as possible. In this case, even if the variables are not cointegrated, the OLS estimator will make the residuals look as stationary as possible. Therefore, the critical values have to be raised slightly, and the critical values from Davidson and MacKinnon (1993) are used.

In this analysis, three forms of the Engle-Granger cointegration test are used. The first is:

(3.3.7) $$y_t = \beta_0 + \beta_1 t + \beta_2 m_t + \varepsilon_t$$

where y is the logarithm of industrial production, and m is the logarithm of the monetary aggregate. The second form of the cointegration test is:

(3.3.8) $$y_t = \beta_0 + \beta_1 t + \beta_2 m_t + \beta_3 p_t + \beta_4 R_{1t} + \varepsilon_t$$

where p is the logarithm of the consumer price index, and R_{1t} is the Treasury bill rate. The final form of the cointegrating regression is:

(3.3.9) $$y_t = \beta_0 + \beta_1 t + \beta_2 m_t + \beta_3 p_t + \beta_4 R_{2t} + \varepsilon_t$$

where R_{2t} is the commercial paper rate. For all three cases, the stationarity test on the residuals is the same.

As table 3.3 shows, there is evidence that in all three cases, the variables are not cointegrated. Combining the results from tables 3.1 to 3.3, implies that the variables are integrated of order one, and not cointegrated. This means that the appropriate form of the causality test uses the first differences of all variables.

Finally, Stock and Watson (1989) argue that the money-income causality tests are sensitive to unit roots and to the time trends in the series. Therefore, like Stock and Watson (1989), the order of the deterministic components are analyzed by regressing the first difference of each series against a constant, time and its own lags.

In this case, the lag lengths are determined statistically using Schwarz's (1978) criterion. The Schwarz criterion (S.C.), balances the bias associated with a parsimonious parameterization, against the inefficiency associated with overparameterization. The S.C. is used as the model selection criterion because Yi and Judge (1988) show that the S.C.'s asymptotic probability of overestimating the true size of the model is zero, whereas the other model selection criteria asymptotically overestimate the true size of the model with a positive probability. The optimal lag structure is determined by minimizing the log S.C. which is defined as:

(3.3.10) $$\log \mathrm{S.C.} = \ln \tilde{\sigma}^2 + \frac{K \ln N}{N}$$

where $\tilde{\sigma}^2$ is the estimated variance, K is the number of explanatory variables, and N is the number of observations. Thus, the S.C. tries to minimize the variance of the estimates, but the minimum variance is offset by the penalty of increasing the lag lengths.

The trend regression is given by:

(3.3.11) $$\Delta m_t = \alpha_0 + \alpha_1 t + \sum_{i=1}^{a} \delta_i \Delta m_{t-i} + \xi_t$$

where the lag length a is chosen using S.C.. We then test the null hypothesis $\hat{\alpha}_1 = 0$. As table 3.4 shows, Sum M1, Sum M2, Sum M3, Divisia M1A, and Divisia M1 exhibit evidence of a deterministic trend.

The drift regression is given by:

(3.3.12) $$\Delta m_t = \beta_0 + \sum_{i=1}^{b} \gamma_i \Delta m_{t-i} + \zeta_t$$

where the lag length b is chosen using S.C.. We then test the null hypothesis $\hat{\beta}_0 = 0$. Table 3.4 provides evidence that all monetary aggregates have significant drifts.

III.4. BIVARIATE GRANGER CAUSALITY TESTS

As stated earlier, the definition of causality that I use is based on Granger's notion of causality, which states that X "causes" Y, if the past history of X can be used to predict Y more accurately than just using the past history of Y. The analysis in this section follows the seminal work on money-income causality by Sims (1972), by using a bivariate process to determine the direction of causality.

In this case, the test for Granger causality consists of the following set of equations:

(3.4.1)
$$Y_t = \alpha_0 + \sum_{i=1}^{a} \gamma_i Y_{t-i} + \sum_{j=1}^{b} \beta_j X_{t-j} + \varepsilon_t$$
$$X_t = \theta_0 + \sum_{i=1}^{c} \delta_i X_{t-i} + \sum_{j=1}^{d} \phi_j Y_{t-j} + \xi_t$$

where X and Y are stationary time series, and the residuals ε and ξ are white noise disturbances. Since the variables are stationary, an asymptotic F test can be used to determine if the coefficients are jointly equal to zero.

This causality test can have four different outcomes. First of all, if $\beta_j = 0$ for all j, and $\phi_j \neq 0$ for all j, then Y Granger causes X. If $\beta_j \neq 0$ for all j, and $\phi_j = 0$ for all j, then X Granger causes Y. If $\beta_j = 0$ for all j, and $\phi_j = 0$ for all j, then there is no relationship between X and Y. Finally, if $\beta_j \neq 0$ for all j, and $\phi_j \neq 0$for all j, then there exists feedback between the two equations.

In order to determine if money Granger causes output, the following regression is run:

(3.4.2)
$$\Delta y_t = \alpha_0 + \sum_{i=1}^{a} \gamma_i \Delta y_{t-i} + \sum_{j=1}^{b} \beta_j \Delta m_{t-j} + \varepsilon_t$$

where y is the logarithm of industrial production, m is the logarithm of the monetary aggregate, and the lag lengths a and b are chosen such that the S.C. is minimized. The entire parameter space is searched, where the maximum number of months searched for each lag was 15. We then test the null hypothesis $\beta_j = 0$ for all j. If we can reject the null hypothesis, then there is evidence that money Granger causes output.

In order to determine if output Granger causes money, the following regression is run:

$$\Delta m_t = \theta_0 + \sum_{i=1}^{a} \delta_i \Delta m_{t-i} + \sum_{j=1}^{d} \phi_j \Delta y_{t-j} + \xi_t \tag{3.4.3}$$

and the lag lengths c and d are chosen such that the S.C. is minimized. We then test the null hypothesis $\phi_j = 0$ for all j, and if we can reject the null hypothesis, then there is evidence that output Granger causes money.

First of all, table 3.5 provides evidence that only Sum M2, Divisia M2, Divisia M3, and Divisia L, Granger cause industrial production. All other monetary aggregates except Sum M1 (which exhibits feedback), are independent of industrial production. Therefore, there is evidence supportive of the Keynesian and Monetarist's point of view, that changes in the money supply cause changes in the level of output, and there is evidence that supports the RBC theory that money is neutral. As well, all monetary aggregates do not support the reverse causality theory which is also supported by RBC theorists, which states that changes in output cause changes in the money supply.

Secondly, the results in table 3.5 support Belognia (1995), who argues that the analysis of the effects of the money supply, is dependent upon which monetary aggregate is used. For example, the results for Sum M3 state that changes in the money supply are independent of the changes in the level of output, but the results for Divisia M3 state changes in the money supply cause changes in the level of output.

Therefore, a general statement concerning the effects of the money supply has on the level of output cannot be made, since the results are dependent upon which monetary aggregate is used.

III.5. HOLMES-HUTTON GRANGER CAUSALITY TESTS

As argued earlier, the parametric Granger causality tests that are used to test the causal relationship between money and output are sensitive to the particular causality test used, the method of detrending nonstationary time series, lag length selection, and functional form specification. As well, the results of the parametric Granger causality tests are dependent upon a specific functional form, and the homoscedasticity and the normality of the errors. Therefore, this section comes from the work of Holmes and Hutton (1990a), who argue that causality tests should be performed using a methodology - the multiple rank F test - where the results will be invariant to monotonic transformations of all variables, and be robust to alternative distributions of the error terms.

Holmes and Hutton (1990a), state that if X causes Y, then Y must be a function of X:

(3.5.1) $Y = f(X)$

and if Y is a function of X, then any strictly monotonic transformation of some or all of the variables in (X,Y), will not eliminate this causal or functional relationship, including the rank transformation, which ranks the observations from lowest (being 1), to largest (being N).

The invariance to the rank transformation only holds if in the case of fixed X variables, no ties occur, and in the case of some or all stochastic X, the error terms are generated by a continuous c.d.f.. When this occurs, there exists a one to one relationship between any particular variable X, and its rank R(X). Therefore, if X causes Y, then:

(3.5.2) $R(Y) = F[R(X)];$ where $F = R f R^{-1}$.

The benefit of using the rank ordering of the variable is that the multiple rank F test can be used rather than the normal parametric F test, to test for the causal relationship. The only difference between the multiple rank F test, and the parametric F test, is that the rank orderings of the variables are used rather than the raw data.

Conover and Iman (1982) and Olejnik and Algina (1985), have found that there are a number of significant benefits associated with using the multiple rank F test. By running Monte Carlo studies, Conover and Iman (1982) and Olejnik and Algina (1985) compare the power, and the Type I error frequencies (where Type I errors are rejections of the null hypothesis when in fact, it is true), of the rank and parametric F tests for the equality of regression lines for both extreme and less extreme departures from normality of the error distribution, normal and nonnormal distributions of the covariate, varying strengths of the relationship, and for various sample sizes. These authors report that in small samples with stochastic X, the multiple rank F test is robust against the nonnormality of the errors, and for the normal distribution, the loss in power due to the ranks versus the raw data is small. As well, the power advantages of the multiple rank F test increased with more extreme departures from the assumptions of normality and homoscedasticity, and as the relationship weakened.

As Holmes and Hutton (1990a, p.90) state:

> " With little to lose in employing the multiple rank F test when all parametric assumptions are met and much to be gained when the relationship is weak and such assumptions are violated, the rank F test appears to be an appealing alternative to parametric testing."

Therefore, the multiple rank F test is used to determine the relationship between money and output.

In order to determine if money Granger causes output, the following regression is run:

(3.5.3) $$R(\Delta y_t) = \alpha_0 + \sum_{i=1}^{a} \gamma_i R(\Delta y_{t-i}) + \sum_{j=1}^{b} \beta_j R(\Delta m_{t-j}) + \varepsilon_t$$

where y is the logarithm of industrial production, m is the logarithm of the monetary aggregate, R indicates the rank ordering of the variable, and the rank ordering of the lag variables are done separately. As before, the lag lengths a and b are chosen such that the S.C. is minimized.

In order to determine if output Granger causes money, the following regression is run:

(3.5.4) $$R(\Delta m_t) = \theta_0 + \sum_{i=1}^{c} \delta_i R(\Delta m_{t-i}) + \sum_{j=1}^{d} \phi_j R(\Delta y_{t-j}) + \xi_t$$

and the lag lengths c and d are chosen such that the S.C. is minimized.

As table 3.6 shows, the results for the Divisia monetary aggregates are the same whether the multiple rank F test or the parametric F test is used. The tests using Divisia M1A, Divisia M1, FFDM1 and FFDM2, all provide evidence that the changes in the money supply are independent of the changes in output. For Divisia M2, Divisia M3 and Divisia L, it appears that changes in the money supply cause changes in the level of output.

Table 3.6 also shows, that there are significant changes in the results for the simple sum monetary aggregates. First of all, using the parametric F test, the causality test involving Sum M1 provided evidence of feedback between money and output, but when the multiple rank F test is used, the changes in the money supply are independent of the changes in output. Second, table 3.5 shows that when using the parametric F test, the changes in Sum M3 are independent of the changes in output, but when the multiple rank F test is used, table 3.6 shows that changes in Sum M3 cause changes in output. Finally, for the remaining simple sum monetary aggregates, the results are the same whether or not the multiple rank F test is used.

The differences between the results of the two tests is probably due to the weakness of the relationship between Sum M1 and industrial production, and Sum M3 and industrial production. As argued earlier, in such a case, the multiple rank F test has significant power advantages.

Therefore, as with the Granger causality results using the parametric F test, no general statement can be made about the relationship between money and output when the Granger causality results are determined using the multiple rank F test, because the results vary depending on which monetary aggregate is used. However, there is still no evidence supporting the reverse causality theory.

III.6. STOCK-WATSON GRANGER CAUSALITY TESTS

Sections 4 and 5, showed that some monetary aggregates Granger cause output, and thus have strong predictive values in forecasting industrial production. This evidence is supportive of the Keynesian and Monetarist point of view of the effectiveness of monetary policy. The remaining monetary aggregates are independent of output, and thus have limited value in forecasting output. This evidence is supportive of the RBC point of view that movements in aggregate output have real rather than monetary origins.

However, Eichenbaum and Singleton (1986), found that the inclusion of inflation and the interest rate decreases the importance of money That is, the marginal predictive value of money decreases in the output equation. This result is refuted by Bernanke (1986), who emphasized that when a time trend is added to the causality regression, such as Runkle (1987) who used a linear time trend, and Litterman and Weis (1985) who use a quadratic time trend, the marginal predictive value of money increases substantially in the four variable system which includes inflation and interest rates.

Some RBC advocates argue that changes in the level of output are caused directly by the changes in the interest rate. Therefore, while changes in the money supply may seem to affect the level of output, it is only because money is related to the interest rate and as a result, any causation between the money supply and the level of output is the result of omitting an important variable, the interest rate. If this is the case, then we would expect that the inclusion of the interest rate would cause the marginal predictive values of the monetary aggregates to decrease, and as a result, the effects of changes in the money supply should be analyzed through the indirect effect by using prices and interest rates, rather than by the direct effect of money itself.

In order to determine whether or not the inclusion of interest rates and the time trend affects the marginal predictive value of the monetary aggregates, I follow the work of Stock and Watson (1989) who include inflation, the interest rate, and a polynomial function of time in order to determine the marginal predictive value of money.

Therefore, I consider the following specification with stationary variables:

$$(3.6.1)\ \Delta y_t = \alpha_0 + \sum_{i=1}^{a} \gamma_i \Delta y_{t-i} + \sum_{j=1}^{b} \beta_j \Delta p_{t-j} + \sum_{k=1}^{c} \delta_i \Delta m_{t-i} + \sum_{l=1}^{d} \theta_i \Delta R_{t-i} + f(t) + \varepsilon_t$$

where y is the logarithm of industrial production, p is the logarithm of the consumer price index, m is the logarithm of the monetary aggregate, and R is the nominal interest rate. $f(t)$ is a polynomial function of time, and ε is a standard white noise disturbance term. The inclusion $f(t)$ is equivalent to detrending each variable individually, and thus the causality test focuses on the marginal predictive value of detrended money growth. As with Stock and Watson (1989), I test for causality with no time trend, with a linear time trend, and with a quadratic time trend.

Stock and Watson (1989), use the Treasury bill rate as the short term interest rate in equation (3.6.1). However, Friedman and Kuttner (1993) argue that the Stock and Watson (1989) results are not robust to different short term interest rates such as the commercial paper rate.

Friedman and Kuttner (1993), explain that the commercial paper rate, which is the interest rate on short term unsecured borrowing by corporations, and the Treasury bill rate, which is the interest rate on unsecured borrowing by the U.S. Government, will each provide a better gauge of the financial prices that matter for the determination of real economic activity, depending on the question being asked. If you are trying to capture the influence that interest rates have on the spending behavior of private sector borrowers, then the commercial paper rate is superior to measure this effect. If you are trying to capture the influence that interest rates have on the behavior of those who save and invest, then the Treasury bill rate will be superior, because it better represents the returns available to most savers. Therefore, like Friedman and Kuttner (1993), I use both the commercial paper rate, and the treasury bill rate.

Unlike previous studies, the lag lengths of equation (3.6.1) are determined using the S.C. statistical procedure. Since there are now four variables, searching the entire parameter space becomes computationally prohibitive. Thus, I follow Serletis (1990), and use a sequential procedure to determine the lag structure.

The first step of the sequential procedure, is to use the S.C. to determine the optimal order of the one-dimensional autoregressive process for Δy_t alone. The next step is to fix the lag structure for Δy_t and use the S.C. to determine the optimal bivariate relationship. Third, start with the optimal bivariate autoregressive model and use the S.C. to determine the optimal trivariate model. This continues until the entire lag structure is specified. In all cases, 15 was set to be the maximum number of potential lags for each variable.

First of all, table 3.7 shows that the inclusion of inflation and the interest rate changes the results for only 3 of the monetary aggregates. For Sum M1, Sum L, and Divisia M1, the monetary aggregate goes from having no marginal predictive value, to having significant marginal predictive values for output. These results are consistent with the results of Stock and Watson (1989).

For Sum M1A, and Divisia M1A, the monetary aggregate still does not have any marginal predictive value. For the rest of the monetary aggregates, they still have statistically significant marginal predictive values.

Friedman and Kuttner (1993), find that even though the F statistics for the effect of the interest rate on income are larger for the commercial paper rate, in no case did this have a significant effect on the marginal predictive value for money. The evidence presented in table 3.7 confirms the results found in Friedman and Kuttner (1993), that the marginal predictive value for money is unaffected by the short term interest rate used, even though the commercial paper rate had a higher F statistic.

Finally, for Sum M2, Sum M3 and Sum L, the inclusion of the linear and quadratic time trend caused the marginal predictive value of the monetary aggregate to become statistically insignificant. For the remaining monetary aggregates, the inclusion of the different time trends has no significant effect on the marginal predictive value of money. this result is in contrast to the results of Stock and Watson (1989).

This section provides evidence that the inclusion of prices and interest rates into the causality regression, results in the monetary aggregates having a strong marginal predictive value in forecasting industrial production, and that the inclusion of time trends has no significant effect on these results. Therefore, there still may have been an omitted variable problem, but the changes in the money supply have a direct effect on the level of output rather than just an indirect effect through the interest rate.

III.7. CONCLUSION

The goal of this analysis was to provide evidence supporting either the Keynesian and Monetarist point of view, or the RBC point of view, in an attempt to help discriminate between competing schools of thought. However, as with previous studies, I was unable to obtain convincing evidence supporting one school of thought over the other. What I did find, was that the results depended on the monetary aggregate used in the analysis.

Even though we cannot state that in general money is neutral, or money causes output, or even output causes money, we still obtained a number of other conclusions.

First of all, it appears that the broader based monetary aggregates such as M2, M3, and L do provide evidence that money Granger causes industrial production. Second, like Belognia (1995), there appears to be a difference in the results obtained using simple sum and Divisia monetary aggregates, at least in the two bivariate models.

With results consistent with Stock and Watson (1989), and Friedman and Kuttner (1993), the inclusion of a short term interest rate does tend to increase the marginal predictive value of money, but that the short term interest rate can be either the Treasury bill rate or the commercial paper rate, and that the inclusion of different time trends does not significantly alter the results.

Therefore, for policy analysis and model feasibility testing, it appears that researchers will have to make explicit decisions concerning whether or not they want to use the simple sum, or the theoretically correct Divisia monetary aggregate, and whether or not the monetary aggregate is narrowly or broadly defined.

Furthermore, the use of the new FFDM monetary aggregates does not appear to perform well in forecasting output in any of the three causality tests, and it also appears that the money and output relationship still remains a puzzle that needs to be addressed in macroeconomics.

NORMALIZED UNITED STATES MONETARY AGGREGATES

Figure 3.1

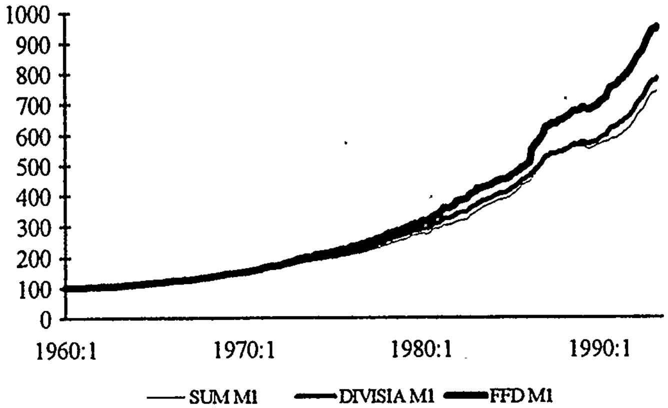

Figure 3.2

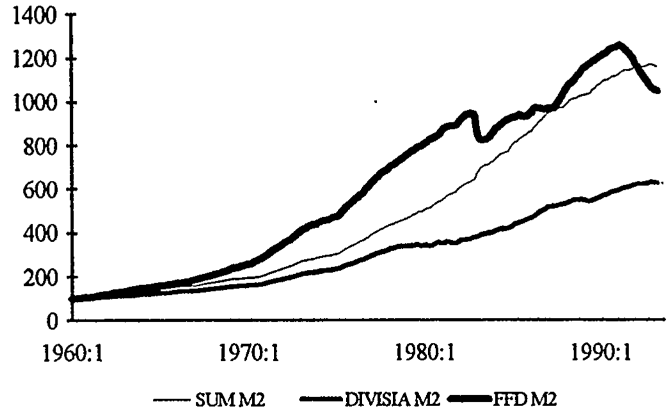

Figure 3.3

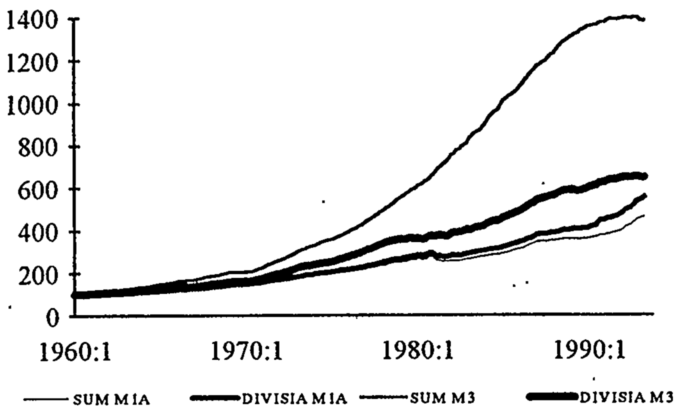

Figure 3.4

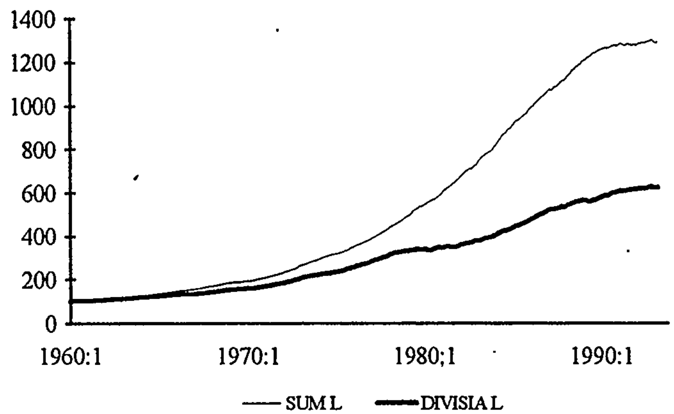

TABLE 3.1
AUGMENTED DICKEY-FULLER (ADF) UNIT ROOT TESTS IN LEVELS

Regression: $\Delta z_t = \alpha_0 + \alpha_1 t + \alpha_2 z_{t-1} + \sum_{j=1}^{k} \beta_j \Delta z_{t-j} + \varepsilon_t$

VARIABLE	WITHOUT TREND	WITH TREND
INDUSTRIAL PRODUCTION	-2.141	-2.772
CONSUMER PRICE INDEX	-0.125	-2.153
T-BILL RATE	-1.760	-1.324
COMMERCIAL PAPER RATE	-1.737	-1.244
SUM M1A	0.759	-2.172
SUM M1	1.971	-2.528
SUM M2	-1.627	0.870
SUM M3	-1.990	1.250
SUM L	-1.492	0.244
DIVISIA M1A	1.283	-2.154
DIVISIA M1	2.454	-2.862
DIVISIA M2	-0.948	-1.054
DIVISIA M3	-1.269	-0.676
DIVISIA L	-1.087	-0.886
FFD M1	0.558	-2.143
FFD M2	-2.400	0.912

NOTES: Sample period, monthly data 1960:1 - 1993:4. All series were first transformed into logarithms (except the nominal interest rates). Results are reported for an ADF statistic of order 7 -- see Said and Dickey (1984). The 95% critical value of the ADF test is -2.869 and -3.422 for the "no trend" and "trend" versions of the test, respectively. An asterisk indicates significance at the 5% level.

TABLE 3.2
AUGMENTED DICKEY-FULLER (ADF) UNIT ROOT TESTS IN FIRST DIFFERENCES OF LEVELS

Regression: $\Delta z_t = \alpha_0 + \alpha_1 t + \alpha_2 z_{t-1} + \sum_{j=1}^{k} \beta_j \Delta z_{t-j} + \varepsilon_t$

VARIABLE	WITHOUT TREND	WITH TREND
INDUSTRIAL PRODUCTION	-5.838*	-6.030*
CONSUMER PRICE INDEX	-2.728	-2.666
T-BILL RATE	-7.372*	-7.451*
COMMERCIAL PAPER RATE	-7.461*	-7.552*
SUM M1A	-4.860*	-4.920*
SUM M1	-4.407*	-4.862*
SUM M2	-3.690*	-4.016*
SUM M3	-2.892*	-3.347
SUM L	-2.325	-2.619
DIVISIA M1A	-4.970*	-5.135*
DIVISIA M1	-4.552*	-5.220*
DIVISIA M2	-4.041*	-4.120*
DIVISIA M3	-3.714*	-3.898*
DIVISIA L	-3.642*	-3.743*
FFD M1	-4.953*	-5.006*
FFD M2	-3.500*	-4.525*

NOTES: Sample period, monthly data 1960:1 - 1993:4. All series were first transformed into logarithms (except the nominal interest rates). Results are reported for an ADF statistic of order 7 -- see Said and Dickey (1984). The 95% critical value of the ADF test is -2.869 and -3.422 for the "no trend" and "trend" versions of the test, respectively. An asterisk indicates significance at the 5% level.

TABLE 3.3
ENGLE-GRANGER COINTEGRATION TESTS

Regression: **(1)** $Y_t = \beta_0 + \beta_1 t + \beta_2 X_t + \varepsilon_t$

(2) $\Delta\hat{\varepsilon}_t = \alpha\hat{\varepsilon}_{t-1} + \sum_{i=1}^{b} \phi_i \hat{\varepsilon}_{t-i} + \zeta_t$

VARIABLE	ENGLE-GRANGER COINTEGRATION TESTS (m,y)	(m,y,p,R_1)	(m,y,p,R_2)
SUM M1A	-3.1694	-3.1221	-3.7164
SUM M1	-3.4315	-3.8129	-3.2204
SUM M2	-3.1523	-3.4574	-3.4533
SUM M3	-3.2136	-3.4572	-3.5930
SUM L	-2.9891	-3.2433	-3.4281
DIVISIA M1A	-3.1343	-3.1531	-3.2379
DIVISIA M1	-3.7443*	-3.3971	-3.3518
DIVISIA M2	-3.3048	-2.8406	-3.1796
DIVISIA M3	-3.3689	-2.9059	-3.2513
DIVISIA L	-3.2398	-2.8945	-3.5541
FFD M1	-3.8124*	-3.2910	-3.5116
FFD M2	-3.4614	-3.4370	-3.5392

NOTES: Sample period, monthly data 1960:1 - 1993:4. All series were first transformed into logarithms (except for th interest rates. The 10% critical value of the cointegration test is -3.50 for the two variable system, and -4.15 for the four variable system. An asterix indicates significance at the 10% level. R_1 is the Treasury bill rate, and R_2 is the commercial paper rate.

TABLE 3.4
TESTS FOR TREND AND DRIFT

Trend Regression: $\Delta m_t = \alpha_0 + \alpha_1 t + \sum_{i=1}^{a} \delta_i \Delta m_{t-i} + \zeta_t$

Drift Regression: $\Delta m_t = \beta_0 + \sum_{i=1}^{b} \gamma_i \Delta m_{t-i} + \xi_t$

VARIABLE		TIME		DRIFT
SUM M1A	(1)	1.220	(1)	8.124**
SUM M1	(1)	3.655**	(5)	5.090**
SUM M2	(1)	-2.001*	(1)	7.283**
SUM M3	(3)	-2.167*	(3)	4.066**
SUM L	(3)	-1.640	(3)	3.983**
DIVISIA M1A	(1)	1.995*	(1)	9.352**
DIVISIA M1	(1)	4.172**	(1)	11.130**
DIVISIA M2	(1)	-0.960	(1)	7.460**
DIVISIA M3	(1)	-1.532	(1)	7.438**
DIVISIA L	(1)	-1.051	(1)	8.300**
FFD M1	(1)	1.587	(1)	10.990**
FFD M2	(12)	0.503	(12)	3.810**

NOTES: Sample period, monthly data 1960:1 - 1993:4. All series were first transformed into logarithms. Numbers in parentheses indicate the optimal (in the minimum SC sense) lag. Test statistics are significant at the **1%, *5%, and +10% level.

TABLE 3.5
GRANGER CAUSALITY RESULTS

Regression: (1) $\Delta y_t = \alpha_0 + \sum_{i=1}^{a} \gamma_i \Delta y_{t-i} + \sum_{j=1}^{b} \beta_j \Delta m_{t-j} + \varepsilon_t$

(2) $\Delta m_t = \theta_0 + \sum_{i=1}^{c} \delta_i \Delta m_{t-i} + \sum_{j=1}^{d} \phi_j \Delta y_{t-j} + \xi_t$

VARIABLE		m→y F-VALUE		y→m F-VALUE	DIRECTION OF CAUSALITY
SUM M1A	(2,1)	3.0101 [1,393]	(1,1)	0.2857 [1,395]	NONE
SUM M1	(2,1)	4.5986* [1,393]	(5,2)	3.7037 [2,386]	m↔y
SUM M2	(2,1)	6.0979* [1,393]	(1,1)	0.7995 [1,395]	m→y
SUM M3	(2,1)	3.0217 [1,393]	(3,1)	0.0016 [1,391]	NONE
SUM L	(2,1)	1.7359 [1,393]	(3,1)	2.4499 [1,391]	NONE
DIVISIA M1A	(2,1)	2.2955 [1,393]	(1,1)	0.0164 [1,395]	NONE
DIVISIA M1	(2,1)	3.5599 [1,393]	(1,1)	0.0000 [1,395]	NONE
DIVISIA M2	(2,1)	14.5308* [1,393]	(1,1)	0.4199 [1,395]	m→y
DIVISIA M3	(2,1)	12.1564* [1,393]	(1,1)	0.1329 [1,395]	m→y
DIVISIA L	(2,1)	11.8557* [1,393]	(1,1)	1.3839 [1,395]	m→y
FFD M1	(2,1)	1.1474 [1,393]	(1,1)	0.9457 [1,395]	NONE
FFD M2	(2,1)	1.3858 [1,393]	(1,1)	3.3089 [1,395]	NONE

NOTES: Sample period, monthly data 1960:1 - 1993:4. Numbers in parentheses indicate the optimal (in the minimum SC sense) lag. The degrees of freedom are given in the brackets. An asterix indicates significance at the 5% level (rejection of the hypothesis of no causality).

TABLE 3.6
CAUSALITY RESULTS FOR HOLMES-HUTTON RANK MODEL

Regression: (1) $R(\Delta y_t) = \alpha_0 + \sum_{i=1}^{a} \gamma_i R(\Delta y_{t-i}) + \sum_{j=1}^{b} \beta_j R(\Delta m_{t-j}) + \varepsilon_t$

(2) $R(\Delta m_t) = \theta_0 + \sum_{i=1}^{c} \delta_i R(\Delta m_{t-i}) + \sum_{j=1}^{d} \phi_j R(\Delta y_{t-j}) + \xi_t$

VARIABLE		m→y F-VALUE		y→m F-VALUE	DIRECTION OF CAUSALITY
SUM M1A	(3,1)	2.3238 [1,391]	(3,1)	0.2249 [1,391]	NONE
SUM M1	(3,1)	2.8494 [1,391]	(3,1)	0.6379 [1,391]	NONE
SUM M2	(3,1)	12.2490* [1,391]	(3,1)	1.5642 [1,391]	m→y
SUM M3	(3,1)	4.7526* [1,391]	(3,1)	0.0553 [1,391]	m→y
SUM L	(3,1)	2.6678 [1,391]	(3,1)	1.6180 [1,391]	NONE
DIVISIA M1A	(3,1)	0.5875 [1,391]	(1,1)	0.0058 [1,395]	NONE
DIVISIA M1	(3,1)	0.6823 [1,391]	(1,1)	0.0410 [1,395]	NONE
DIVISIA M2	(3,2)	10.8017* [2,390]	(1,1)	0.5731 [1,395]	m→y
DIVISIA M3	(3,2)	9.9004* [2,390]	(1,1)	0.0536 [1,395]	m→y
DIVISIA L	(3,1)	6.9746* [1,391]	(1,1)	1.1954 [1;395]	m→y
FFD M1	(3,1)	0.0087 [1,391]	(2,1)	0.0515 [1,393]	NONE
FFD M2	(3,1)	3.1057 [1,391]	(3,1)	3.6616 [1,391]	NONE

NOTES: Sample period, monthly data 1960:1 - 1993:4. Numbers in parentheses indicate the optimal (in the minimum SC sense) lag. The degrees of freedom are given in the brackets. An asterix indicates significance at the 5% level (rejection of the hypothesis of no causality).

TABLE 3.7
CAUSALITY RESULTS FOR STOCK-WATSON MODEL

Regression: (1) $\Delta y_t = \alpha_0 + \sum_{i=1}^{a} \gamma_i \Delta y_{t-i} + \sum_{j=1}^{b} \beta_j \Delta p_{t-j} + \sum_{k=1}^{c} \delta_k \Delta m_{t-k} + \sum_{l=1}^{d} \theta_l \Delta R_{t-l} + f(t) + \varepsilon_t$

VARIABLE	TIME TREND	CAUSAL VARIABLE		T-BILL F-VALUE		COMMERCIAL PAPER F-VALUE
SUM M1A	None	Money	(2,1,1,1)	2.1383 [1,391]	(2,1,1,1)	1.9575 [1,391]
		Interest Rate		3.4272^{+} [1,391]		6.5622* [1,391]
	Linear	Money	(2,1,1,1)	2.4180 [1,390]	(2,1,1,1)	2.2182 [1,390]
		Interest Rate		3.3180^{+} [1,390]		6.3926* [1,390]
	Linear, Quadratic	Money	(2,2,1,1)	1.0424 [1,388]	(2,2,1,1)	0.9546 [1,388]
		Interest Rate		3.9315* [1,388]		6.2249* [1,388]
SUM M1	None	Money	(2,1,1,1)	4.7589* [1,391]	(2,1,1,1)	4.3091* [1,391]
		Interest Rate		4.0552* [1,391]		6.9255** [1,391]
	Linear	Money	(2,1,1,1)	6.1589* [1,390]	(2,1,1,1)	5.5986* [1,390]
		Interest Rate		3.9948* [1,390]		6.7152** [1,390]
	Linear, Quadratic	Money	(2,2,1,1)	3.1413^{+} [1,388]	(2,2,1,1)	2.7721^{+} [1,388]
		Interest Rate		4.4172* [1,388]		6.4301* [1,388]

TABLE 3.7 continued
CAUSALITY RESULTS FOR STOCK-WATSON MODEL

Regression: (1) $\Delta y_t = \alpha_0 + \sum_{i=1}^{a} \gamma_i \Delta y_{t-i} + \sum_{j=1}^{b} \beta_j \Delta p_{t-j} + \sum_{k=1}^{c} \delta_k \Delta m_{t-k} + \sum_{l=1}^{d} \theta_l \Delta R_{t-l} + f(t) + \varepsilon_t$

VARIABLE	TIME TREND	CAUSAL VARIABLE		T-BILL F-VALUE		COMMERCIAL PAPER F-VALUE
SUM M2	None	Money	(2,1,2,1)	5.7229** [2,390]	(2,1,2,1)	5.1595** [2,390]
		Interest Rate		1.6353 [1,390]		3.8212+ [1,390]
	Linear	Money	(2,1,2,1)	5.4597** [2,389]	(2,1,2,1)	4.9148** [2,389]
		Interest Rate		1.6201 [1,389]		3.8009+ [1,389]
	Linear, Quadratic	Money	(2,2,1,1)	2.1056 [1,388]	(2,2,1,1)	1.7169 [1,388]
		Interest Rate		4.6646* [1,388]		6.6580** [1,388]
SUM M3	None	Money	(2,1,1,1)	4.5130* [1,391]	(2,1,1,1)	4.3056* [1,391]
		Interest Rate		3.7664+ [1,391]		6.8784** [1,391]
	Linear	Money	(2,1,1,1)	3.9992* [1,390]	(2,1,1,1)	3.8238+ [1,390]
		Interest Rate		3.7415+ [1,390]		6.8448** [1,390]
	Linear, Quadratic	Money	(2,2,1,1)	1.1588 [1,388]	(2,2,1,1)	1.0255 [1,388]
		Interest Rate		4.1970* [1,388]		6.4460* [1,388]

TABLE 3.7 continued
CAUSALITY RESULTS FOR STOCK-WATSON MODEL

Regression: (1) $\Delta y_t = \alpha_0 + \sum_{i=1}^{a} \gamma_i \Delta y_{t-i} + \sum_{j=1}^{b} \beta_j \Delta p_{t-j} + \sum_{k=1}^{c} \delta_k \Delta m_{t-k} + \sum_{l=1}^{d} \theta_l \Delta R_{t-l} + f(t) + \varepsilon_t$

VARIABLE	TIME TREND	CAUSAL VARIABLE		T-BILL F-VALUE		COMMERCIAL PAPER F-VALUE
SUM L	None	Money	(2,1,1,1)	4.1429* [1,391]	(2,1,1,1)	3.8837* [1,391]
		Interest Rate		3.2119+ [1,391]		6.2672* [1,391]
	Linear	Money	(2,1,2,1)	3.6848+ [1,390]	(2,1,1,1)	3.4549+ [1,390]
		Interest Rate		3.1843+ [1,390]		6.2282* [1,390]
	Linear, Quadratic	Money	(2,2,1,1)	1.1890 [1,388]	(2,2,1,1)	1.0239 [1,388]
		Interest Rate		3.7839+ [1,388]		5.9983* [1,388]
DIVISIA M1A	None	Money	(2,1,1,1)	1.9385 [1,391]	(2,1,1,1)	1.3486 [1,391]
		Interest Rate		3.5083* [1,391]		6.2296* [1,391]
	Linear	Money	(2,1,1,1)	2.2947 [1,390]	(2,1,1,1)	1.6403 [1,390]
		Interest Rate		3.400+ [1,390]		6.0155* [1,390]
	Linear, Quadratic	Money	(2,2,1,1)	1.221 [1,388]	(2,2,1,1)	0.7112 [1,388]
		Interest Rate		3.9961* [1,388]		5.9625* [1,388]

TABLE 3.7 continued
CAUSALITY RESULTS FOR STOCK-WATSON MODEL

Regression: (1) $\Delta y_t = \alpha_0 + \sum_{i=1}^{a} \gamma_i \Delta y_{t-i} + \sum_{j=1}^{b} \beta_j \Delta p_{t-j} + \sum_{k=1}^{c} \delta_k \Delta m_{t-k} + \sum_{l=1}^{d} \theta_l \Delta R_{t-l} + f(t) + \varepsilon_t$

VARIABLE	TIME TREND	CAUSAL VARIABLE		T-BILL F-VALUE		COMMERCIAL PAPER F-VALUE
DIVISIA M1	None	Money	(2,1,1,1)	4.5157* [1,391]	(2,1,1,1)	3.5015^{+} [1,391]
		Interest Rate		4.1782* [1,391]		6.4805* [1,391]
	Linear	Money	(2,1,2,1)	5.7766* [1,390]	(2,1,1,1)	4.5657* [1,390]
		Interest Rate		4.1401* [1,390]		6.2075* [1,390]
	Linear, Quadratic	Money	(2,2,1,1)	3.3489^{+} [1,388]	(2,2,1,1)	2.4473 [1,388]
		Interest Rate		4.5762* [1,388]		6.0526* [1,388]
DIVISIA M2	None	Money	(2,1,1,1)	13.1620** [1,391]	(2,1,1,1)	11.6649** [1,391]
		Interest Rate		4.9565* [1,391]		6.8083** [1,391]
	Linear	Money	(2,1,1,1)	12.9114** [1,390]	(2,1,1,1)	11.4489** [1,390]
		Interest Rate		4.8583* [1,390]		6.7025** [1,390]
	Linear, Quadratic	Money	(2,2,1,1)	6.9069* [1,388]	(2,2,1,1)	5.8118* [1,388]
		Interest Rate		5.0882* [1,388]		6.3810* [1,388]

TABLE 3.7 continued

CAUSALITY RESULTS FOR STOCK-WATSON MODEL

Regression: (1) $\Delta y_t = \alpha_0 + \sum_{i=1}^{a} \gamma_i \Delta y_{t-i} + \sum_{j=1}^{b} \beta_j \Delta p_{t-j} + \sum_{k=1}^{c} \delta_k \Delta m_{t-k} + \sum_{l=1}^{d} \theta_l \Delta R_{t-l} + f(t) + \varepsilon_t$

VARIABLE	TIME TREND	CAUSAL VARIABLE		T-BILL F-VALUE		COMMERCIAL PAPER F-VALUE
DIVISIA M3	None	Money	(2,1,1,1)	11.2863** [1,391]	(2,1,1,1)	10.0507** [1,391]
		Interest Rate		4.8811* [1,391]		6.9851** [1,391]
	Linear	Money	(2,1,2,1)	10.8512** [1,390]	(2,1,1,1)	9.6585** [1,390]
		Interest Rate		4.8017* [1,390]		6.9061** [1,390]
	Linear, Quadratic	Money	(2,2,1,1)	5.4328* [1,388]	(2,2,1,1)	4.5402* [1,388]
		Interest Rate		5.0356* [1,388]		6.5277* [1,388]
DIVISIA L	None	Money	(2,1,1,1)	11.4950** [1,391]	(2,1,1,1)	10.1011** [1,391]
		Interest Rate		4.3348* [1,391]		6.2797* [1,391]
	Linear	Money	(2,1,1,1)	11.2021** [1,390]	(2,1,1,1)	9.8446** [1,390]
		Interest Rate		4.2516* [1,390]		6.1909* [1,390]
	Linear, Quadratic	Money	(2,2,1,1)	5.9142* [1,388]	(2,2,1,1)	4.8775* [1,388]
		Interest Rate		4.6050* [1,388]		5.9520* [1,388]

TABLE 3.7 continued

CAUSALITY RESULTS FOR STOCK-WATSON MODEL

Regression: (1) $\Delta y_t = \alpha_0 + \sum_{i=1}^{a} \gamma_i \Delta y_{t-i} + \sum_{j=1}^{b} \beta_j \Delta p_{t-j} + \sum_{k=1}^{c} \delta_k \Delta m_{t-k} + \sum_{l=1}^{d} \theta_l \Delta R_{t-l} + f(t) + \varepsilon_t$

VARIABLE	TIME TREND	CAUSAL VARIABLE		T-BILL F-VALUE		COMMERCIAL PAPER F-VALUE
FFD M1	None	Money	(2,1,1,1)	1.7717 [1,391]	(2,1,1,1)	1.3789 [1,391]
		Interest Rate		1.8531 [1,391]		4.7615* [1,391]
	Linear	Money	(2,1,2,1)	2.0514 [1,390]	(2,1,1,1)	1.6115 [1,390]
		Interest Rate		1.6819 [1,390]		4.5016* [1,390]
	Linear, Quadratic	Money	(2,2,1,1)	0.8633 [1,388]	(2,2,1,1)	0.7317 [1,388]
		Interest Rate		2.5416 [1,388]		4.7827* [1,388]
FFD M2	None	Money	(2,1,1,1)	1.9300 [1,391]	(2,1,1,1)	1.9068 [1,391]
		Interest Rate		3.5549^{+} [1,391]		6.8504** [1,391]
	Linear	Money	(2,1,1,1)	1.4314 [1,390]	(2,1,1,1)	1.4366 [1,390]
		Interest Rate		3.5265^{+} [1,390]		6.8100** [1,390]
	Linear, Quadratic	Money	(2,2,1,1)	0.8287 [1,388]	(2,2,1,1)	0.8022 [1,388]
		Interest Rate		4.1236* [1,388]		6.4804* [1,388]

NOTES: Sample period, monthly data 1960:1 - 1993:4. Numbers in parentheses indicate the optimal (in the minimum SC sense) lag. The degrees of freedom are given in the brackets. Test statistics are significant (rejection of the hypothesis of no causality) at the **1%, *5%, and $^{+}$10% level.

CHAPTER IV: ASYMMETRIC UNANTICIPATED MONEY SUPPLY SHOCKS

IV.1. INTRODUCTION

Following along the lines of testing both the empirical robustness of RBC models and whether money matters; I turn to Cooley and Hansen (1989, p.746), who speculate

> "...that the most important influence of money on short-run fluctuations are likely to stem from the money supply process on expectations of relative prices, as in the natural rate literature. That is, if money does have a significant effect on the characteristics of the cycle it is likely to come about because the behavior of the monetary authority has serious informational consequences for private agents."

What this means, is that the RBC model that introduces money in the form of a cash-in-advance constraint implies that if money does matter, then the effect of the total change in the money supply process causes changes in the level of output, but the total effect is dominated by the effect of the unanticipated changes in monetary policy.

The role of unanticipated money growth was developed by the "rational expectation" monetary models of Lucas (1972,1973) and Sargent and Wallace (1975). In these models, economic agents form their expectations rationally. Suppose that the monetary authority announces that it intends to increase the money supply. Since the economic agents form their expectations rationally, they take this information into account when forming their expectations, and thus, are able to anticipate the effects of the increase in the money supply on the price level, such that the level of output remains unchanged at its natural level.

Thus, there exists an exploitable Expectational Phillips Curve which has the general form:

(4.1.1) $$Y = Y^* + \beta(\pi - \pi^e)$$

where Y is observed output, Y^* is the natural level of output, π is the rate of inflation, π^e is expected inflation and β is a positive parameter. Equation (4.1.1) states that if the actual rate of inflation is greater than expected, then output will be greater than its natural level, and if the actual rate of inflation is less than expected, then output will be less than its natural level.

However, suppose that the monetary authorities surprise the economic agents by increasing the money supply without announcing their intentions. Now firms and workers have incomplete information and thus would misperceive the increase in the price level as an increase in relative prices. In response, firms increase the supply of output, and workers increase the supply of labor. The increase in output and the supply of labor are only temporary, since once the economic agents realize that there has been no change in the relative prices, the level of output and labor supply would return to their natural levels. Therefore, anticipated changes in the money supply raise the price level, but has no effect on real output, and unanticipated changes in the money supply can affect real variables in the short run.

In the previous chapter, there was evidence that money did matter, that is, it had statistically significant marginal predictive value in forecasting output. However, the causality tests used did not decompose the changes in the money supply into anticipated and unanticipated money supply changes.

Therefore, the analysis used in this chapter tries to determine the predictive role of unanticipated changes in the money supply. In doing so, I follow Cover (1992) who examines the effect of unanticipated changes in the money supply, but allows for the distinction between positive unanticipated money supply shocks, and negative unanticipated money supply shocks. By allowing the distinction between the two types of shocks, Cover (1992) is able to test for asymmetry in the unanticipated changes in the money supply. That is, it becomes possible to analyze whether positive money supply shocks have a greater affect on output than negative money supply shocks, or if it is the other way around.

The asymmetries arise in the following manner, as described by De Long and Summers (1988). First of all, suppose that the results suggest that there is an insignificant positive unanticipated monetary shock, and a significant negative unanticipated monetary shock. This implies that wages and prices are quick to adjust upwards, but are slow to adjust downwards. For example, consider an unanticipated increase in the money supply which begins to reduce unemployment below its natural level. It is then in the interest of the employed workers, for the firm to increase the worker's wages. Efficiency wage considerations which arise from turnover, morale, or recruiting, implies that it is in the firms' interest to raise the wages as well. However, if there is negative unanticipated monetary shock, there is an incentive for the employed workers to fail to recognize the decrease in the money supply, and therefore resist wage reductions.

Therefore, it seems plausible that the adjustments that are in common with both the firms and the workers will occur quicker than those adjustments that are only in the interest of the firms. This implies that prices are upwardly flexible, but downwardly rigid, and that asymmetric monetary affects can arise.

As with the previous chapter, and in the spirit of Belongia (1995) who argues that the results will depend on whether simple sum or Divisia monetary aggregates are used, 12 monetary aggregates are analyzed for asymmetric effects of positive and negative unanticipated monetary shocks, using the methodology of Cover (1992).

Section 2 discusses the methodology used to obtain the estimates of how positive and negative monetary shocks affect output. Section 3 presents the results of the marginal predictive value of the positive and negative unanticipated money supply shocks for forecasting output. The results presented use four different money supply process, and output equations which contain only the current positive and negative monetary shocks, and output equations which contain current shocks plus four lags of each shock. Section 4 concludes.

IV.2. EMPIRICAL PROCEDURE

The data used in the asymmetric analysis consists of monthly data from 1968:1 to 1993:3, for the United States. The series are industrial production, net Federal outlays, net Federal receipts, the unemployment rate which includes all workers (including resident armed forces), the Treasury bill rate, the monetary base which is the Federal Reserve Bank of St. Louis' adjusted monetary base, simple sum and Divisia indices for M1A, M1, M2, M3, and L. As well, the monetary aggregates FFDM1 and FFDM2 are also studied.

In order to follow Cover (1992) as closely as possible, the monthly series are rendered quarterly by averaging. Thus, the data analyzed becomes quarterly data from 1968:1 to 1993:1.

Following Cover (1992), the first step in the analysis of asymmetric unanticipated money supply shocks is to define a money supply process. The residuals from the money supply process are equal to the unanticipated money supply. The unanticipated money supply is then separated into positive and negative shocks, and inserted into the output supply equation. The shocks are then tested to see if they are jointly statistically significant.

In order to test the robustness of the results, four different money supply processes are used. The first money supply process includes variables used in Barro and Rush (1980). The money supply process is defined as:

(4.2.1) $$\Delta m_t = \alpha_0 + \sum_{i=1}^{6} \beta_i \Delta m_{t-i} + \sum_{j=1}^{3} \gamma_j Ur_{t-j} + \delta_t Fedv_t + \varepsilon_t$$

where m is the logarithm of the monetary aggregate. Ur is defined as U/(1-U) where U is the unemployment rate. Fedv is real Federal expenditure relative to normal Federal expenditure:

$$\log NO_t = 0.2 \log NO_t + 0.8 \log NO_{t-1}$$

where NO is net Federal outlays.

The unemployment variable is included to account for a countercyclical policy response of money to the level of economic activity, such as an increase in the money growth rate when income is below its natural level. It may also account for a decline in real income, which then lowers the holdings of real balances, which in turn would decrease the amount of government revenue from money issue for a given value of the monetary growth rate.

The government expenditure variable is included to account for an aspect of the revenue motive of money creation. That is, an exogenous level of government expenditure is financed by a combination of taxes and money issue.

Finally, the inclusion of the lagged monetary variable is to account for elements of serial dependence or lagged adjustment that has not been captured by the other independent variables.

The second money supply process used, follows Mishkin (1982). The money supply process is:

(4.2.2) $$\Delta m_t = \alpha_0 + \sum_{i=1}^{4} \beta_i \Delta m_{t-i} + \sum_{j=1}^{4} \gamma_j \Delta R_{t-j} + \sum_{k=1}^{4} \delta_k \mathrm{Feds}_{t-k} + \varepsilon_t$$

where m is the logarithm of the monetary aggregate, R is the Treasury bill rate, and Feds is the net Federal budget surplus, and is equal to net Federal receipts minus net Federal outlays.

The variables used in this equation were found by regressing the monetary growth rate against four lags of a wide range of macroeconomic variables such as the inflation rate, the growth rate of nominal GNP, the growth rate of real GNP, the unemployment rate, the Treasury bill rate, the growth rate of real government expenditure, the Federal budget surplus, the growth rate of Federal debt, and the balance of payments on current account. Then, only the variables that are jointly significant at the 5% level or higher are included.

The third money supply process is the optimal money supply process determined by Cover (1992) using the Akaike Information Criterion.

In this case, the money supply process becomes:

(4.2.3) $$\Delta m_t = \alpha_0 + \sum_{i=1}^{4} \beta_i \Delta m_{t-i} + \sum_{j=1}^{2} \gamma_j \Delta mb_{t-j} + \delta_1 \Delta R_{t-1} + \theta_1 Ur_{t-1} + \phi_1 Feds_{t-1} + \mu_1 \Delta y_{t-1} + \varepsilon_t$$

where mb is the logarithm of the monetary base, y is the logarithm of industrial production, and the remaining variables are previously defined.

These three money supply processes have the same structure as the ones defined in Cover (1992), and the structure does not change for the different monetary aggregates. However, as shown in the previous chapter, the results will depend on the lag structure of the equation used, and this lag structure may depend on the monetary aggregate used. Therefore, unlike Cover (1992), I use a fourth money supply process which is defined as:

(4.2.4) $$\Delta m_t = \alpha_0 + \sum_{i=1}^{a} \beta_i \Delta m_{t-i} + \sum_{j=1}^{b} \gamma_j \Delta mb_{t-j} + \sum_{k=1}^{c} \delta_k \Delta R_{t-k} + \sum_{l=1}^{d} \theta_l Ur_{t-l} + \sum_{q=1}^{e} \phi_q Feds_{t-q} + \sum_{p=1}^{f} \mu_p \Delta y_{t-p} + \varepsilon_t$$

where all variables have been previously defined.

The lags a, b, c, d, e, f, were chosen using the stepwise procedure used in Serletis (1990), and described in the previous chapter. As well, the lags were chosen using the S.C. rather than the Akaike Information Criterion used by Cover (1992). The optimal lag structure for all monetary aggregates except for Sum M3, is one lag of each variable. For Sum M3, the lag structure is 6 lags of money, 1 lag of the monetary base, 6 lags of the Treasury bill rate, 2 lags for the unemployment rate, and 1 lag for the Federal budget surplus and industrial production.

The next step is to use the residuals from the money supply process, and separate them into positive and negative unanticipated money supply shocks. We then insert the money supply shocks into the output supply process and determine whether or not they are statistically significant. Cover (1992) uses a joint estimation of the output and money supply process through the use of a nonlinear interactive variable to present the positive and negative money supply shocks.

However, due to problems replicating the algorithm written and used by Cover (1992), this analysis uses the equally valid two step procedure used by Barro and Rush (1980). This two step procedure requires three distinct series of money supply shocks. The complete series of shocks, which is equal to the residual series from one of the money supply processes is defined as *shock*. The negative unanticipated money supply shock, neg, equals the money supply shock if the shock is negative, otherwise it is equal to zero: or neg = min(*shock*,zero). The positive unanticipated money supply shock, pos, equals the money supply shock if the shock is positive, otherwise it is equal to zero: or pos = max(*shock*,zero). Once this done, the output equation can be estimated using whatever number of lags of the three series of shocks.

The output equation used in this analysis and in Cover (1992), is specified as a function of one lag of output growth, current and lagged values of money shock terms, and the current and one lagged value of the first difference of the Treasury bill rate.

The inclusion of the Treasury bill rate in the output supply process is because models of economic growth typically imply that the interest rate affects the desired capital stock and therefore, affects capacity output. However, since neither Barro and Rush (1980) nor Mishkin (1982) includes the first difference of the Treasury bill rate in their output equations, this analysis follows Cover (1992) and presents results that include and exclude the Treasury bill rate in the output supply process.

Therefore, the four output supply processes studied are:

(4.2.5) $$\Delta y_t = \alpha_0 + \beta_1 \Delta y_{t-1} + \gamma_1 \Delta R_t + \gamma_2 \Delta R_{t-1} + \delta_1 POS_t + \delta_2 NEG_t + \varepsilon_{1t}$$

(4.2.6) $$\Delta y_t = \alpha_0 + \beta_1 \Delta y_{t-1} + \delta_1 POS_t + \delta_2 NEG_t + \varepsilon_{2t}$$

(4.2.7) $$\Delta y_t = \alpha_0 + \beta_1 \Delta y_{t-1} + \gamma_1 \Delta R_t + \gamma_2 \Delta R_{t-1} + \sum_{i=0}^{4} \delta_i POS_{t-i} + \sum_{j=0}^{4} \theta_j NEG_{t-j} + \varepsilon_{3t}$$

(4.2.8) $$\Delta y_t = \alpha_0 + \beta_1 \Delta y_{t-1} + \sum_{i=0}^{4} \delta_i POS_{t-i} + \sum_{j=0}^{4} \theta_j NEG_{t-j} + \varepsilon_{4t}$$

where y is the logarithm of industrial production, R is the Treasury bill rate, POS is the positive unanticipated money supply shock, and NEG is the negative unanticipated money supply shock.

The results of the analysis of asymmetric unanticipated monetary shocks is discussed in the next section.

IV.3. EMPIRICAL EVIDENCE

Tables 4.1 and 4.2 report the results for the output supply process that includes no lagged values of money shocks. The only difference between the two tables is that the Treasury bill rate terms are excluded from the output supply process in table 4.2.

Unlike Cover (1992), the results depend on which money supply process is used, but in general, except for Sum M1A in table 4.2 and FFDM2 in both tables, there is weak, or no evidence of significant asymmetric effects. These results are consistent with the results found in Belongia (1995), who also found no evidence of asymmetric money supply shocks.

In all cases, except for FFDM2 and Sum M2 in the S.C. optimal case in table 4.1, the positive unanticipated money supply shocks are not statistically significant. For Sum M1A, Sum M1, Sum M2, Sum M3, Sum L, Divisia M1A, and FFD M1, there appears to be weak evidence of a statistically significant negative unanticipated money supply shocks. However, these results are not consistent across the different money supply processes used. FFDM2 appears to have an asymmetric effect, where the positive effect is significant and the negative effect is insignificant.

When four lags of the monetary shocks are used in tables 4.3 and 4.4, the results of the tests for asymmetric effects provide evidence that neither positive or negative unanticipated money supply shocks have statistically significant marginal predictive value.

The tests of SUM(POS) = 0, and SUM(NEG) = 0 are performed to test the hypothesis that the cumulative effect (or partial sum) of the money supply shock is different from zero, and except for FFDM2 and FFDM1 in table 4.3, the cumulative effects of either positive or negative money supply shocks does not appear to be statistically significant.

For FFDM2 in tables 4.3 and 4.4, the cumulative effect of the positive money supply shock is significant, and for FFDM1 in table 4.3, the cumulative effects of the negative money supply shock is significant.

Therefore, the results in table 4.1 to 4.4, tend to support the results of Belongia (1995), who found no asymmetric effects. The evidence provided here, contradicts the evidence found in Cover (1992), who found strong negative unanticipated money supply effects. As well, the results presented here provides evidence that unanticipated money does not matter, since it does not have a statistically significant marginal predictive value in forecasting output.

IV.4. CONCLUSION

The analysis performed in this chapter was done to determine whether or not there was an explicit role for unanticipated money in determining future values for the level of output, as argued by the natural rate literature. If there exists a strong causal relationship between the changes in unanticipated money supply and changes in the level of output, then the results found in chapter 3, where there is evidence of a causal relationship between the changes in the money supply and changes in the level of output, would be due to the causal relationship between unanticipated money and output. If this were the case, then there would be no explicit role for anticipated changes in the money supply, and there would be evidence supporting the RBC framework.

However, the analysis performed in this chapter provided evidence that there is no relationship between the changes in the unanticipated money supply and the level of output, and that the positive and negative money supply shocks yield the same result. These results are robust, because they are consistent across four different money supply processes, and four different output supply processes. The results are also consistent with the findings of Belongia (1995), who found no asymmetric effects in the unanticipated money supply.

As well, these results provide evidence that when the sample is expanded from 1987 to 1993, there is a significant change in the results. Cover (1992) found that between 1951 and 1987, the negative unanticipated money supply shock had a much larger effect on the level of output, than did the positive unanticipated money supply shock. This analysis, found that between 1968 and 1993, this was no longer the case, since both the positive and negative unanticipated money supply shocks did not have a significant effect on the level of output. Therefore, as with most causality tests, the test for asymmetric money supply shocks may be dependent upon the sample period used.

Finally, unlike most studies involving simple sum and Divisia monetary aggregates, the results obtained in this chapter provide evidence that in this case, the simple sum and Divisia monetary aggregates do not provide different results.

TABLE 4.1
OUTPUT SUPPLY PROCESS - NO LAGS OF MONEY SHOCKS

VARIABLE	BARRO-RUSH	MODIFIED MISHKIN	COVER OPTIMAL	S.C. OPTIMAL
SUM M1A				
POS=0	(-0.0564)	(-0.4346)	(-0.5310)	(-0.0771)
NEG=0	(0.8236)	(1.6690)*	(1.6690)*	(2.0800)**
POS=NEG	0.2295	1.4577	1.6210	1.5246
SUM M1				
POS=0	(-0.6920)	(-0.7210)	(-0.7964)	(-0.2560)
NEG=0	(0.9468)	(1.3520)$^{+}$	(1.0830)	(1.2610)
POS=NEG	1.0208	1.4844	1.1913	0.8457
SUM M2				
POS=0	(1.0330)	(0.7470)	(0.9853)	(2.1120)**
NEG=0	(0.0158)	(1.3000)$^{+}$	(-0.2180)	(-1.1770)
POS=NEG	0.2539	0.2905	0.3946	3.6372^{+}
SUM M3				
POS=0	(-0.2417)	(0.6014)	(0.6244)	(0.8108)
NEG=0	(1.0580)	(0.5610)	(-0.1924)	(0.1134)
POS=NEG	0.5850	0.0001	0.2173	0.1555
SUM L				
POS=0	(-0.4282)	(1.1260)	(1.2470)	(0.8467)
NEG=0	(1.7350)*	(0.7778)	(0.4191)	(0.2998)
POS=NEG	1.6462	0.0686	0.2350	0.0900
DIVISIA M1A				
POS=0	(-0.0492)	(-0.6112)	(-0.2875)	(-0.2652)
NEG=0	(-0.1732)	(1.3280)$^{+}$	(0.5731)	(0.8907)
POS=NEG	0.0047	1.3512	0.2778	0.5070

TABLE 4.1 continued
OUTPUT SUPPLY PROCESS - NO LAGS OF MONEY SHOCKS

VARIABLE	BARRO-RUSH	MODIFIED MISHKIN	COVER OPTIMAL	S.C. OPTIMAL
DIVISIA M1				
POS=0	(-0.7233)	(-0.5686)	(-0.5187)	(-0.2952)
NEG=0	(-0.3178)	(-0.1092)	(-0.7466)	(-0.0391)
POS=NEG	0.0693	0.0721	0.0263	0.0172
DIVISIA M2				
POS=0	(-0.0326)	(-0.2847)	(-0.1939)	(1.2160)
NEG=0	(-0.2396)	(1.2240)	(0.0709)	(-0.0324)
POS=NEG	0.0185	0.7540	0.0245	0.6168
DIVISIA M3				
POS=0	(-0.1797)	(-0.4902)	(-0.6150)	(0.5947)
NEG=0	(-0.2725)	(1.1370)	(0.3562)	(0.1208)
POS=NEG	0.0057	0.8704	0.3373	0.0944
DIVISIA L				
POS=0	(-0.5787)	(-0.0238)	(-0.6450)	(0.3864)
NEG=0	(0.1586)	(0.5690)	(0.5303)	(0.5217)
POS=NEG	0.2073	0.1034	0.4873	0.0029
FFD M1				
POS=0	(-0.8629)	(-0.3495)	(-0.0792)	(-0.1171)
NEG=0	(-0.7854)	(-1.7810)*	(-2.3060)**	(-1.6890)**
POS=NEG	0.0398	1.5666^{+}	3.0678^{+}	1.5744*
FFD M2				
POS=0	(2.0350)**	(2.5900)**	(2.3750)**	(2.6080)**
NEG=0	(-1.4570)	(-1.4180)	(1.5230)	(-1.5330)
POS=NEG	4.9647*	6.8630**	6.2149*	7.0888**

NOTES: Sample period, quarterly data 1968:1 - 1993:1. The t-ratios are in parentheses, and the F statistics are not. $^{+}$, *, ** significant at the 10%, 5%, and 1% level respectively.

TABLE 4.2
OUTPUT SUPPLY PROCESS WITHOUT TREASURY BILL RATE - NO LAGS OF MONEY SHOCKS

VARIABLE	BARRO-RUSH	MODIFIED MISHKIN	COVER OPTIMAL	S.C. OPTIMAL
SUM M1A				
POS=0	(-0.6819)	(-1.3600)	(-1.7650)*	(-0.5860)
NEG=0	(2.1610)**	(2.3110)**	(2.4020)**	(1.9180)*
POS=NEG	2.4104	4.8078*	6.4361*	2.2042
SUM M1				
POS=0	(-1.1410)	(-1.1430)	(-1.2130)	(-0.6994)
NEG=0	(2.1810)**	(1.7500)*	(1.4650)$^{+}$	(1.2040)
POS=NEG	4.1121*	2.8824^{+}	2.4170	1.2904
SUM M2				
POS=0	(0.9815)	(1.0430)	(0.8543)	(1.7340)*
NEG=0	(-0.1197)	(-0.4731)	(-0.6542)	(-1.4060)$^{+}$
POS=NEG	0.3178	0.7076	0.7493	3.4309^{+}
SUM M3				
POS=0	(-1.1530)	(0.0364)	(-0.1390)	(-0.0586)
NEG=0	(2.1210)**	(0.5940)	(0.4343)	(1.3700)$^{+}$
POS=NEG	3.7351^{+}	0.1213	0.1245	0.7479
SUM L				
POS=0	(-0.1001)	(1.0680)	(1.3180)$^{+}$	(1.1700)
NEG=0	(2.4320)**	(1.0750)	(1.0220)	(0.6610)
POS=NEG	2.1506	0.0037	0.0270	0.0656
DIVISIA M1A				
POS=0	(-0.3878)	(-1.2330)	(-0.9961)	(-0.4334)
NEG=0	(1.1150)	(2.1340)**	(0.9481)	(0.2853)
POS=NEG	0.7290	4.2310*	1.4196	0.1855

TABLE 4.2 continued

OUTPUT SUPPLY PROCESS WITHOUT TREASURY BILL RATE - NO LAGS OF MONEY SHOCKS

VARIABLE	BARRO-RUSH	MODIFIED MISHKIN	COVER OPTIMAL	S.C. OPTIMAL
DIVISIA M1				
POS=0	(-0.5968)	(-0.8515)	(-0.6092)	(-0.9437)
NEG=0	(0.7596)	(0.6397)	(-0.1890)	(0.4178)
POS=NEG	0.6312	0.7869	0.0524	0.5834
DIVISIA M2				
POS=0	(0.3238)	(-0.7508)	(-0.5694)	(0.7335)
NEG=0	(0.1643)	(1.3140)	(0.4390)	(-0.6014)
POS=NEG	0.0058	1.4420	0.3532	0.6217
DIVISIA M3				
POS=0	(0.1370)	(-0.6270)	(-0.7207)	(0.2629)
NEG=0	(0.1446)	(1.1050)	(0.3475)	(-0.4925)
POS=NEG	0.0002	0.9988	0.4103	0.1902
DIVISIA L				
POS=0	(0.0537)	(0.1067)	(-0.2042)	(0.6215)
NEG=0	(0.5769)	(0.5805)	(0.4212)	(-0.1558)
POS=NEG	0.1016	0.0573	0.1330	0.2252
FFD M1				
POS=0	(-0.9293)	(-0.8538)	(-0.6201)	(-0.8114)
NEG=0	(0.2642)	(-0.6928)	(-1.3090)$^{+}$	(-0.9581)
POS=NEG	0.4076	0.0342	0.5836	0.1671
FFD M2				
POS=0	(2.1680)**	(2.9010)**	(2.4330)**	(2.4950)**
NEG=0	(-1.6750)*	(-1.3060)$^{+}$	(-1.5210)$^{+}$	(-1.4850)$^{+}$
POS=NEG	5.9188*	7.9526**	6.5014*	6.6162*

NOTES: Sample period, quarterly data 1968:1 - 1993:1. The t-ratios are in parentheses, and the F statistics are not. $^{+}$, *, ** significant at the 10%, 5%, and 1% level respectively.

TABLE 4.3
OUTPUT SUPPLY PROCESS - FOUR LAGS OF MONEY SHOCKS

VARIABLE	BARRO-RUSH	MODIFIED MISHKIN	COVER OPTIMAL	S.C. OPTIMAL
SUM M1A				
POS=0	0.1240	0.1703	0.3254	0.4929
NEG=0	0.6260	1.3600	1.3132	1.1793
POS=NEG	0.3555	0.5357	0.7178	0.7387
SUM(POS)=0	0.1102	0.2953	0.1974	0.1069
SUM(NEG)=0	1.0846	0.5587	0.0312	0.1798
SUM M1				
POS=0	0.2884	0.2664	0.3494	0.4506
NEG=0	0.6944	0.7542	0.8292	0.9615
POS=NEG	0.5513	0.5215	0.5420	0.7058
SUM(POS)=0	0.0262	0.0057	0.0002	0.1787
SUM(NEG)=0	0.1111	0.0124	0.3769	0.2372
SUM M2				
POS=0	0.5368	1.4622	0.6747	1.9196
NEG=0	1.2594	0.3512	0.1803	0.1550
POS=NEG	1.0167	0.6059	0.2274	0.8529
SUM(POS)=0	1.2627	3.0946^{+}	1.7548	5.0531^{*}
SUM(NEG)=0	0.4829	0.0270	0.0331	0.0267
SUM M3				
POS=0	1.6754	1.3177	1.5878	2.0191
NEG=0	2.4933	0.9410	0.6602	2.2327
POS=NEG	2.2082	1.0539	1.1268	2.3101
SUM(POS)=0	0.2182	0.1871	0.0002	0.0299
SUM(NEG)=0	0.1348	1.5389	0.5568	0.0028

TABLE 4.3 continued
OUTPUT SUPPLY PROCESS - FOUR LAGS OF MONEY SHOCKS

VARIABLE	BARRO-RUSH	MODIFIED MISHKIN	COVER OPTIMAL	S.C. OPTIMAL
SUM L				
POS=0	0.9175	1.5795	2.6509	2.1642
NEG=0	1.1632	0.3981	0.8372	0.4039
POS=NEG	0.9058	0.7549	1.7749	1.1415
SUM(POS)=0	0.7345	0.0769	0.0781	0.0048
SUM(NEG)=0	0.0010	0.1784	0.9019	1.5319
DIVISIA M1A				
POS=0	0.4705	0.3556	0.4229	0.3551
NEG=0	1.4223	0.8707	0.7368	0.7122
POS=NEG	1.1474	0.8086	0.7304	0.5734
SUM(POS)=0	1.2809	1.6501	1.8328	0.5873
SUM(NEG)=0	2.2805	0.4632	0.0971	0.7224
DIVISIA M1				
POS=0	0.5538	0.7523	0.7881	0.2818
NEG=0	1.2120	0.6062	0.7638	1.0214
POS=NEG	0.9765	0.3436	0.5572	0.7866
SUM(POS)=0	0.9969	1.1517	1.4252	0.2435
SUM(NEG)=0	0.2691	1.2438	1.4105	0.4485
DIVISIA M2				
POS=0	0.2846	0.2901	0.4733	0.6404
NEG=0	1.6477	0.4718	0.5176	1.0104
POS=NEG	1.1903	0.4133	0.5416	0.6148
SUM(POS)=0	0.9567	0.0485	1.4331	0.8236
SUM(NEG)=0	3.5802*	0.0021	0.1618	0.2589

TABLE 4.3 continued

OUTPUT SUPPLY PROCESS - FOUR LAGS OF MONEY SHOCKS

VARIABLE	BARRO-RUSH	MODIFIED MISHKIN	COVER OPTIMAL	S.C. OPTIMAL
DIVISIA M3				
POS=0	0.5439	0.3856	0.3499	0.5539
NEG=0	1.7250	0.4968	0.2227	0.8134
POS=NEG	1.3911	0.5392	0.3037	0.6784
SUM(POS)=0	0.7871	0.0545	0.3187	0.8839
SUM(NEG)=0	2.0627	0.3126	0.0333	0.1046
DIVISIA L				
POS=0	0.4156	0.3470	0.4395	0.2049
NEG=0	1.5589	0.8744	0.1727	0.4534
POS=NEG	1.1517	0.6351	0.3002	0.1550
SUM(POS)=0	1.0460	0.0937	0.8069	0.2943
SUM(NEG)=0	2.9063^{+}	1.3081	0.0387	0.0694
FFD M1				
POS=0	0.2215	0.1944	0.2486	0.1730
NEG=0	0.4443	2.2232	1.8171	2.3798
POS=NEG	0.2719	1.3835	1.3005	1.8858
SUM(POS)=0	0.0704	0.1868	0.0049	0.2327
SUM(NEG)=0	0.0450	4.8489**	4.4213*	2.7369
FFD M2				
POS=0	1.7256	3.2116^{+}	3.0675^{+}	3.3563^{+}
NEG=0	1.1853	1.0302	1.1213	1.1427
POS=NEG	2.0815	3.4504^{+}	3.3765^{+}	3.5464^{+}
SUM(POS)=0	4.6014**	10.2126**	9.0199**	9.9595**
SUM(NEG)=0	0.7795	0.3267	0.6444	0.5649

NOTES: Sample period, quarterly data 1968:1 - 1993:1. $^{+}$, *, ** significant at the 10%, 5%, and 1% level respectively.

TABLE 4.4
OUTPUT SUPPLY PROCESS WITHOUT TREASURY BILL RATE - FOUR LAGS OF MONEY SHOCKS

VARIABLE	BARRO-RUSH	MODIFIED MISHKIN	COVER OPTIMAL	S.C. OPTIMAL
SUM M1A				
POS=0	0.4687	0.4602	0.8510	0.8137
NEG=0	1.0387	1.2809	1.9690	1.5766
POS=NEG	0.5881	0.7213	1.9429	1.2888
SUM(POS)=0	0.2044	1.1250	0.1782	0.1265
SUM(NEG)=0	2.3908	0.5343	0.0136	0.4827
SUM M1				
POS=0	0.9167	0.9612	0.4980	0.5938
NEG=0	0.5434	0.4563	1.0999	0.6546
POS=NEG	0.4956	0.2305	0.7353	0.6567
SUM(POS)=0	0.1693	0.5957	0.2104	0.5561
SUM(NEG)=0	0.3082	0.5487	0.4928	0.0934
SUM M2				
POS=0	0.9939	0.1737	0.8319	2.0642
NEG=0	1.8410	1.0528	0.5917	0.5836
POS=NEG	1.2611	0.7361	0.6402	1.1486
SUM(POS)=0	0.2014	0.1232	2.2903	6.6517*
SUM(NEG)=0	3.4240+	0.0199	0.0133	0.0564
SUM M3				
POS=0	1.3552	0.5001	0.9174	1.6771
NEG=0	1.9489	0.7836	1.3294	2.7520+
POS=NEG	1.6718	0.8518	1.1116	2.2407
SUM(POS)=0	0.1806	0.1092	0.1941	0.0563
SUM(NEG)=0	1.7904	0.3628	1.1477	0.0923

TABLE 4.4 continued

OUTPUT SUPPLY PROCESS WITHOUT TREASURY BILL RATE- FOUR LAGS OF MONEY SHOCKS

VARIABLE	BARRO-RUSH	MODIFIED MISHKIN	COVER OPTIMAL	S.C. OPTIMAL
SUM L				
POS=0	1.3347	0.3721	1.6118	1.4926
NEG=0	1.9029	1.6233	0.5499	0.5647
POS=NEG	1.6467	1.1468	0.7009	0.5965
SUM(POS)=0	0.2039	0.2563	0.0053	0.0059
SUM(NEG)=0	2.1692	1.3190	1.3930	1.8613
DIVISIA M1A				
POS=0	1.0960	0.2606	1.0506	0.8399
NEG=0	2.1853	1.8324	0.5475	0.5777
POS=NEG	1.7019	1.1061	0.3679	0.3022
SUM(POS)=0	0.0162	0.1049	1.4216	0.6752
SUM(NEG)=0	1.2737	0.3446	0.0069	0.7934
DIVISIA M1				
POS=0	1.4038	0.3980	0.7551	0.6137
NEG=0	1.4871	1.1754	0.4258	0.5895
POS=NEG	1.5676	0.7816	0.1879	0.6848
SUM(POS)=0	0.6177	0.1415	0.5758	0.1288
SUM(NEG)=0	0.1421	0.0242	1.1183	0.1402
DIVISIA M2				
POS=0	0.6214	1.4206	0.3593	0.6659
NEG=0	0.9861	0.9332	1.1370	0.8678
POS=NEG	0.7812	1.0848	0.7827	0.4498
SUM(POS)=0	2.1538	4.0734*	1.0548	2.0283
SUM(NEG)=0	0.0802	0.0066	0.3036	0.4412

TABLE 4.4 continued
OUTPUT SUPPLY PROCESS WITHOUT TREASURY BILL RATE - FOUR LAGS OF MONEY SHOCKS

VARIABLE	BARRO-RUSH	MODIFIED MISHKIN	COVER OPTIMAL	S.C. OPTIMAL
DIVISIA M3				
POS=0	2.1857	0.4132	0.2310	0.6189
NEG=0	4.4465*	1.3528	0.5100	0.5381
POS=NEG	3.7465*	0.8551	0.3718	0.4052
SUM(POS)=0	0.7864	0.0006	0.0831	1.7026
SUM(NEG)=0	0.0102	1.8623	0.0114	0.2444
DIVISIA L				
POS=0	0.7183	0.7322	0.1255	0.5395
NEG=0	1.5877	0.6982	0.3210	0.3953
POS=NEG	0.8253	0.3115	0.1798	0.2729
SUM(POS)=0	1.4101	0.0345	0.1599	1.2815
SUM(NEG)=0	0.3364	1.005	0.1046	0.1575
FFD M1				
POS=0	0.2656	0.2391	0.2678	0.3331
NEG=0	0.2256	1.1744	0.7465	0.9290
POS=NEG	0.1374	0.7264	0.4784	0.7395
SUM(POS)=0	0.0274	0.0961	0.0898	0.1725
SUM(NEG)=0	0.1412	2.4875	2.8464+	1.3342
FFD M2				
POS=0	1.2482	2.8421+	2.2501	2.6525
NEG=0	0.9152	0.6833	0.6451	0.7426
POS=NEG	1.6595	2.9855+	2.4543	2.7143
SUM(POS)=0	4.1874*	8.6337**	6.7833*	8.0648**
SUM(NEG)=0	0.9243	0.0797	0.3618	0.2448

NOTES: Sample period, quarterly data 1968:1 - 1993:1. +, *, ** significant at the 10%, 5%, and 1% level respectively.

CHAPTER V: CONCLUSION

The previous chapters of this thesis have discussed a number of interrelated topics concerning whether central banks can use monetary policy to influence the level of output in the economy. In other words, the previous chapters tried to determine whether or not money matters.

The first step of the analysis was to present a theory explaining why we would believe that the changes in the money supply do, or do not have any causal effects on the level of output. The standard Keynesian modeling framework states that there is a causal relationship between the money supply and the level of output, and that it is the changes in the money supply that cause the changes in the level of output.

However, chapter II presents a relatively new modeling framework that states that there is no causal relationship between the money supply and the level of output. The Real Business Cycle modeling framework is a competitive dynamic equilibrium modeling framework, where a representative agent makes decisions concerning consumption and leisure patterns over time. Unlike previous macroeconomic modeling techniques, the Real Business Cycle theorists argue that the fluctuations in aggregate macroeconomic variables are generated by random technology shocks that affect the quantity of output produced from capital and labor inputs.

Chapter II also showed that the there is no specific role for money within the Real Business Cycle models. Therefore, in a Real Business Cycle model, the central bank is unable to influence the level of output in the economy, thus implying that money is neutral, and that the changes in the money supply have no effect on the level of output.

As tables 2.1 to 2.2 showed, the basic Real Business Cycle model is able to replicate the stylized facts of the actual economy rather well, considering how simple it is. Tables 2.1 to 2.4 also show that the performance of the Real Business Cycle models can be improved by the inclusion of non-convexities into the preferences (Hansen (1985)), or by the inclusion of aggregate demand shocks (McGratten (1994b)). However, there still exists a number of criticisms that must be addressed before Real Business Cycle models are widely accepted as a model of the macroeconomy.

It would now seem that there is at least two competing models of thought concerning the macroeconomy, Keynesian theory, and Real Business Cycle theory. In an attempt to discriminate among the competing schools of thought, chapter III analyzes the causal relationship between money and output. In doing so, a number of issues were addressed. First of all, in order to test the robustness of the results, three different causality tests were performed. A basic bivariate Granger causality model, a Holmes-Hutton rank Granger causality model, and a Stock-Watson Granger causality model. As well, by using three different specifications of the causality test, chapter III addressed a number of criticisms concerning causality testing. The criticisms that were addressed are the use of ad hoc lag length determination, the dependence of the causality results on the functional form used, the assumption of normally distributed error terms, and the fact that different causality results cannot be compared because the different causality tests tend to study different sample periods.

As well, following Serletis (1988), and Belongia (1995), who argue that the study of monetary effects is dependent on the monetary aggregate used, the analysis in chapter III used 12 different money aggregates. 5 simple sum, 5 Divisia, and 2 FFDM aggregates.

The results found in chapter III, provide evidence in support of the statement that monetary effects are dependent on which monetary aggregate is used. Tables 3.5 to 3.7 show that depending on the monetary aggregate used two different causal relationships can appear. One being that changes in the money supply cause changes in output, and the other being that the fluctuations in the level of output are independent of the money supply. As a result, a general statement concerning the effects that the changes on the money supply has on the level of output cannot be made. Therefore, chapter III was not able to provide clear support for either of the competing schools of thought.

Chapter III studied the relationship between the level of output and the combined anticipated and unanticipated money supply. However, Cooley and Hansen (1989) argue that Real Business Cycle models do not rule out the result that money may affect output through unanticipated money supply shocks. Therefore, the causal relationships found in chapter III may support both Keynesian models and Real Business Cycle models, if the causal relationship is being driven by unanticipated money supply shocks, since both models state that unanticipated money supply shocks can affect the level of output.

Chapter IV tested this hypothesis by separating the money supply into anticipated and unanticipated money supply shocks. Then following Cover (1992), the unanticipated money supply shocks were divided into positive shocks and negative shocks in order to test the hypothesis that there exists some sort of rigidity in the economy that causes an asymmetric effect to occur in the causal relationship between the unanticipated money supply shock and the level of output. Once again, following Belongia (1995), the monetary effects are tested over 12 different monetary aggregates.

The results found in chapter IV, provided evidence that the fluctuations in the level of output is independent of the unanticipated money supply shocks, and that there is no asymmetric effect in the unanticipated money supply. That is, the positive unanticipated money supply shock does not have a significantly larger effect on output, than a negative unanticipated money supply shock, and the negative unanticipated money supply shock does not have a significantly larger effect, than the positive unanticipated money supply shock. However, unlike previous studies using simple sum and Divisia monetary aggregates, the results in chapter IV did not depend on the monetary aggregate used.

The most significant policy result obtained from this analysis concerning the ability of the Federal Reserve to manipulate the fluctuations in output, by altering the money supply is that the Federal Reserve must make a distinction between which monetary aggregates are going to be used to analyze the effects of policy decisions. As Chapters III and IV show, the monetary aggregates which had significant marginal predictive values for the combination of anticipated and unanticipated money supply shocks, but not for unanticipated money supply shocks, supports models which argue that anticipated changes in the money supply have real effects, such as the Keynesian and Monetarist models. The cases where the monetary aggregates had no marginal predicative value for either anticipated or unanticipated money supply shocks, provides support for models that argue that changes in the money supply do not have real effects, such as Real Business Cycle models. Therefore, there is a problem that can arise because the Federal Reserve implements the same policy decisions across all monetary aggregates even though different monetary aggregates require different policy decisions.

On theoretical grounds, the analysis was unable to discriminate between competing schools of thought concerning the macroeconomy, because the different monetary aggregates yielded different results. However, it does appear that between 1960 and 1993, for the U.S. times series, unanticipated money supply shocks do not have any effect on the level of output. Since this result can occur in both Real Business Cycle models and Keynesian models, we are still left without a general consensus concerning the preferred modeling techniques.

These results are by no means definitive. There are a number of areas that this analysis can be expanded or improved. First of all, in order to replicate the results of Cover (1992), a nonlinear approach to the estimation of the unanticipated effects should have been performed, and the equations used in Cover (1992) are not necessarily based on equations that have been determined optimally, so there may exist a number of errors in the estimation procedure. Also, the method used to separate the money supply into anticipated and unanticipated effects needs to be addressed. The simple procedure used here and in previous papers, may not be picking out the anticipated and unanticipated effects in the most efficient manner.

There are also a couple of interesting extensions. It would have been informative to test for causality in the anticipated money supply in order to double check the result that it tends to be the anticipated effect that drives the causality relationship. As well, just because there is no asymmetric effect in the unanticipated money supply, does not mean there are no asymmetric effects in the anticipated money supply. Thus, it would be interesting to determine if there are rigidities in the economy that would cause an increase in the money supply to have a larger impact on the level of output than a decrease in the money supply.

As for the answer to the question does money matter?, it still remains to be answered in a definitive way. However, after the analysis done here, it appears that the answer will depend on the monetary aggregate used, and thus, modeling and estimation techniques will have to take this into account before a definitive answer can be found.

REFERENCES

Backus, D.K. and P.J. Kehoe, (1992), "International Evidence on the Historical Properties of Business Cycles", The American Economic Review 82, pgs. 864-888.

Barnett, W.A., (1980), "Economic Monetary Aggregates: An Application of Aggregation and Index Number Theory", Journal of Econometrics, 14, pgs. 11-48.

Barnett, W.A., D. Fisher and A. Serletis, (1992), "Consumer Theory and the Demand for Money" Journal of Economic Literature, 30, pgs. 2086-2119.

Barro, R.J., (1977), "Unanticipated Money Growth and Unemployment in the United States", The American Economic Review, pgs. 101-115.

Barro, R.J., (1978), "Unanticipated Money, Output, and the Price Level in the United States", Journal of Political Economy, pgs. 549-580.

Barro, R.J., (1989), "New Classicals and Keynesians, or the Good Guys and the Bad Guys", Schweiz Zeitschrift für Volkswirtschaft und Statistik.

Barro, R.J. and M. Rush, (1980), "Unanticipated Money and Economic Activity" in S. Fischer (ed.), Rational Expectations and Economic Policy, University of Chicago Press.

Belongia, M.T., (1995), "Measurement Matters: Recent Results from Monetary Economics Re-examined", Journal of Political Economy, forthcoming.

Bernanke, B.S., (1986), "Alternative Explanations of the Money-Income Correlation", Carnegie-Rochester Conference Series on Public Policy, 25, pgs. 49-100.

Campbell, J.Y., and N.G. Mankiw, (1987), "Permanent and Transitory Components and Macroeconomic Fluctuations", The American Economic Review, pgs. 111-117.

Chadha, B and E. Prasad, (1994), "Are Prices Countercyclical? Evidence from the G-7", Journal of Monetary Economics, 34, pgs. 239-257.

Christiano, L.J., (1986), "Money and the U.S. Economy in the 1980s: A Break from the Past?", Federal Reserve Bank of Minneapolis Quarterly Review, 10, pgs. 2-13.

Cochrane, J.H., (1988), "How Big is the Random Walk in GNP?", Journal of Political Economy, pgs. 893-920.

Cogley, T. and J.M. Nason, (1995), "Effects of the Hodrick-Prescott Filter on the Trend and Difference Stationary Time Series: Implications for Business Cycle Research", Journal of Economic Dynamics and Control, 19 , pgs. 253-278.

Conover, W.J. and R.L. Iman, (1982), "Analysis of Covariance Using Rank Transformation", Biometrics, 38, pgs. 715-724.

Cooley, T.F. and G.D. Hansen, (1989), "The Inflation Tax in a Real Business Cycle Model", The American Economic Review, pgs. 733-748.

Cooley, T.F. and L.E. Ohanian, (1991), "The Cyclical Behavior of Prices", Journal of Monetary Economics, 28, pgs. 25-60.

Corriveau, L., (1994), "Entrepreneurs, Growth and Cycles", Economica, 61, pgs. 1-15.

Cover, J.P., (1992), "Asymmetric Effects of Positive and Negative Money-Supply Shocks", Quarterly Journal of Economics, pgs. 1261-1282.

Cuthberson, K., S. Hall, and M.D. Taylor, (1992), Applied Economic Techniques, New York: Phillip Allen.

Davidson, R. and J.G. MacKinnon, (1993), Estimation and Inference in Econometrics, Oxford University Press.

De Long, J.B. and L.H. Summers, (1988), "How Does Macroeconomic Policy Affect Output", Brookings Papers on Economic Activity, pgs. 433-480.

Dickey, D.A. and W.A. Fuller, (1981), "Likelihood Ratio Statistics for Autoregressive Time Series With a Unit Root", Econometrica, 49, pgs. 1057-1072.

Diewert, W.E., (1976), "Exact and Superlative Index Numbers", Journal of Econometrics, 4(2), pgs. 115-145.

Diewert, W.E., (1978), "Superlative Index Numbers and Consistency in Aggregation" Econometrica, 46(4), pgs. 883-900.

Durlauff, S.N., (1989), "Output Persistence, Economic Structure, and the Choice of Stabilization Policy", Brookings Papers on Economic Acitvity.

Eichenbaum, M. and K.J. Singleton, (1986), "Do Equilibrium Real Business Cycle Theories Explain Postwar U.S. Business Cycles", NBER Macroeconomics Annual, pgs. 91-134.

Engle, R.F. and C.W.J. Granger, (1987), "Cointegration and Error Correction: Representation, Estimation and Testing", Econometrica, 55, pgs. 251-276.

Feige, E.L. and D.K. Pearce, (1979), "The Casual Causal Relationship Between Money and Income: Some Caveats for Time Series Analysis", The Review of Economics and Statistics, 61, pgs. 521-523.

Fleissig, A., D. Fisher, and A. Serletis, (1995), Mimeo.

Friedman, B.M. and K.N. Kuttner, (1993), "Another Look at the Evidence on Money-Income Causality" Journal of Econometrics, 57, pgs. 189-203.

Geweke, J., R. Meese and W. Dent, (1983), "Comparing Alternative Tests of Causality in Temporal Systems: Analytical Results and Experimental Evidence" Journal of Econometrics, 21, pgs. 161-194.

Gordon, D.V. and K. Sakyi-Bekoe, (1993), "Testing the Export-Growth Hypothesis: Some Parametric and Non-Parametric Results for Ghana" Applied Economics, pgs. 553-563.

Granger, C.W.J., (1988), "Some Recent Developements in a Concept of Causality" Journal of Econometrics, 39, pgs. 199-211.

Hansen, G.D., (1985), "Indivisible Labour and the Business Cycle", Journal of Monetary Economics, 16, pgs. 309-327.

Hansen, G.D. and E.C. Prescott, (1995), "Recursive Methods for Computing Equilibria of Business Cycle Models", in T.F. Cooley, (ed.) Frontiers of Business Cycle Research, Princeton University Press.

Hodrick, R.J. and E.C. Prescott, (1980), "Postwar Business Cycles: An Empirical Investigation", Carnegie Mellon University, Pittsburg, mimeo.

Holmes, J.M. and P.A. Hutton, (1988), "A Functional-Form, Distribution Free Alternative to Parametric Analysis of Granger Causal Models", Advances in Econometrics, 7, pgs. 211-225.

Holmes, J.M. and P.A. Hutton, (1990a), "On the Causal Relationship Between Government Expenditure and National Income" The Review of Economics and Statistics, pgs. 87-95.

Holmes, J.M. and P.A. Hutton, (1990b), "Small Sample Properties of the Multiple Rank F-Test with Lagged Dependent Variables" Economics Letters, 33, pgs. 55-61.

Hsiao, C., (1981), "Autoregressive Modelling and Money-Income Causality Detection" Journal of Monetary Economics, 7, pgs. 85-106.

King, M., (1990), Money and Monetary Mechanisms in Canada, Master Thesis, University of Calgary, Calgary, Alberta.

King, R.G. and C.I. Plosser, (1984), "Money, Credit, and Prices in a Real Business Cycle", The American Economic Review, pgs. 363-380.

King, R.G., C.I. Plosser and S.T. Rebelo, (1988a), "Production, Growth and Business Cycles: I. The Basic Neoclassical Model", Journal of Monetary Economics, 21, pgs. 195-232.

King, R.G., C.I. Plosser and S.T. Rebelo, (1988b), "Production, Growth and Business Cycles: II. New Directions", Journal of Monetary Economics, 21, pgs. 309-341.

King, R.G. and S.T. Rebelo, (1993), "Low Frequency Filtering and Real Business Cycles", Journal of Economic Dynamics and Control, 17, pgs. 207-231.

Kirman, A.P., (1992), "Whom or What Does the Representative Individual Represent?", Journal of Economic Perspectives, 6, pgs. 117-136.

Kydland, F.E. and E.C. Prescott, (1982), "Time to Build Aggregate Fluctuations", Econometrica, 50, pgs. 1345-70.

Kydland, F.E. and E.C. Prescott, (1990), "Business Cycles: Real Facts and a Monetary Myth", Federal Reserve Bank of Minneapolis Quarterly Review, pgs. 3-18.

Liiterman, R. and L. Weiss, (1985), "Money, Real Interest Rates, and Output: A Reinterpretation of Postwar U.S. Data", Econometrica, 53, pgs. 129-156.

Lucas, R.E. Jr., (1972), “Expectations and the Neutrality of Money”, Journal of Economic Theory, April.

Lucas, R.E. Jr., (1973), “Some International Evidence on Output-Inflation Tradeoffs”, The American Economic Review, June.

Mankiw, G.N., (1989), "Real Business Cycles: A New Keynesian Perspective", Journal of Economic Perspectives, 3, pgs. 79-90.

Manuelli, R.E., (1986), "Modern Business Cycle Analysis: A Guide to the Prescott-Summers Debate", Federal Reserve Bank of Minneapolis Quarterly Review, pgs. 3-7.

McCallum, B.T., (1986), "On 'Real' and 'Stickey-Price' Theories of the Business Cycle", Journal of Money, Credit, and Banking, 18, pgs. 397-414.

McCallum, B.T., (1989a), Monetary Economics: Theory and Policy, New York, MacMillan Publishing Company.

McCallum, B.T., (1989b), "Real Business Cycle Models", in R.J. Barro (ed.), Modern Business Cycle Theory, Cambridge, Mass.: Harvard University Press.

McGratten, E.R., (1994a), "A Note on Computing Competitive Equilibria in Linear Models", Journal of Economic Dynamics and Control, 18, pgs. 149-160.

McGrattan, E.R., (1994b), "The Macroeconomic Effects of Distortionary Taxation", Journal of Monetary Economics, 33, pgs. 573-601.

Mendozza, E.G., (1991), "Real Business Cycles in a Small Open Economy", The American Economic Review, pgs. 797-820.

Mishkin, F.S., (1982), "Does Anticipated Monetary Policy Matter? An Econometric Investigation", Journal of Political Economy, 90, pgs.22-51.

Nelson, C. and C.I. Plosser, (1982), "Trends and Random Walks in Macroeconomic Time Series", Journal of Monetary Economics, 10, pgs. 139-167.

Olejnik, S.F. and J. Algina, (1985), "A Review of Nonparametric Alternatives to Analysis Covariance", Evaluation Review, 9(1), pgs. 51-83.

Perron, P., (1989), "The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis", Econometrica, 57, pgs. 1361-1401.

Plosser, C.I., (1989) "Understanding Real Business Cycles", Journal of Economic Perspectives, 3, pgs. 51-75.

Prescott, E.C., (1986), "Theory Ahead of Business Cycle Measurement", Federal Reserve Bank of Minneapolis Quarterly Review, 10, pgs. 9-22.

Runkle, D., (1987), "Vector Autoregressions and Reality", Journal of Business and Economic Statistics, 5, pgs. 437-442.

Said, S.E. and A. Dickey, (1984), "Testing for Unit Roots in Autoregressive-Moving Average Models of Unknown Order" Biometrica, 71, pgs. 599-607.

Sargent, T.J., and N. Wallace, (1975), "Ratonal Expectations, the Optimal Monetary Instrument and the Optimal Money Supply Rule", Journal of Political Economy, April.

Schwarz, G., (1978), "Estimating the Dimension of a Model", The Annals of Statistics, 6, pgs. 461-464.

Serletis, A., (1988), "The Empirical Relationsh8ip Between Money, Prices, and Income Revisited", Journal of Business and Economic Statistics, 6, pgs. 351-358.

Serletis, A., (1990), "Velocity Effects of Anticipated and unanticipated Money Growth and Its Variability", Applied Economics, 22, pgs. 775-783.

Serletis, A., (1995), "Random Walks, Breaking Trend Functions, and the Chaotic Structure of the Velocity of Money", Journal of Business and Economic Statistics, forthcoming.

Serletis, A. and M. King, (1993), "The Role of Money in Canada", Journal of Macroeconomics, pgs. 91-107.

Serletis, A. and M. King, (1994), "Deterministic Trends and Money-Output Causality", Applied Financial Economics, pgs. 143-147.

Serletis, A. and D. Krause, (1995), "Nominal Stylized Facts of U.S. Business Cycles", The University of Calgary. Calgary, mimeo.

Sims, C.A., (1972), "Money, Income, and Causality", The American Economic Review, pgs. 540-552.

Singleton, K.J., (1988), "Econometric Issues in the Analysis of Equilibrium Business Cycle Models" Journal of Monetary Economics, 21, pgs. 361-386.

Smith, R.T., (1992), "The Cyclical Behavior of Prices", Journal of Money, Credit, and Banking, 24, pgs. 413-430.

Snowdon, B., H. Vane and P. Wynarczyk, (1994), A Modern Guide to Macroeconomics : An Introduction to Competing Schools of Thought, Edward Elgar Publishing, England.

Stadler, G.W., (1994), "Real Business Cycles", Journal of Economic Literature, 32, pgs. 1750-83.

Stock, J.H. and M.W. Watson, (1989), "Interpreting the Evidence on Money-Income Causality" Journal of Econometrics, 40, pgs. 161-181.

Thorten, D.L. and D.S. Batten, (1985), "Lag-Length Selection and Tests of Granger Causality between Money and Income", Journal of Money, Credit, and Banking, 17, pgs. 164-178.

Varian, H., (1982), "The Nonparametric Approach to Demand Analysis", Econometrica, 50, pgs. 945-973.

Yi, G., and G. Judge, (1988), "Statistical Model Selection Criteria", Economics Letters, 28, pgs. 47-51.

Zellner, A., (1979), "Causality and Econometrics", in K. Brunner, and A.H. Meltzer, (eds.), Carnegie-Rochester Conference Series on Public Policy, Vol.10, North-Holland, New York.

Zivot, E. and D.W.K. Andrews, (1992), "Further Evidence on the Great Crash, the Oil Price Shock, and the Unit Root hypothesis" Journal of Business and Economic Statistics, 10, pgs. 251-270.

APPENDIX I: THE COMPOSITION OF 4 MONETARY AGGREGATES

M1 consists of:

- Currency and travelers' checks
- Demand deposits held by consumers
- Demand deposits held by businesses
- Other checkable deposits
- Super NOW accounts held at commercial banks
- Super NOW accounts held at thrifts

M2 consists of:

- M1 plus
- Overnight RPs
- Overnight Eurodollars
- Money market mutual fund shares
- Money market deposit accounts at commercial banks
- Money market deposit accounts at thrifts
- Savings deposits at commercial banks
- Savings deposits at savings and loans (S&Ls)
- Savings deposits at mutual savings banks (MSBs)
- Savings deposits at credit unions
- Small time deposits and retail RPs at commercial banks
- Small time deposits at S&Ls and MSBs and retail RPs at thrifts
- Small time deposits at credit unions

M3 consists of:

- M2 plus
- Large time deposits at commercial banks
- Large time deposits at thrifts
- Institutional money market funds
- Term RPs at commercial banks and thrifts
- Term Eurodollars

L consists of:

- M3 plus
- Savings bonds
- Short term Treasury securities
- Bankers' acceptances
- Commercial paper