AN INVESTIGATION OF INFLATIONARY EXPECTATIONS, MONEY GROWTH, AND THE VANISHING LIQUIDITY EFFECT OF MONEY ON THE INTEREST RATE IN SOUTH AFRICA : ANALYSIS AND POLICY IMPLICATION.

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Declaration of Originality

The author hereby declares that the contents of this dissertation, unless specifically indicated to the contrary, are his own work and that the thesis has not been submitted simultaneously or, at any other time, for another degree.

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As the candidate's supervisor I have/have not approved this thesis/dissertation for submission

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PREFACE

This thesis measures the extent to which the interest rate falls after an increase in the money supply. Even though the South African Reserve Bank has as a commitment, a goal for the inflation rate to vary between a prescribed band, it still needs to be able to use active monetary policy if economic conditions require intervention. To this end it is of interest to measure the number of quarters for which interest rates remain low after the liquidity of the macro-economy improves. In the monetary literature (for example Melvin (1983)) there are methods that have been used to measure the duration of the decline in the interest rate. These models have not to our knowledge been tested using South African data. We find evidence that the monetary authorities can induce falling interest rates for approximately one quarter using appropriate monetary policy. This result was subjected to testing under alternative assumptions concerning the structure of the error term and found to be robust. This thesis argues for the first time, that there may not be a set pattern to the time path of the interest rate, and inflationary expectations may cause the interest rate to rise, however, this rise is not confined to one uniform adjustment over time, but may occur in separate discrete adjustments. This theoretical innovation and the possibility of an identification problem suggested we estimate another more general model of interest rate determination.

The second model we estimate is that of Mehra (1985). After a careful analysis of the data to ensure that there are no major statistical problems with the South African data, we find that inflationary expectations result in a higher interest rate especially in times of higher expected inflation. Thus, one benefit of the Reserve Bank's current policy that aims for a band between which the rate of inflation (appropriately defined) must fall, is an improved operation of the transmission mechanism. Therefore, if intervention is required, say, if the economy suffers a severe supply shock, then monetary policy can be effective.

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CHAPTER 1

INTRODUCTION

Earlier empirical work describes the effect of higher money growth on interest rates over time. First, there is a fall in the interest rate as a result of a liquidity effect. This is followed by the income and expectations effect. The liquidity effect results in a fall in the nominal rate of interest following an increase in the growth rate of the money supply. At some later stage, the interest rate increases as a result of the income and expectations effects. The interest rate takes time to increase as prices and incomes are slow to adjust. The whole process can be described as a traditional transmission mechanism with a liquidity, income and Fisher or expectations effect.

However, if the expectations effect occurs rapidly or if there is a reduction in the lagged effect of income, then the liquidity effect will not be observed. Empirical work has confirmed this trend of the vanishing liquidity effect. Mishkin (1981) suggests that the liquidity effect of money on interest rates did not exist and Melvin's (1983) work implied that the liquidity effect existed in the '50s and the '60s but vanished in the '70s. Makin (1983), on the other hand, reports evidence consistent with the presence of a statistically significant but quantitatively weak liquidity effect.

The main objectives of this dissertation are:

- ⇨ Firstly, to further investigate the existence of this liquidity effect, using South African data.
- ⇨ Secondly, to determine if there is any econometric evidence of the vanishing liquidity effect in the South African macro-economy.
- ⇨ Thirdly, the dissertation seeks to establish whether the vanishing liquidity effect is due to inflationary expectations that arise as a consequence of the increase in the money supply.

Chapter 2 provides a theoretical investigation of the existence of the liquidity effect. It initially draws on an article by Melvin (1985) stressing the expected pattern of the response of the interest rate to changes in the money growth rate. Secondly, it presents the theoretical investigation of the existence of the liquidity effect using the 'Fisher' equation approach to interest rate determination. Chapter 2 also looks at the reasons for the changing pattern of monetary effects on interest rates and analyses the impact of inflationary expectations and monetary growth on the liquidity effect. In Chapter 3, several different empirical tests are carried out to support the theoretical background surrounding the existence of the liquidity effect and whether this effect vanishes as a result of inflationary expectations. It presents evidence on the subject using South African data, describing the short-lived liquidity effect. Chapter 4 concludes the dissertation with a discussion of the policy implication of the observed pattern on the interest rate from monetary growth.

CHAPTER 2

THEORETICAL INVESTIGATION OF THE EXISTENCE OF THE LIQUIDITY EFFECT

2.1 Introduction

The existence of the liquidity effect will be theoretically investigated in this chapter by drawing on the literature of:

- ✓ Melvin (1983), explaining the usual pattern of interest rates over time from a monetary shock and the 'stylized' lag distribution of monetary effects on interest rates, and;
- ✓ Mehra (1985), using the 'Fisher' equation approach to interest rate determination.

Section 2.4 of this Chapter also looks at the reasons for the changing pattern of monetary effects on interest rates and analyses the impact of inflationary expectations and monetary growth on the liquidity effect. It draws on the literature that attempts to explain the short duration of the liquidity effect as a result of inflationary expectations. An example of such study is Friedman (1968) which suggests that inflationary expectations rise because of the increase in the money supply growth rate.

Given the central role of interest rates, both real and nominal, in influencing a wide range of economic activities and the high and volatile interest rates and inflation rates present in most economies, the explanation of the divergence between the theoretical and empirical results on this issue warrants serious consideration.

2.2 The Stylized Lag Distribution of Monetary Effects on Interest Rates

Cagan, (1969) states the only crucial assumption that is widely accepted is that an economy adjusts to monetary changes through a combination of changes in interest rates and income. To understand the effects of changes in monetary policy on the interest rate, one should consider the important relationship between money and the interest rate. For instance, if a central bank wants to keep interest rates down, it can do so by buying securities. This raises their prices and lowers their yields. In the process, it also increases the quantity of reserves available to banks, hence the amount of credit, and ultimately the quantity of money. The initial impact of increasing the quantity of money at a faster rate than in the past is to make interest rates lower than they otherwise would have been. However, this is only the beginning of the process and not the end. The whole process can be explained by both the 'monetary transmission mechanism' as well as by the 'stylized pattern' of interest rates that result from higher monetary growth.

2.2.1 The Monetary Transmission Mechanism

The Monetary Transmission Mechanism is the process by which an expansionary monetary policy affects aggregate demand[1] through adjustments to interest rates and price levels.

Two steps in the Transmission Mechanism

- First, an increase the nominal money stock increase real balances[2], which generates a portfolio dis-equilibrium at the prevailing interest rate and level of income, implying that people are holding more money than they want.

[1] Aggregate demand refers to the total demand for goods and services in the economy.
[2] Real balances are also referred to as the real money stock, which is nominal money stock, M (controlled by the monetary authorities) divided by the price level, P.

- The second stage of the transmission mechanism process occurs when people adjust their portfolio holdings to get back to equilibrium, that is where demand and supply of money are equal. This is done when the portfolio holders attempt to reduce their money holdings by buying other assets, thereby changing the assets' prices. These portfolio adjustments thereby lead to a change in asset prices as well as in interest rates, which can result in adjustments to spending. The spending adjustments in turn, result in changes in aggregate demand, which lead to income adjustments. Therefore, through the transmission mechanism, changes in the real money stock affect the level of output in the economy.

2.2.2 The 'Stylized Pattern' of Higher Monetary Growth on the Interest Rate

The traditional analysis of the effects of changes in money growth on the interest rate is also explained by a 'stylized pattern', (Melvin, 1983), which falls into four areas, namely, liquidity, financial, income and expectations effects.

- <u>Liquidity Effect</u>

With an increase in the growth rate of money there is an excess supply of money at current levels of income, interest rate, and price level. If the price level and real income adjust slowly, then the nominal interest rate must decline in order to equate money demand and money supply. This initial fall in the nominal and real[3] interest rate is known as the liquidity effect.

- <u>Financial Effect</u>

The financial effect is a decline and later rise, over time, in the interest rate following an increase in money growth after the liquidity effect explained above. When the growth rate of the money supply increases, excess reserves of banks also increase. Banks use short-term marketable securities to adjust to changes in their reserves in the short-run, and only adjust their loan portfolios over time.

[3] If the price level and inflationary expectations adjust slowly, a reduction in the nominal interest rate implies a reduction in the real rate.

Thus as the rate of the money supply growth increases, the financial effect will lead banks to purchase securities and thereby lower the rate of interest in response. Over time, as loan portfolios adjust, the demand for marketable securities falls, which tends to increase the interest rate.

- Income Effect

The extent to which monetary changes affect interest rates will eventually depend upon the speed of the adjustment in income. Over time, nominal income will rise following the increased growth rate of the money supply (due to a higher price level as well as short-run increases in real income) and this rise in nominal income will increase money demand which in turn leads to higher interest rates.

- Fisher or Expectations Effect

Finally, there is the 'Fisher' or Expectations effect. The nominal interest rate increases if inflationary expectations adjust upwards with higher money growth. If expected inflation has no effect on the real rate of interest in the steady state, then the rise in the nominal rate must be proportional to the increase in expected inflation.

Hence, the 'stylized pattern' or expected pattern of the interest rate over time from an increase in the money supply growth occurs through these four effects. The 'stylized pattern' can be observed by estimating the distributed lag regression of money growth on the nominal interest rate using Equation (1) below, which is adapted from Melvin (1983:183).

$$\Delta i_t = \alpha + \sum_{j=0}^{k} \beta_{t-j} \Delta gM_{t-j} \qquad (1)$$

Where Δi_t - is the change in the interest rate at time t;

t - is the number of observations;

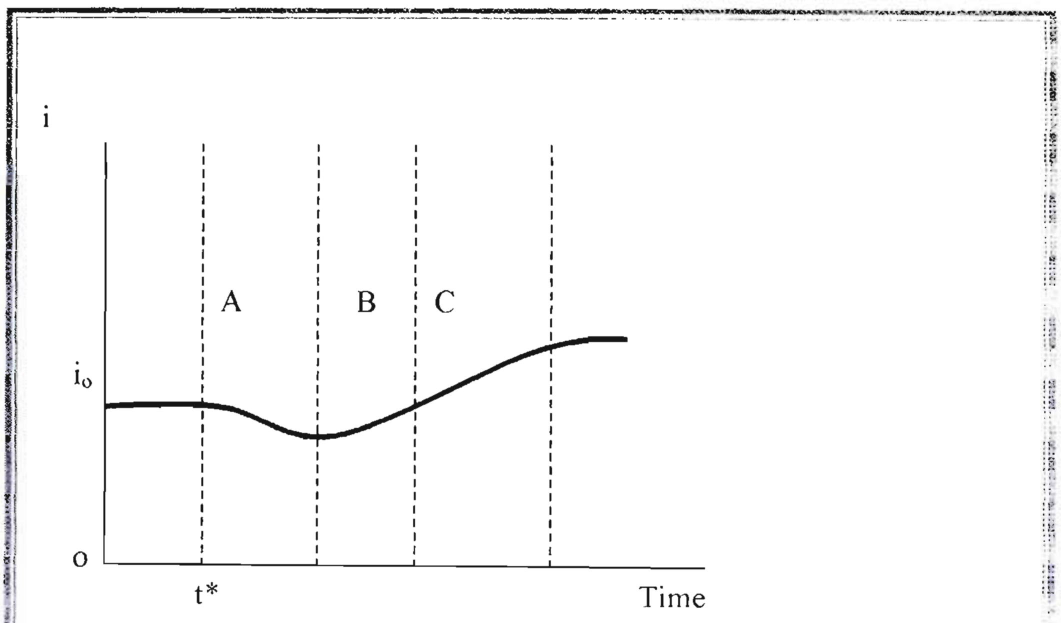
k - is the number of lags; and

ΔgM - is the change in the growth rate of money.

The existence and strength of the liquidity effect can be noted by examining the sign and size of the coefficients on the first few lags of the money growth variable using money growth as the only right hand side explanatory variable. For a well-defined liquidity effect, the coefficients in the first few lags are expected to be negative and increasingly negative, so that, when they are accumulated and plotted over time, the familiar tendency of the liquidity effect is apparent. That is, the interest rate falls at first and only subsequently rises following the impact of the other effects.

This expected interest rate pattern, which follows an expansionary monetary policy, can also be illustrated diagrammatically (starting at time t^*) using Figure 1: 'The Stylized Lag Distribution of Monetary Effects on the Interest Rate'.

FIGURE 1: **The Stylized Lag Distribution of Monetary Effects on the Interest Rate**



Source: M.Melvin, 1983, p189

In terms of the effects discussed above, region A reflects the operation of the liquidity effect; the income effect occurs in region B, while the financial effect is active in both A and B. Region C reflects the expectations effect as the nominal interest rate increases due to the anticipation of higher future inflation.

2.3 Theoretical Investigation of the Existence of the Liquidity Effect using the Fisher Equation Approach to Interest Rate Determination

The work of Mehra in 1985 seemed to confirm the stylized pattern of the above section. In particular, his work, which developed through the estimation of a regression equation using the Fisher equation approach to interest rate determination, showed the presence of a statistically significant liquidity effect in a period of low inflation. Mehra's approach involves the estimation of the standard Fisher equation in which the determinants of the real interest rate is explicitly specified by means of an IS-LM model augmented by an Aggregate Supply relationship. The sign and size of the estimated coefficient appearing on the money growth variable in the associated Fisher equation is then used to infer the existence and the magnitude of the liquidity effect.

Consider the following IS-LM-Aggregate Supply model:

$$IS: i(1-T) - \pi = \alpha_0 + \alpha_1 X + \alpha_2 Y + \alpha_3 SS + \alpha_4 Z_t + U_{st} \quad \ldots\ldots (2)$$

$$\alpha_2, \alpha_3 < 0 \qquad \alpha_1, \alpha_4 > 0$$

$$LM: i(1-T) = \frac{b_o}{b_2} + \frac{b_0 Y}{b_2} + \frac{1}{b_1}(P - M + Y) + U_{st} \quad \ldots\ldots (3)$$

$$b_1, b_2 > 0$$

$$AS: P = c_0 + P^e + c_1 Y + c_2 SS + U_{st} \quad \ldots\ldots (4)$$

$$c_1, c_2 > 0$$

Where all the variables except i and Z are in natural logarithms;

π - is the expected rate of inflation;

Y - is the real output;

X - is the exogenous component of aggregate real demand, which captures the effects of changes in the autonomous components of aggregate real demand such as real exports and real government expenditures.

M - is the nominal money stock;

P - is the price level;

P^e - is the expected price level;

i - is the nominal interest rate;

SS - is the supply shock variable measuring the relative price of energy.

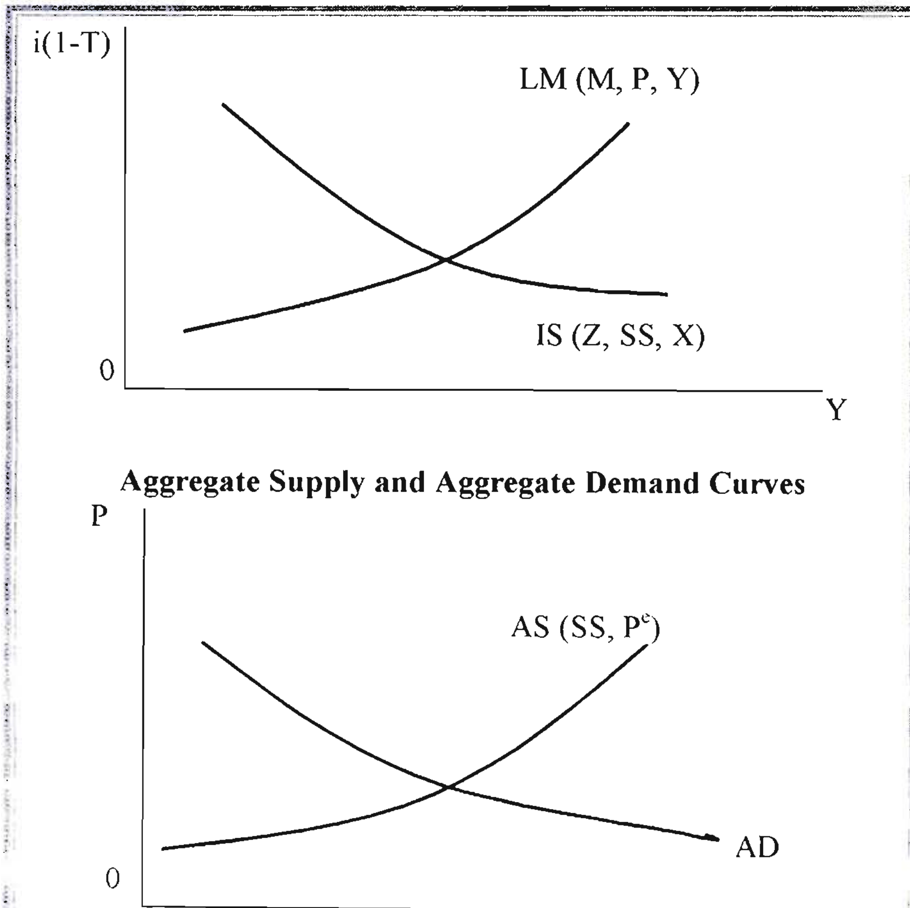
Z - is the percentage change in real output lagged one period. It proxies for the effect of income induced investment expenditures; the so-called investment accelerator effect.

T - is the average marginal tax rate on interest income;

U_{st} - s=1,2,3, are stochastic error terms

The three equations, IS-LM-Aggregate Supply can be represented graphically in Figure 2 below.

FIGURE 2: **IS and LM Curves including Aggregate Demand and Supply**



*Aggregate demand curve (AD) is derived by combining the IS and LM curves

Source: Y. Mehra, 1985, p26

Equation (2) is the equation of the downward sloping IS curve (Figure 2) showing an inverse relationship between the after-tax real interest rate, $i(1 - T) - \pi$, and real output Y. The position of the IS curve depends upon the exogenous component of the real demand X, the lagged growth of real income Z and the supply shock, SS. Equation (3) is the equation of the LM curve showing a positive relationship between the after-tax nominal rate $i(1 - T)$ and real output Y; its position depends upon the price level P, and the nominal money stock M. Equation (4) is the equation of the aggregate supply curve implying a positive relationship between the price level and real output; its position depends upon the expected price level P^e and the supply shock variable SS. U_1, U_2 and U_3 respectively, are stochastic error terms appearing in the IS, LM and AS relationships.

To derive the Fisher equation associated with the macro model described above, equation (2) through (4) can be combined to get the following:

$$i_t = (1 - (1 - T)) [A_0 + A_1 X_t + A_2 SS_t + A_3 DM_t + A_4 Z_t + A_5 \pi_t] + V_t \quad \ldots\ldots\ldots (5)$$

Where DM_t is $(M - P^e - Y)$, and A_1, A_2, A_3, A_4, and A_5 are the parameters in the nominal interest rate equation. The nominal interest rate in equation (5) responds positively to increases in expected inflation ($A_5 > 0$); the exogenous component of real demand ($A_1 > 0$); and real income ($A_4 > 0$). The supply stock variable has an uncertain effect upon the nominal interest ($A_2 < 0$, $A_2 = 0$, $A_2 > 0$), as it depends on import prices which can both rise or fall. The coefficient on the money stock variable is expected to be negative ($A_3 < 0$), implying that a higher money stock depresses the nominal interest rate.

The stochastic term V_t in (5) is the reduced form disturbance term and is related to the stochastic terms appearing in the IS, LM, and AS relationships in the following way:

$$V_t = ((c_1 - b_1) U_{1t} + \alpha_2 U_{2t} + \alpha_3 U_{3t}) / (d) \quad \ldots\ldots\ldots (6)$$

Where $d = (b_1 - c_1 + b_2 \alpha_2)$.

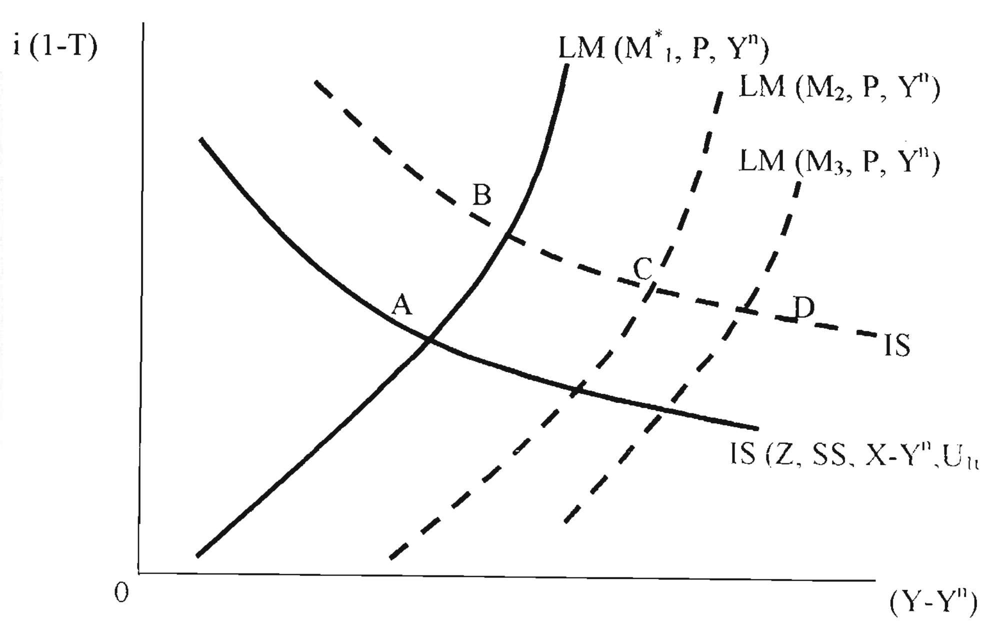
Equation (6) shows that the stochastic shifts occurring in the IS, LM, and AS relationships, can cause stochastic shifts in the nominal interest rate equation (5) and thus cause the actual nominal interest rate to deviate in the short-run from the value implied by the behavior of expected inflation, autonomous real demand, the relative price of energy, and the money stock.

In the above framework, the existence of the liquidity effect is investigated by examining the statistical significance of the parameter A_3, which is usually estimated with ordinary least squares. However, the use of ordinary least squares may not be appropriate if any one of the right-hand side explanatory variables appearing in equation (5) is correlated with the error term V_t, as the ordinary least square estimates of the parameters will be inconsistent and this may yield an incorrect inference about the existence of the liquidity effect. Of interest here, is the possibility that the error term V_t may be correlated with the money growth variable due to the way the monetary authorities implement its monetary policy. This problem referred to as the problem of autocorrelation (tested in Section 3.4.1), can be overcome if the monetary authorities conduct monetary policy by focusing solely on monetary aggregates. In this case, any random rise in the nominal interest rate ($V_t = 0$) as a result of a random shift in the IS, the LM, or the AS relationship is not offset by the monetary authority letting money growth (M) deviate from its targeted value. Here, the money growth variable is likely to be predetermined and not correlated with the error term V_t. However, if the monetary authorities, though still focusing on the monetary aggregates, do partially smooth interest rates, then a positive correlation between DM_t and V_t may exist. This can be illustrated by the following example.

Consider a stronger than expected increase in the exogenous component of real demand causing an upward random shift in the IS relation ($U_{1t} > 0$). It is clear from equation (6) that a positive shock in the IS relation will cause a positive shock ($V_t > 0$) in the nominal interest rate equation (5). This will cause the nominal interest rate to rise. If the monetary authorities decide to prevent or reduce the extent of this rise, it would let the money stock (M) rise and thereby create a positive covariance between DM_t and V_t.

In this case, the ordinary least squares estimation procedure will generate an inconsistent estimate of the liquidity effect A_3. The extent of the least squares bias in the estimate of the liquidity effect parameter in equation (5) becomes more severe if the monetary authorities conduct a monetary policy focusing on interest rates. In the case, in which the Reserve Bank fixes a nominal interest rate and stands ready to maintain it, a regression equation like (5) is not relevant. This is so because the nominal rate is predetermined, and the nominal money stock simply responds to any discrepancy between the actual and the targeted value of the nominal interest rate. If the reserve bank is successful in this interest rate pegging policy, the regression of the nominal rate on the right-hand side explanatory variables as in equation (5) should yield a coefficient on the money growth variable, which is not statistically different from zero. The above point can be illustrated graphically by Figure 3 below.

FIGURE 3: **Shift in IS and LM Curves**



All variables are as defined in the test. U1t is the stochastic error term in the IS relationship and M^*_1 is the targeted level of the money stock. M_2 and M_3 are actual levels of the money stock. $M_3 > M_2 > M^*_1$

Source: Mehra, 1985: 27

Figure 3 shows an initial equilibrium at point A in the IS-LM diagram. Consider a positive stochastic shock in the IS relationship, arising for instance from a stronger than anticipated increase in aggregate demand. This shock causes the IS curve to shift upward moving the equilibrium point from A to B resulting in an upward pressure on the after-tax nominal interest rate. If the reserve bank does not smooth the interest rate, then the actual money stock stays at M^*_1, the targeted level. But if the reserve bank does smooth interest rates, it may let the actual money stock rise to M_2, resulting in a new equilibrium at point C in Figure 3. At this point, we have a higher money stock and a higher level of after-tax nominal interest rate, (compare the interest rate at A to the interest rate at C in Figure 3).

On the other hand, if the reserve bank decides to eliminate completely the rise in the nominal interest rate, it may cause the money stock to rise enough to yield the equilibrium point D shown in Figure 3, with a higher money stock ($M_3 > M^*_1$). Notice at point D that interest rates have returned close to the level at A. Thus, a positive stochastic shock in the IS relationship combined with a partial smoothing of interest rates creates a positive correlation between money and the error term in the nominal interest rate regression.

2.4 Inflationary Expectations and Money Growth - Impact on the Liquidity effect

Section 2.2.2 points out that after an initial drop in interest rates caused by an increase in the money growth rate, the interest rates would tend to increase due to the financial, income, and expectations effects. Regarding the financial effect, it is not clear whether banks are able to adjust to their loan portfolios quickly. If a quick adjustment occurs, then a more rapid increase in interest rates following the initial fall in rates would be expected.

Considering the income effect, if changes in nominal income follow closely the changes in the money growth rate over time, then the income effect should contribute to a faster rise in the interest rates following an increase in the growth rate of the money supply. However, it is well known that the price level and the real income do not adjust fully as the money supply changes. Therefore, it seems highly unlikely then that the dramatic shortening of the observed liquidity effect could be due to a changing income effect. If the financial and income effects can be ruled out as an explanation of the change of monetary effects on interest rates, then the focus falls on the Fisher or expectations effect.

While Section 3.5 of Chapter 3 provides empirical evidence with South African data, confirming the shortening of the liquidity effect caused by inflation expectations, the next section draws on theory and empirical tests of earlier work in order to attempt to justify the fact that the vanishing liquidity effect is due to inflationary expectations that occur as a result of an increase in the money growth rate.

2.4.1 Inflationary Expectations and Interest Rates Effects

In 1973, Arthur Burns stated:

- "At present there is no real alternative to a restrictive monetary policy. To be sure, if we permitted money and credit to expand at a more rapid pace, short-term interest rates would decline for a brief period. But in so doing we would be adding fuel to the inflationary fires now raging. Before very long, interest rates would rise again, and probably well beyond their present level, as both lenders and borrowers adjusted to the quickened pace of inflation. The simple and inescapable truth is that inflation and high nominal interest rates go together".

Inflation is a process of continuously rising prices with which, all of us are thoroughly and depressingly familiar. In early times, it was commonly believed that an expansionary monetary policy would significantly lower interest rates, while more recently policymakers have realised that during a time of high interest rates caused by rapid inflation, increasing the money supply will only increase anticipated inflation and thus increase nominal interest rates even further.

To illustrate the linkages between the nominal interest rate and expected inflation, it is useful to refer to the Fisher's equation below, which states that the nominal interest rate (i_t) equals the real interest rate plus expected inflation.

$$i_t = E_t\,(r_{t+1} / I_t) + E_t\,(\pi_{t+1} / I_t) \quad \ldots\ldots(7)$$

Where r_{t+1} = real interest rate in the next period or period $_{t+1}$,

π_{t+1} = inflation rate in the next period or period $_{t+1}$.

Both expectations (E_t) are conditional on the information available at time t, (I_t). In terms, of equation (7), money supply announcements affect interest rates by altering the information set and thereby changing expectations. It is important to stress that this is the only way that announcements of changes in money supply can affect interest rates, since announcements have no impact on actual money balances.

Friedman (1968) has argued that in a high inflationary environment, inflationary expectations become very responsive to money growth making the expectation effect strong and prompt enough to overpower the short-term liquidity effect. In the context of the Mehra model discussed in Section 2.3, money growth is associated with a reduction in the nominal interest rate provided that the expected inflation rate variable π_t, is not immediately affected by the current acceleration in the money growth rate. If the expectations effect of higher money growth occurs rapidly, then higher money growth may not depress the nominal interest rate, not even in the short run. This means there is no liquidity effect.

Blejer (1978) confirms the result that a reduced liquidity effect is due to a 'greater sensitivity to inflation on the part of economic agents when the inflation rate is higher'. He postulates that the fast increase in the nominal interest rates following a monetary expansion seems to indicate that in countries with a long history of rapid inflation, economic agents tend to invest more resources in improving their inflation forecasts and hastening the process of translating monetary changes into price expectations.

However, more recent theoretical contributions have indicated the response of the nominal interest rate to anticipated inflation is less that unity. We seek to confirm whether this is so using South African data.

Robert Mundell (1963) demonstrates that by reducing the value of real money balances, and hence wealth, inflation results in a rise in savings and a reduction in the real rate of interest. The nominal interest rate again rises by less than the rate of inflation as the demand for real balances falls, thus increasing the capital intensity of the economy and lowering the real rate of return. Thomas Sargent's (1972, 1973, 1976) analysis indicates, when using a general equilibrium macroeconomic model, the magnitude of the response of the nominal interest rate to anticipated inflation depends upon the structural parameters of the model. Only under certain extreme conditions (for example, vertical LM, horizontal IS curve) will an increase in the anticipated rate of inflation produce an immediate equivalent rise in the nominal interest rate. In general, the response will be less than perfect.

2.5 Conclusion

This Chapter sheds light on the traditional analysis of the effects of changes in money growth on nominal interest rates that occurs through four effects:

- The Liquidity Effect;
- The Financial Effect;
- The Income Effect; and
- The Fisher or Expectations Effect.

The important assumption underlying the description of the time pattern of the effects of a higher money supply growth on the interest rate is that both the income and expectations effect of a current acceleration in money supply growth occurs with a lag

If this assumption is not valid, for example, if the expectations effect of higher money supply growth occurs rapidly or if there is a reduction in the lag effect of money on income, the liquidity effect will not be maintained as interest rates will rise shortly after its initial fall. Section 2.4 reviews the literature on inflationary expectations and points out that the shortening of the liquidity effect can be attributed to higher inflationary expectations.

Earlier research such as Cagan (1969) has indicated that the monetary authority could induce falling interest rates for two or three quarters by increasing the growth rate of the money supply. This is a sufficiently long horizon to be politically attractive, and allows, the monetary authority to follow a policy of actively managing interest rates. This dissertation hopes to investigate the time period for which it is possible to have the liquidity effect before inflationary expectations reduce the impact of higher liquidity (as seen in section 2.4). One would not want the monetary authorities to lower interest rates if the liquidity effect is weak or if the expectations effect is particularly strong. It should be noted that there is nothing in theory to prevent the expectations effect from becoming operative prior to the other effects. Something not noted in the literature but we present here.

This Chapter draws on Mehra (1985) who examines the interest rate effect using the IS-LM-Aggregate Supply model of the macro-economy. From this model, it is possible to obtain a reduced form equation for the interest rate as a function of money supply growth keeping constant a number of variables including the expected rate of inflation. The existence and the magnitude of the liquidity effect is determined by estimating the coefficient attached to the money growth variable in (5). We do this using South African data in the next chapter. In addition, we estimate the Melvin (1983) model and examine the time pattern of the interest rate to determine which of the four effects predominate

CHAPTER 3

EMPIRICAL INVESTIGATION OF THE VANISHING LIQUIDITY EFFECT OF MONEY ON THE INTEREST RATE

3.1 Introduction

Economists have long been interested in the time pattern of the effects of money growth on the nominal and real interest rate. The analytical framework that underlies the empirical investigation differs widely among economists. However, in each case, inferences about the existence of the liquidity effect are based upon a nominal interest rate regression in which money growth appears either as a sole regressor (Melvin, 1983), or as one of the right hand side regressors (Mehra, 1985).

This chapter reports the empirical results concerning the existence, magnitude, and temporal stability of the liquidity effect using both Melvin and Mehra models applied to South African data. The aim of this econometric chapter is to determine whether the interest rate declines for a few months following an increase in the growth rate of the money supply, and then subsequently rises when expected inflation increases. Such patterns have been observed in other countries. Of interest here is whether these patterns are evident in the South African data. Much empirical work is undertaken without examining the data. This chapter avoids this common practice by using a number of tests to explore the properties of the data for the Mehra model before performing any regression analysis.

3.2 Early Empirical Works Confirming the Existence and the Vanishing Liquidity Effect

Earlier work, which examines the time pattern of the effects of higher monetary growth on interest rates, confirmed that interest rates fall following an increase in the money supply growth rate. Cagan and Gandofi (1969) estimated equation (1) of Section 2.2.2 of Chapter 2, over the period 1951 to 1965 using monthly data and found that the interest rate declines for six months (or two quarters) following an increase in money growth and only then begins to rise. Gibson (1970) using the same sample period found results similar to Cagan and Ganfodi. With the latter's definitions of money and interest rates used, Gibson found that the initial negative effects on the interest rate began to be reversed four to nine months later. Gibson estimate of the time period of the liquidity effect is slightly longer. Our estimate below is closer to that of Cagan and Ganfodi.

As far as the 'stylized pattern' examined in Section 2.2.2 above, is concerned, earlier literature sought to examine the response pattern of the interest rate to changes in the money growth rate. Notable studies include Cagan and Gandolfi (1969), and Gibson (1970), which establish the 'stylized pattern'. Melvin (1983) using monthly data, a short-term interest rate on commercial paper and M2 estimates equation (1), over various sub-periods. His results indicate a familiar tendency for the interest rate to fall at first and then rise following an increase in the growth rate of money supply.

The work of Mehra (1985) provides estimates for the coefficient associated with increases in the money growth on the nominal interest rate. We estimate a similar equation (5) in section 2.3 below but using South African data. He shows the presence of a statistically significant liquidity effect in periods of low inflation. We attempt to look for a similar pattern in the South African data. Mehra shows the liquidity effect vanishing for a high-inflation period. The results also show that based on the full sample period without splitting the data into high and low inflation period, the estimate of the liquidity effect coefficient is statistically insignificant. These results imply that the liquidity effect is not temporally stable and there did not appear to exist a significant liquidity effect for the high inflation period.

They also show that during periods of high inflation the liquidity effect has a limited impact. In other words, the liquidity effect may not be stable over time. We confirm all of these results using South African data.

3.3 Testing the Stylized Pattern to Confirm the Existence of the Liquidity Effect in South Africa

In this section, an attempt is made to test empirically whether the pattern shown in Chapter 2, Section 2.2.2 (Figure 1), is evident when using South African data. We estimate the following equation using ordinary least squares and include 12 lags of the money supply.

$$\Delta i_t = \alpha + \sum_{j=0}^{k=12} \beta_{t-j} \Delta gM_{t-j} \quad \text{.................................(8)}$$

Where $'i_t'$ - Monthly average of 1-year 'Treasury bill'[4] yield (Period 1977 to 2000)

t - Number of observation

k - Number of lags

'ΔgM' - Current growth rate of the nominal money stock (M1)[5] relative to its most recent growth rate

Data Used

While the data for the interest rate variable 'i' is obtained from the IMF publication, International Financial Statistics, the monetary variable (M1) is obtained from the South African Quarterly Bulletin for the period of 1977 to 2000. (Refer to Appendix A for the data used in the regression). The statistics of the data used are given in Table 1.

[4] The Treasury bill rate is the tender rate on 91-day bills.
[5] M1 are notes and coin in circulation plus cheque and transmission deposits of the domestic private sector with monetary institution, plus other demand deposits held by the domestic private sector. We use M1 to make our results consistent with Mehra's model.

Table 1: **Statistics for Data Used in Regression Equation (8) for Sample Period 1977 to 2000**

	Δi	ΔgM
Maximum	23.2	13.44
Minimum	-19.28	-7.75
Mean	0.20646	1.6015
Median	-0.0833	1.29
Std. Deviation	5.0218	3.7298
Skewness	0.53958	-0.05551
Kurtosis -3	3.4570	-0.10506
Coefficient of Variation	24.3233	2.3289

3.3.1 Proposed Monte Carlo Study

Using South African data and the model proposed by Melvin (1983), (equation (8)), (where the change in the interest rate is determined by changes in the growth rate of the money supply), it has been found that the path of the interest rate following a sustained[6] change (but not permanent[7] change) in the rate of growth of the money supply shows some unexpected effects. There are a number of approaches that could be adopted to deal with these unexpected effects including collecting more data, estimating the model with different definitions of the money supply and using different interest rates. Rather than do this we recognize that using a Monte Carlo study can solve this problem.

Simply, put, such a Monte Carlo study would take the following form. For the equation of interest (8) and a particular error distribution, make 10,000 estimates of each of the coefficients, or β_{t-j}. Calculate the mean of these 10,000 estimates. Then the effect of a sustained monetary shock on the change in the interest rate can be determined by calculating the cumulative sum of these means over time.

The following attempts to convey the steps of the Monte Carlo experiment. The exact SHAZAM (White (1997)) commands are provided in the next section.

[6] Sustained change is where the ΔgM_t increases by 1 unit for one time period.
[7] A permanent change is where ΔgM_t increases by 1 unit for more than one period.

1. Specification: $\Delta\, i_t = \alpha + \sum_{j=0}^{t=12} \beta_{t-j}\, \Delta gM_{t-j} + \varepsilon_t$

Notice we have 12 coefficients, not counting α and twelve independent variables fixed in repeated samples. We are to focus on all the β's in this instance. We append the usual error term to the ε_t to the specified equation.

2. Initial Values

TABLE 2: **Initial Values of the β's from Regression of Equation (8)**

	Value
β_0	0.3
β_1	0.5
β_2	0.4
β_3	0.3
β_4	0.04
β_5	0.03
β_6	0.06
β_7	0.23
β_8	0.27
β_9	0.29
β_{10}	0.25
β_{11}	0.21
β_{12}	0.08

These values were chosen from an initial investigation of the data. Although these particular 'known' values are immaterial, those estimated using the ordinary least squares estimator are employed as initial values here.

3. Sample Size: T=262

This is the size of the initial data. In a Monte Carlo study of this type it is usual to use 10000 drawings of the error vector.

4. Begin a DO-LOOP

Generate 262 ε_t from a $N\sim(0,\ Var\ (20.82))$. This creates a distribution of errors following the Gaussian distribution but with the variation of the errors estimated from the ordinary least squares' residuals.

Generate 262 $\Delta\, i_t$ using $\sum_{j=0}^{t=12} \beta_{t-j}\, \Delta gM_{t-j}$ and ε_t

Estimate β_{t-j} and take care to keep all 10,000 estimates of each β.

5. End the DO-LOOP after 10,000 iterations

   Now the process of collecting a large number of estimates of coefficients is complete.
6. Calculate the mean of the 10,000 estimates of the coefficients. This is a sample distribution of the β's and we estimate the mean of this distribution by finding the average of the 10,000 estimates of *each* coefficient.

3.3.2 The SHAZAM Programme

The following is the programme used to perform the Monte Carlo study. The *'s are not an integral part of the programme. They are an attempt to link the lines of the programme to the steps 1 to 6 of section 3.3.1 above.

<u>The SHAZAM Programme</u>

```
* Set up data and output files
file 11 a:/data2.txt
* Set the sample size. See Point 3. above.
sample 1 262
* Read in the data. We are to use all the variables.
Read (11) di dm m1 m2 m3 m4 m5 m6 m7 m8 m9 m10 m11 m12
* Set up the same random numbers each time the programme is used
set ranfix
* make sure you have enough memory
* Begin DO-LOOP. See Point 4. above.
do #=1, 10000
* Select the errors as described in Point 4. Above
```

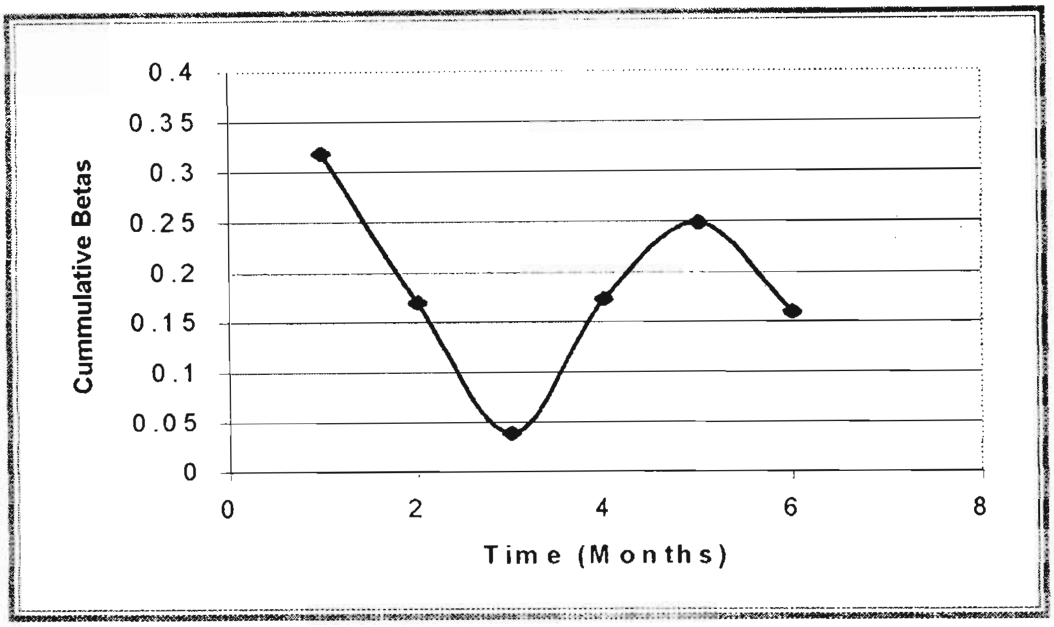
The SHAZAM Programme - Cont'd

```
Bear in mind SHAZAM needs the standard deviation instead of the variance.
genr e=nor(4.5629)
* The errors have been selected.
* Generate the dependent variable
genr diy = -4.5+0.3*dm+0.5*m1+0.4*m2+0.3m3+0.04*m4+0.03*m5+0.06*m6 &
0.23*m7+0.27*m8+0.29*m9+0.25*m10+0.21*m11+0.08*m12 + e
*Perform one regression and save the coefficients.
ols diy dm m1 m2 m3 m4 m5 m6 m7 m8 m9 m10 m11 m12 / coef=beta
endo
* End of the DO-LOOP. See Point 5. Above.
* Calculate the means of all the coefficients.
Matrix beta=beta'
stat beta / mean=sumb
sample 1 7
```

3.3.3 Results

When the cumulative value of the coefficients are plotted across time as is done in Figure 4, we notice that the pattern of the change in interest rates follows the expected pattern as in Section 2.2.2 of Chapter 2 (Figure 1). It can be observed that the interest rate declines for around 3 to 4 months following the increase in money growth and then begins to rise.

FIGURE 4: **The Stylized Lag Distribution of Monetary Effects on Interest Rates based on South African Data.**



One possibility not considered in the literature and raised for the first time in this dissertation is that the stages underlying the "stylized pattern" of interest rates need not follow one another. It is possible that some of the inflationary effect can affect the interest rate before the liquidity effect, and the balance of any expectations effect may only be made up later. There is yet another reason for the observed pattern being different from the "stylized pattern" that is, there may be both demand and supply variation in the data making it difficult to identify meaningful equilibria. Partly to overcome the identification problem, we decided to estimate another model in the next section. This is the Mehra model and is in Section 3.4 below. In addition, in Section 2.4.1 we noted the possibility of a less than complete response of the interest rate to expected inflation, which we find in our data.

An examination of the residuals from the Melvin test indicates the presence of autocorrelation. Using an estimate of the degree of autocorrelation from the residuals, we then incorporated this particular error structure into the Monte Carlo framework above. Our initial estimate of the liquidity effect lasting about one quarter remains unchanged.

3.4 Testing the Hypothesis of the Existence and the Vanishing Liquidity Effect

The hypothesis of the existence of, and the vanishing, liquidity effect is tested by estimating the Mehra (1985) specification (equation (5) of Chapter 2), for sample period 1986 to 1999, using some proxy variables, and is reproduced here as equation (9).

$$i = (1/(1 - T)) [A_0 + A_1 X + A_2 SS + A_3 LIQ + A_4 Z + A_5 PE12] \quad \ldots\ldots\ldots\ldots\ldots (9)$$

Data Used

The quarterly data used for each of these variables for the above regression was obtained from the IMF publication, International Financial Statistics (see Appendix B).

- ✓ **i** is the average market yield on a one-year treasury bill;
- ✓ **X** is the normalized value of real exports and real government expenditure. It is the logarithm of the sum of real exports and real government expenditure on goods and services divided by the level of real output (Real Gross Domestic Product - GDP);
- ✓ **SS** is the ratio of the deflator for imports and deflator for GDP adjusted for changes in the exchange rate. It is the price of Home and Imported goods divided by the price of Home goods multiplied by the nominal effective exchange rate;
- ✓ **PE12** is a forecast of inflation (consumer prices) over a 12-month horizon;
- ✓ **T** is the average marginal tax rate over the period 1986 to 1999, taken at 42 percent;
- ✓ **Z** is the lagged value of the rate of growth of real GDP. (It is the percentage change in the real GDP lagged one quarter);
- ✓ **LIQ** is the annualised growth rate of the nominal money stock over the last six months minus its annualised growth rate over the last three years;

The variable LIQ is generated using observations on changes in 'narrow money' over the sample period 1986 to 1999, according to the following relationship provided by Mehra:

$$LIQ = ((M_t / M_{t-1})^2 - 1) - ((M_{t-1} / M_{t-7})^{1/3} - 1)$$

The statistics of the data used in regression equation (9) are given in Table 3 below.

Table 3: **Statistics for Data Used in Regression Equation (9) for Sample Period 1986 to 1996**

Variable	i	X	SS	LIQ	Z	PE12
Maximum	11.67	-0.85	89.33	0.27	5.35	4.36
Minimum	5.03	-1.19	27.76	-0.18	-3.77	0.31
Mean	7.9744	-1.0647	50.6693	0.011636	0.47509	2.4913
Median	8.09	-1.06	48.89	0.01	0.4	2.46
Std. Deviation	1.7104	0.075175	16.3048	0.11885	1.9674	1.1039
Skewness	-0.053010	0.46876	0.48963	0.24504	0.26355	-0.28862
Kurtosis -3	-0.92447	0.039524	-0.71435	-0.78317	0.28656	-0.89954
Coefficient of Variation	0.21448	0.070605	0.32179	10.2136	4.1412	0.44310

The expected signs (based on Mehra (1985)) of the different coefficients in the equation (9) are presented in the Table 4.

TABLE 4: **Expected Sign of the Co-efficients of Equation (9)**

Variables	Expected Sign of the co-efficient
X	$A_1 > 0$
SS	$A_2 < 0$, $A_2 = 0$, $A_2 > 0$
LIQ	$A_3 < 0$
Z	$A_4 > 0$, $A_4 < 0$
PE12	$A_5 > 0$

Turning to the expected signs of the co-efficients, theory cannot place a sign on A_2 and A_4. The liquidity effect posits that A_3 should be less than zero. If inflationary expectations are formed rationally then A_5 must be positive. Higher expenditure with a given money stock means that A_1 is expected to be positive.

Before estimating equation (9) above, several tests are performed so as to familiarise ourselves with the data. This initial exploration falls into the following areas:

- ✓ Testing the correlation between the variables;
- ✓ Multicollinearity;
- ✓ Heteroskedasticity;
- ✓ Testing the non-stationary properties of the variables;
- ✓ Co-integration Analysis; and
- ✓ Autocorrelation.

3.4.1 Other Tests

✓ **Testing for correlation between the variables**

The correlation coefficient between two variables measures the degree to which there is a linear association between them. The correlation coefficient between the interest rate variable (i) and the growth rate of nominal money stock (LIQ), for the whole sample period 1986 to 1999, from Table 3 below is -0.21637. This indicates that the two variables of interest are negatively correlated.

TABLE 5: **Estimated Correlation Matrix of the Variables**

	I	X	SS	LIQ	Z	PE12
I	1.0000	-0.0046471	-0.40095	**-0.21637**	-0.22341	-0.087446
X	-0.0046471	1.0000	0.31306	0.10949	-0.10089	0.15155
SS	-0.40095	0.31306	1.0000	0.17187	-0.036135	0.67383
LIQ	**-0.21637**	0.10949	0.17187	1.0000	-0.030139	0.079355
Z	-0.22341	-0.10089	-0.036135	-0.030139	1.0000	-0.067724
PE12	-0.087446	0.15115	0.67383	0.079355	-0.067724	1.0000

The statistical significance of the correlation can be determined using the 't-test' at the *5 percent* and the *10 percent* significance level. The 'calculated t' is -1.8976 (r / SE(r)) while the 'critical t' with 53 degrees of freedom is -2.000 for the *5 percent* significance level and -1.671 for the *10 percent* significance level. Since the calculated 't' is less than the critical t, we accept the null hypothesis that the two variables are not statistically linearly correlated at the *5 percent* level, however, we reject the null hypothesis at the *10 percent* level of significance. This means that multicollinearity may not be a serious problem in the data. We examine this issue in the next section.

✓ **Multicollinearity**

Multicollinearity occurs when there exists a linear relationship among the explanatory variables in a multiple regression. This problem is related to one of the assumptions of the Classical Linear Regression Model[8] (CLRM) of no perfect collinearity among explanatory variables. In cases of perfect multicollinearity (perfect linear relationship), which is very rare, one cannot obtain estimates of the parameters in a multiple regression, and this prevents one from drawing any statistical inferences and performing any hypothesis tests about the estimates from the sample under consideration.

Of major concern, however, are cases of near, or imperfect or high multicollinearity, where in applications involving economic data, two or more explanatory variables are not exactly linearly related but can be approximately so.

The degree of multicollinearity can be observed by looking at some of indicators of multicollinearity such as:

- ✓ High R^2 (in excess of 0.8) and very few significant 't' ratios;
- ✓ High pairwise correlations (in excess of 0.8) among explanatory variables;
- ✓ Subsidiary, or auxiliary regressions.

Using the variables of Mehra's model and South African data, the R^2 is 0.31 and of the five coefficients only two are significant at the *5 percent* level (one only marginally so) but at a lower level of significance (*10 percent*) three coefficients are significant. These results are drawn from the results in Appendix C.

In addition, returning to Table 5, which gives the coefficient of correlation between each of the variables in equation (9), we can see that all of these correlations are low (less than 0.8), therefore, we can deduce at this stage that the degree of multicollinearity in the explanatory variables of Mehra's model is low, using South African data.

Our finding is further confirmed by using subsidiary or auxiliary regressions, which is simply a way of finding whether one explanatory variable is highly collinear with the other explanatory variables in a model. This is done by regressing each explanatory variable on the remaining explanatory variables and computing the corresponding R^2.

The R^2 values obtained from the auxiliary regressions estimated with the variables in our model are given in Table 6. To find out which explanatory variables are collinear, we have to test whether a particular coefficient of determination is statistically equal to zero, (i.e. $R^2=0$). If an explanatory variable is not a linear combination of the other explanatory variables, then the R^2 of that regression should not be statistically significantly different from zero. The significance of R^2 can be tested by using the following F-ratio shown as equation (10) below.

$$F = \frac{R^2 / (k - 1)}{(1 - R^2) / (n - k)} \quad \ldots\ldots (10)$$

Where R^2 - Coefficient of determination measuring the goodness of fit of a regression line

n - The number of observations; and

k - The number of explanatory variables including the intercept.

[8] With the assumptions of the CLRM, Ordinary Least Square's (OLS) estimates are best linear unbiased estimators (BLUE).

TABLE 6: **Testing the Significance of R^2**

Auxiliary Regressions	Value of R^2	Calculated F Value	Is F significant?
Regression of X on SS LIQ Z and PE12	0.12	1.70	No
Regression of SS on X LIQ Z and PE12	0.51	13.01	Yes
Regression of LIQ on X SS Z and PE12	0.04	0.52	No
Regression of Z on X SS LIQ and PE12	0.02	0.26	No
Regression of PE12 on X SS LIQ and Z	0.46	10.65	Yes

Note: *Significance at the 1% level
In our analysis n=55 and k=6

Table 6 shows only the variables SS and PE12 seem to be collinear with the other explanatory variables, although the degree of collinearity, as measured by R^2, varies considerably. On the basis of our examination of the R^2 and the t-ratio for each variable, the correlation coefficients and the results of the auxiliary regressions, it appears the results are mixed. Clearly there is some multicollinearity but it can hardly be described as severe.

✓ **Heteroskedasticity**

Hetreoskedasticity refers to a situation where the error terms or disturbance term (u_i)[9] entering a population regression function (PRF) do not have equal or constant variance (σ^2). This violates one of the assumptions of the CLRM, which requires the error term to be independently distributed of the exogenous variables with a constant variance. If this assumption is satisfied the error term is homoskedastic.

Though the presence of heteroskedasticity is not common in time series analysis, it is nevertheless important to examine the data for its presence and to provide a remedial measure to ensure the accuracy of the regression results.

[9] Here u_i is an estimate of the error term V_i in Chapter Two.

The presence of heteroskedasticity is indicated by the spread of residuals, which widens or narrows with increasing values of the fitted Y's (or dependent variable). Usually large residuals will show up when compared with other residuals. To detect the possibility of heteroskedasticity in Mehra's model but using South African data, the residuals squared (Res^2) of the regression are plotted against each of the explanatory variables (i.e. X, SS, LIQ, Z and PE12).

The diagrams obtained (refer Appendix D) shown no discernible systematic pattern (such as a linear or quadratic relationship), between the residual squared and the explanatory variables, suggesting that there is no heteroskedasticity in the data.

However, to confirm the result obtained from the graphical analysis, several tests can be performed to detect heteroskedasticity such as:

- The Glejser test;
- The Park test;
- White's General Heteroskedasticity test; and
- Spearman's rank correlation test.

Glejser Test

The Glejser test is performed here to confirm the absence of heteroskedasticity. With the residuals obtained from the initial regression, Glejser suggests regressing the absolute value of the residuals on various functions of the explanatory variables. Some functional forms, he suggested for the regression are:

$$| e_i | = \beta_1 + \beta_2 X_i + u_i$$

$$| e_i | = \beta_1 + \beta_2 \sqrt{X_i} + u_i$$

$$| e_i | = \beta_1 + \beta_2 \frac{1}{X_i} + u_i$$

The null hypothesis in each case is that there is no heteroskedasticity, that is, $\beta_2 = 0$. If this hypothesis is rejected, there is a probably evidence of heteroskedasticity.

The results obtained from regressing the absolute value of the residuals on all the explanatory variables using the first functional form that Glejser suggests are given in the Table 7:

TABLE 7: **Results from the Glejser Tests**

Variables	Coefficients	T - Value
X	0.58056	0.38786
SS	-0.0018706	-0.20175
LIQ	0.64306	0.70948
Z	-0.035237	-0.65029
PE12	0.18042	1.3812

On the basis of the Glejser test, we can see that the result suggests the acceptance of the null hypothesis at the *5 percent* level of significance, therefore confirming the non-existence of heteroskedasticity, for all the slope coefficients using the absolute value of the residuals regressed against the explanatory variables of equation (9). From Section 2.3 (page 17) we noted that a positive correlation between money and the errors indicates interest rate smoothing. Based on the results for LIQ in the Table 7, above there is some evidence for interest rate smoothing in our data given the size of the coefficient although it is not statistically significant. So it appears that our data captures the Reserve Bank moving away from a policy of interest rate smoothing.

✓ **Tests for Non-Stationary Properties in the Variables**

A time-series is defined as non-stationary when its moments (mean, variance, co-variance) are time dependent, that is, they vary with time, while for a stationary series, its mean, variance and auto-covariance (at various lags) remain the same no matter at what time we measure them.

It is important to test for stationarity before performing any regression analysis because if we are regressing one non-stationary time series on another non-stationary time series, this may lead to the phenomenon of spurious results. The phenomenon of spurious regression occurs when regression models involving time series data sometimes give results that are of dubious value, that is, superficially the results look good but on further investigation they look suspect as unrelated times series can appear to be related.

To check if the interest rate regression is spurious one, the rule of thumb, suggested by Granger and Newbold (1974: 111) can be used. It states that, if the R^2 is greater that the Durbin Watson (*d*) statistic, there is a strong likelihood that the results are spurious. In our case, from the initial regression results shown in Appendix C, the R^2 is 0.31091, which is less than the *d* statistic of 0.51444, possibly indicating that the spurious regression problem is not a feature of this data.

Non-stationarity for the interest rate regression equation (9) can be tested as follows:

- ✓ Graphically with the aid of the autocorrelation function of the variables;
- ✓ Some formal tests: - *The $\chi 2$ test (Box-Pierce Statistic),*
  - *The Ljung - Box Statistic;*
- ✓ Using the Augmented Dickey Fuller (ADF) unit root test for the variables.

<u>Graphical test to check for stationary and non-stationary variables</u>

If the autocorrelation function[10] ρ_K falls off rather quickly as the lag K increases, then this indicates a stationary time series. On the other hand if ρ_K does not fall off quickly as K increases, then the series might be non-stationary.

[10] The autocorrelation function tells us how much correlation there is (and by implication how much interdependency there is) between neighboring data points in a series. It is discussed in greater detail in the later part of section 3.4.1.

The autocorrelation functions for the variables are shown in Figures 5 to 10. The autocorrelation falls to zero only gradually, for the interest rate (i) variable, as well as for the explanatory variables X, SS, and PE12, indicating that these variables are non-stationary ones. However, the explanatory variables LIQ and Z have autocorrelation functions falling straight to zero implying that these variables are stationary.

FIGURE 5: **Autocorrelation function of i, sample 1986Q1 to 1999Q3**

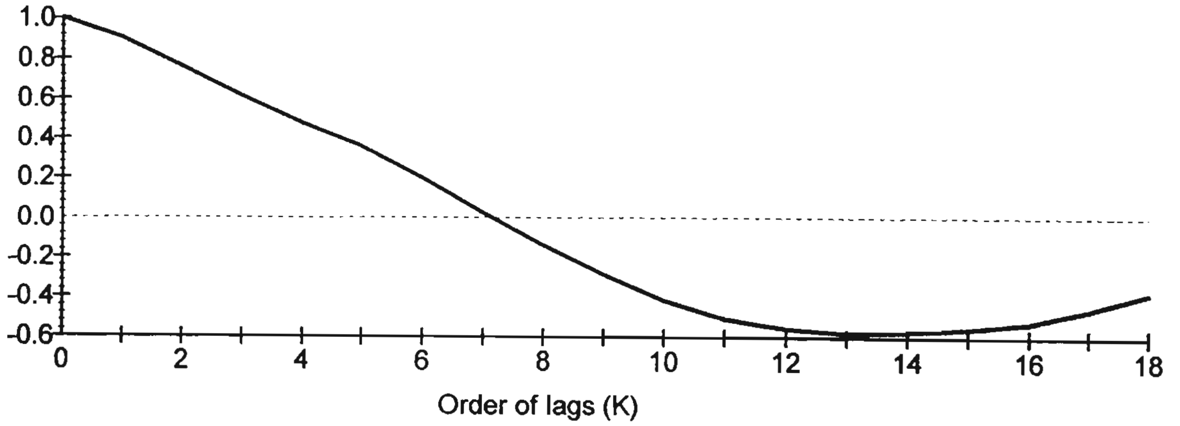


FIGURE 6: **Autocorrelation function of X, sample 1986Q1 to 1999Q3**

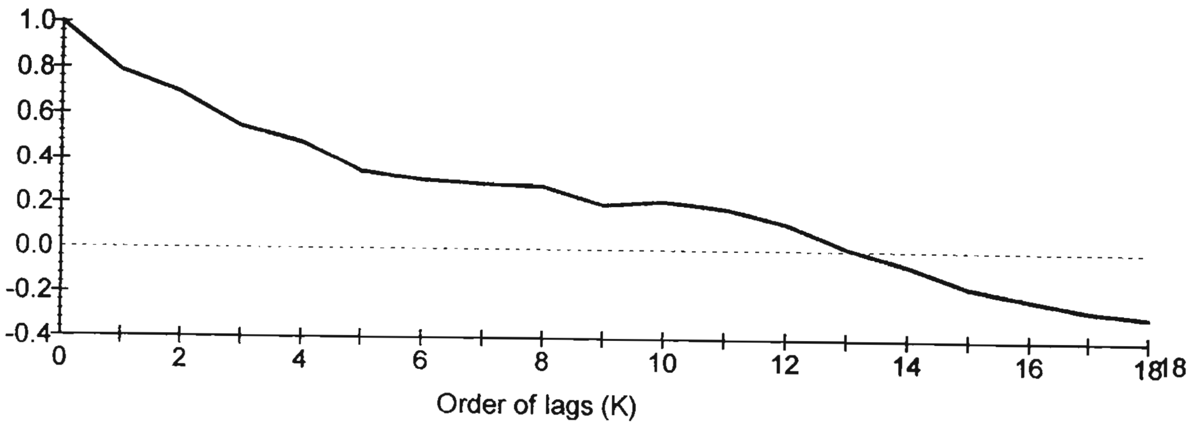


FIGURE 7: **Autocorrelation function of SS, sample 1986Q1 to 1999Q3**

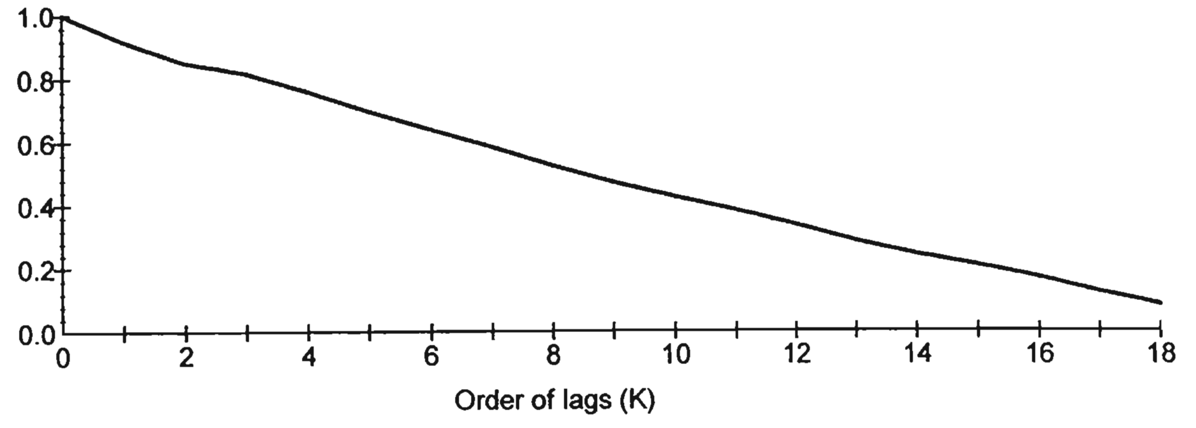


FIGURE 8: **Autocorrelation function of LIQ, sample 1986Q1 to 1999Q3**

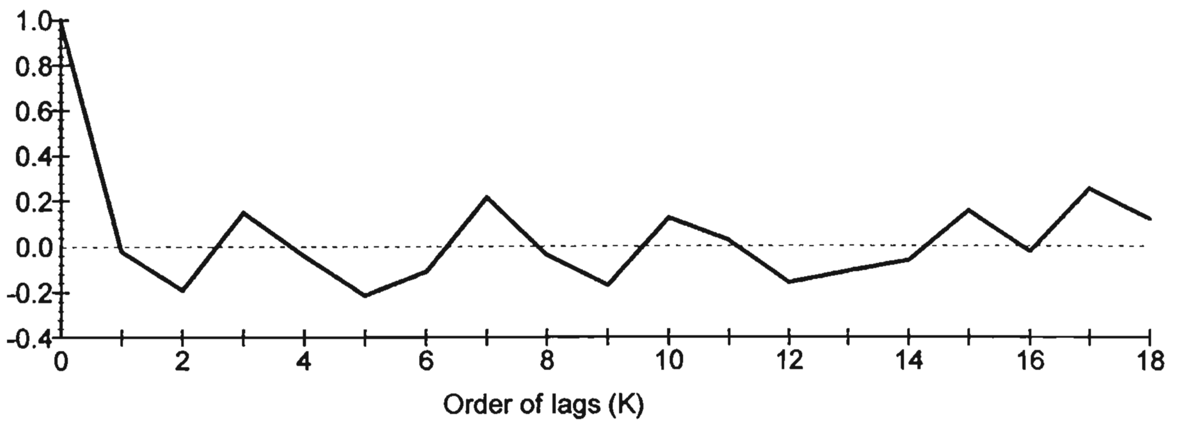


FIGURE 9: **Autocorrelation function of Z, sample 1986Q1 to 1999Q3**

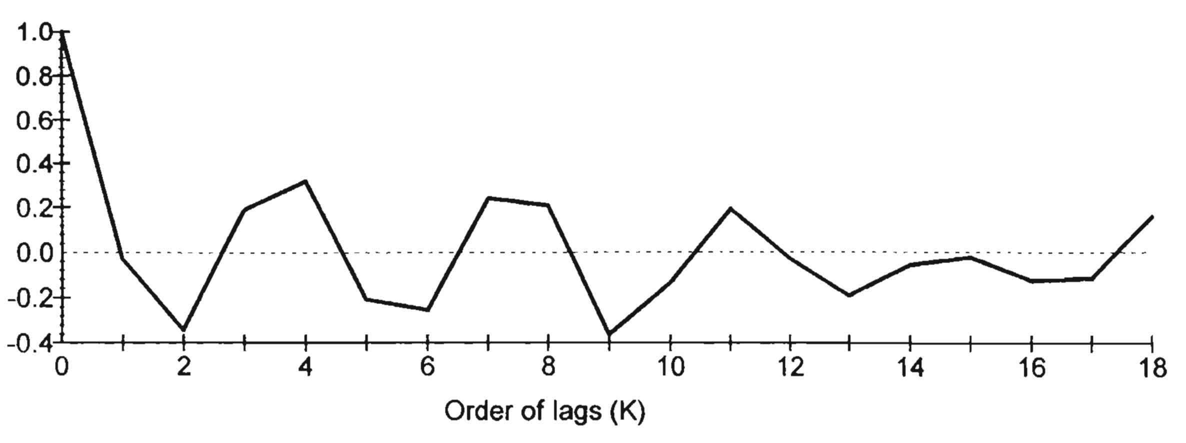
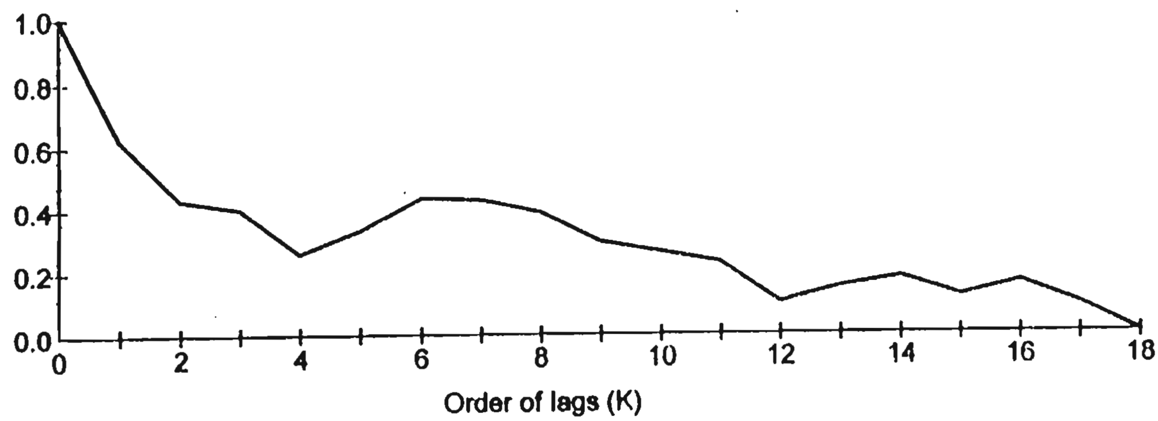


FIGURE 10: **Autocorrelation function of PE12, sample 1986Q1 to 1999Q3**



Formal tests to check for non-stationary

The $\chi 2$ test (Box-Pierce Statistic)

To test the hypothesis that the autocorrelation coefficients (ρ) are zero, (that is $\rho=0$ as K order of lags increase) implying the variable is stationary, the Q statistic given by Box and Pierce, which is (approximately) distributed by Chi-square with K degrees of freedom, is used. The $\chi 2$ test (Box-Pierce Statistic) is used here to confirm the graphical indication that the interest rate variable 'i' and the other variables X, SS, and PE12 are non-stationary variables. Taking K at 15 lags, the Box-Pierce statistic (denoted by Q) estimated for the non-stationary variables (refer to Appendix E) are summarized in Table 8 below.

TABLE 8: **Summary of Box-Pierce Statistics**

Variables	**Lags - Order**	**Box-Pierce Statistics - Q**
I	15	218.2389
X	15	117.4861
SS	15	280.2163
PE12	15	94.2238

The Box-Pierce statistics for all the four variables are far greater than the critical $\chi 2$ value of 30.58 at the *1 percent* level of significance, therefore we reject the hypothesis that the autocorrelation coefficients are zero, implying that the interest rate variable as well that the other variables X, SS and PE12 are all non-stationary variables.

The Ljung - Box Statistic

The Ljung-Box statistic denoted by Q* confirms the result of the Box-Pierce statistic. The Ljung-Box statistic is also distributed as a Chi-square with K degrees of freedom. The calculated - Ljung-Box statistics (Appendix C) for K=15 lags, are 262.3743 for the interest rate variable, 130.5086 for X, 320.2169 for SS and 108.1991 for PE12. Being greater than the critical value at the *1 percent* level of significance, this confirms the result that theses variables are non-stationary.

Using Augmented Dickey Fuller (ADF) unit root test for the variables

Another way to test formally for stationary variables is to use the procedure commonly called a unit root test. If we find that we cannot reject the hypothesis that the variable has a unit root, then we have found evidence that the variable is non-stationary.

From the Dickey-Fuller regression results for unit root tests (Table 9 to 12), we choose the calculated (ADF) with the highest value of the Akaike Information Criterion (AIC), Schwarz Bayesion Criterion (SBC) and Hannan-Quinn Criterion (HQC), (those in bold) and then compare them with the critical value for the augmented Dickey Fuller statistics. So for the interest rate variable and the explanatory variables X, SS and PE12, the absolute value of the ADF statistics are 2.1693, 2.1666, 2.2519 and 4.1115 respectively. With the exception of the variable PE12, all the other variables have absolute values of the ADF statistics less that the absolute critical value of 3.5005 at the 5 *percent* level, implying that we accept the hypothesis that the variables have unit roots, and are therefore non-stationary variables. In consequence, the OLS regression given for our interest rate regression equation (9) may be spurious (i.e. not meaningful).

TABLE 9: **Dickey-Fuller Unit Root Test for Variable I**

Unit root tests for variable I
The Dickey-Fuller regressions include an intercept and a linear trend

50 observations used in the estimation of all ADF regressions.
Sample period from 1987Q2 to 1999Q3

	Test Statistics	LL	AIC	SBC	HQC
DF	-1.7377	-53.3627	-56.3627	-59.2307	-57.4549
ADF(1)	-2.1449	-51.2612	-55.2612	-59.0852	-56.7174
ADF(2)	-2.1381	-51.1971	-56.1971	-60.9772	-58.0174
ADF(3)	-2.3089	-50.7016	-56.7016	-62.4377	-58.8859
ADF(4)	**-2.1693**	-50.7016	**-57.7016**	**-64.3937**	**-60.2500**

95% critical value for the augmented Dickey-Fuller statistic = -3.5005
LL = Maximized log-likelihood AIC = Akaike Information Criterion
SBC = Schwarz Bayesian Criterion HQC = Hannan-Quinn Criterion

TABLE 10: **Dickey-Fuller Unit Root Test for Variable X**

Unit root tests for variable X
The Dickey-Fuller regressions include an intercept and a linear trend

50 observations used in the estimation of all ADF regressions.
Sample period from 1987Q2 to 1999Q3

	Test Statistic	LL	AIC	SBC	HQC
DF	-2.9486	88.9951	85.9951	83.1271	84.9030
ADF(1)	**-2.1666**	92.6301	**88.6301**	**84.8060**	**87.1738**
ADF(2)	-2.0667	92.8807	87.8807	83.1006	86.0604
ADF(3)	-1.9868	93.3123	87.3123	81.5762	85.1280
ADF(4)	-2.1062	93.7818	86.7818	80.0898	84.2335

95% critical value for the augmented Dickey-Fuller statistic = -3.5005
LL = Maximized log-likelihood AIC = Akaike Information Criterion
SBC = Schwarz Bayesian Criterion HQC = Hannan-Quinn Criterion

TABLE 11: **Dickey-Fuller Unit Root Test for Variable SS**

Unit root tests for variable SS
The Dickey-Fuller regressions include an intercept and a linear trend

50 observations used in the estimation of all ADF regressions.
Sample period from 1987Q2 to 1999Q3

	Test Statistic	LL	AIC	SBC	HQC
DF	-2.3390	-87.5919	-90.5919	-93.4599	-91.6841
ADF(1)	-2.7997	-85.8190	-89.8190	-93.6431	-91.2752
ADF(2)	-2.7783	-85.6222	-90.6222	-95.4022	-92.4425
ADF(3)	-2.3595	-85.1378	-91.1378	-96.8738	-93.3221
ADF(4)	**-2.2519**	-85.0220	**-92.0220**	**-98.7141**	**-94.5704**

95% critical value for the augmented Dickey-Fuller statistic = -3.5005
LL = Maximized log-likelihood AIC = Akaike Information Criterion
SBC = Schwarz Bayesian Criterion HQC = Hannan-Quinn Criterion

TABLE 12: **Dickey-Fuller Unit Root Test for Variable PE12**

Unit root tests for variable PE12
The Dickey-Fuller regressions include an intercept and a linear trend

50 observations used in the estimation of all ADF regressions.
Sample period from 1987Q2 to 1999Q3

	Test Statistic	LL	AIC	SBC	HQC
DF	-5.1914	-58.0533	-61.0533	-63.9213	-62.1454
ADF(1)	-4.9097	-57.1731	-61.1731	-64.9971	-62.6293
ADF(2)	**-4.1115**	-57.1141	**-62.1141**	-66.8942	**-63.9344**
ADF(3)	-4.9397	-54.0484	-60.0484	-65.7845	-62.2328
ADF(4)	-3.7893	-53.9839	-60.9839	**-67.6760**	-63.5323

95% critical value for the augmented Dickey-Fuller statistic = -3.5005
LL = Maximized log-likelihood AIC = Akaike Information Criterion
SBC = Schwarz Bayesian Criterion HQC = Hannan-Quinn Criterion

✓ **Co-Integration Analysis**

The conclusion that the regression equation (9) may be spurious suggests that some time series, such as regression (9) are spurious. If this is in fact the case, one would wary of doing regressions based on time series data. But there is no cause for despair. Even if the time series of i, X, SS and PE12 are non-stationary, it is quite possible that there is still a (long-run) stable or equilibrium relationship between them. If that is the case, we say that such time series are co-integrated. Variables are co-integrated with one another if the residuals from the regression using the variables in levels (using levels to obtain a consistent estimate of the long run relationship between two variables) are stationary. Testing whether the interest rate (i) and the other variables X, SS and PE12 are co-integrated can be done in the following way:

Using the Durbin Watson Statistic

$$d = \frac{\sum (e_t - e_{t-1})^2}{\sum (e_t)^2}$$

Where, for this test we define e_t as the residuals of regression. Thus if e_t is a random walk, the expected value of $(e_t - e_{t-1})^2$ is zero; so the d statistic should be close to zero. Thus, we can simply test the hypothesis that $d = 0$, which will imply a hypothesis of no co-integration

From the co-integrating regression (OLS) in Table 13, the value of the DW statistic is 0.34180. The critical value of d is reported in the Table below (reproduced from Pindyck & Rubinfeld, pg 467 Table15.3).

Critical values for Test of DW = 0 for 100 observations

Significance level, 1%	Critical Value of DW
1	0.511
5	0.386
10	0.322

TABLE 13: **Co-integrating Regression of I on X, SS and PE12**

Ordinary Least Squares Estimation

Dependent variable is I

55 observations used for estimation from 1986Q1 to 1999Q3

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONSTANT	14.0808	3.3957	4.1466[.000]
X	3.5798	2.9272	1.2229[.227]
SS	-.072103	.018056	-3.9934[.000]
PE12	.54529	.25623	2.1281[.038]

R-Squared	.24409	R-Bar-Squared	.19962
S.E. of Regression	1.5302	F-stat. F(3, 51)	5.4894[.002]
Mean of Dependent Variable	7.9744	S.D. of Dependent Variable	1.710
Residual Sum of Squares	119.4117	Equation Log-likelihood	-99.3608
Akaike Info. Criterion	-103.3608	Schwarz Bayesian Criterion	-107.3755
DW-statistic	.34180		

Diagnostic Tests

* Test Statistics *	LM Version *	F Version *
* A:Serial Correlation	*CHSQ(4)= 41.9089[.000]	*F(4, 47)= 37.6156[.000]*
* B:Functional Form	*CHSQ(1)= 7.9010[.005]	*F(1, 50)= 8.3876[.006]*
* C:Normality	*CHSQ(2)= 3.4031[.182] *	Not applicable *
* D:Heteroskedasticity	*CHSQ(1)= .089446[.765]	*F(1, 53)= .086334[.770]*

A:Lagrange multiplier test of residual serial correlation

B:Ramsey's RESET test using the square of the fitted values

C:Based on a test of skewness and kurtosis of residuals

D:Based on the regression of squared residuals on squared fitted values

Since the calculated *d* statistic from the regression of 0.34180 is greater than the critical value of *d*=0.322 at the *10 percent* level of significance, we reject the hypothesis that there is no co-integration between the interest rate and the other explanatory variables X, SS and PE12. Thus they are co-integrated. Therefore, we can say that although the interest rate 'i' and the other variables X, SS and PE12 are individually non-stationary, their linear combination is stationary. That is, the four time series are co-integrated, or in other words, there seems to be a long run or equilibrium relationship between them. This implies that equation (9) provides super-consistent[11] estimates of the long run equilibrium parameters. We do not continue with the general to specific approach to testing given our sample size of 55. Clearly this is an avenue for future research.

✓ **Autocorrelation**

The autocorrelation function tells us how much correlation there is (and by implication how much interdependency there is) between neighboring data points in a series. It refers to cases where the error terms or disturbance term, u_i, entering a population regression function (PRF) are auto-correlated or serially correlated, that is where in a time series, the error associated with observation in one period is carried into the future time period. It goes against one of the assumptions of CLRM, of no autocorrelation or serial correlation among the disturbance terms, u_i, that is $E(u_i, u_j) = 0$ for $i \neq j$, implying that one error term is not influenced by a value in the previous period.

<u>Detecting Autocorrelation</u>

Detection of autocorrelation among the error terms of the Mehra model can be carried out by using the following approaches:

- ✓ The Graphical Method;
- ✓ The Runs Test;
- ✓ The Durbin-Watson *d* Test.

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[11] A consistent estimator is one that has no asymptotic bias. If the bias disappears at a rate proportional to T, rather than the usual $\sqrt{T}$, the prefix "super" is used.

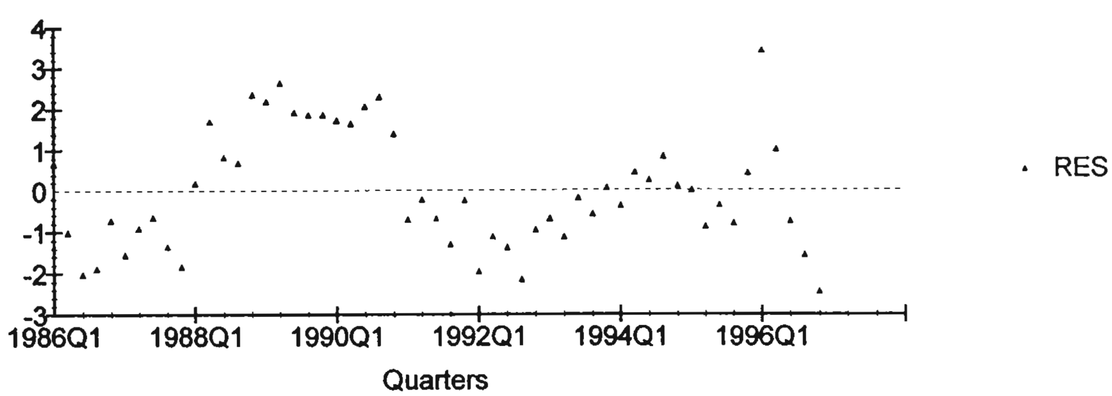
The Graphical Method

A simple visual examination of the least square's residuals of equation (9) can give valuable insights as to the likely presence of autocorrelation among the errors terms.

There are two ways of examining the residuals.

- The first one is plotting the residuals against time (known as time-sequence plot), as shown in the Figure 11 below, which depicts the residuals of the interest rate regression presented in Table 14.

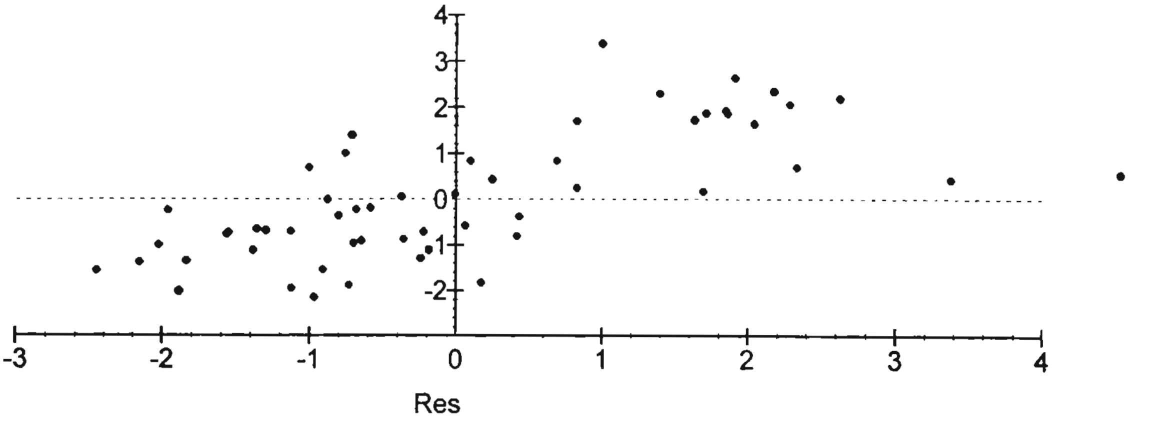
FIGURE 11: **Residuals from the Interest Rate Regression Plotted against time**



An examination of Figure 11 shows that the residuals (Res) do not seem to be randomly distributed. They actually exhibit a distinct behaviour, initially, they are generally negative, then become positive, and thereafter again turn negative, thus indicating the presence of autocorrelation in the error terms of the regression.

- A second way of examining the residuals to detect the presence of autocorrelation is to plot the residuals at time t against their values lagged one period, that is, plot (Res) given in column 1 of Table 14 against (Res(-1)) (the residuals lagged one period) given in column 2, as shown in Figure 12.

FIGURE 12: **Residuals from Interest Rate Regression plotted against its one-period lagged**



The general tenor of Figure 12 is that successive residuals are positively correlated, suggesting positive autocorrelation; most residuals are bunched in the first (northeast) and the third (southwest) quadrants.

TABLE 14: **Residuals of the Interest Rate Regression**

	Res	Res (-1)	D=Res-Res(-1)	D^2	Res^2	Sign
Res_1	0.69912	-	-	-	0.48877	+
Res_2	(0.99960)	0.69912	(1.69872)	2.88565	0.99920	-
Res_3	(2.02210)	(0.99960)	(1.02250)	1.04551	4.08889	-
Res_4	(1.88090)	(2.02210)	0.14120	0.01994	3.53778	-
Res_5	(0.72797)	(1.88090)	1.15293	1.32925	0.52994	-
Res_6	(1.54960)	(0.72797)	(0.82163)	0.67508	2.40126	-
Res_7	(0.90508)	(1.54960)	0.64452	0.41541	0.81917	-
Res_8	(0.64521)	(0.90508)	0.25987	0.06753	0.41630	-
Res_9	(1.35560)	(0.64521)	(0.71039)	0.50465	1.83765	-
Res_{10}	(1.83390)	(1.35560)	(0.47830)	0.22877	3.36319	-
Res_{11}	0.17783	(1.83390)	2.01173	4.04706	0.03162	+
Res_{12}	1.69500	0.17783	1.51717	2.30180	2.87303	+
Res_{13}	0.83033	1.69500	(0.86467)	0.74765	0.68945	+
Res_{14}	0.69443	0.83033	(0.13590)	0.01847	0.48223	+
Res_{15}	2.33550	0.69443	1.64107	2.69311	5.45456	+
Res_{16}	2.17840	2.33550	(0.15710)	0.02468	4.74543	+
Res_{17}	2.62650	2.17840	0.44810	0.20079	6.89850	+
Res_{18}	1.91390	2.62650	(0.71260)	0.50780	3.66301	+
Res_{19}	1.84850	1.91390	(0.06540)	0.00428	3.41695	+
Res_{20}	1.86090	1.84850	0.01240	0.00015	3.46295	+
Res_{21}	1.71550	1.86090	(0.14540)	0.02114	2.94294	+
Res_{22}	1.63440	1.71550	(0.08110)	0.00658	2.67126	+
Res_{23}	2.04480	1.63440	0.41040	0.16843	4.18121	+
Res_{24}	2.28610	2.04480	0.24130	0.05823	5.22625	+
Res_{25}	1.39420	2.28610	(0.89190)	0.79549	1.94379	+
Res_{26}	(0.70988)	1.39420	(2.10408)	4.42715	0.50393	-
Res_{27}	(0.22128)	(0.70988)	0.48860	0.23873	0.04896	-
Res_{28}	(0.68131)	(0.22128)	(0.46003)	0.21163	0.46418	-
Res_{29}	(1.29530)	(0.68131)	(0.61399)	0.37698	1.67780	-
Res_{30}	(0.23995)	(1.29530)	1.05535	1.11376	0.05758	-
Res_{31}	(1.95970)	(0.23995)	(1.71975)	2.95754	3.84042	-
Res_{32}	(1.12000)	(1.95970)	0.83970	0.70510	1.25440	-
Res_{33}	(1.37960)	(1.12000)	(0.25960)	0.06739	1.90330	-
Res_{34}	(2.15570)	(1.37960)	(0.77610)	0.60233	4.64704	-
Res_{35}	(0.96508)	(2.15570)	1.19062	1.41758	0.93138	-
Res_{36}	(0.69810)	(0.96508)	0.26698	0.07128	0.48734	-
Res_{37}	(1.12290)	(0.69810)	(0.42480)	0.18046	1.26090	-
Res_{38}	(0.18697)	(1.12290)	0.93593	0.87596	0.03496	-
Res_{39}	(0.58369)	(0.18697)	(0.39672)	0.15739	0.34069	-
Res_{40}	0.06617	(0.58369)	0.64986	0.42231	0.00438	+
Res_{41}	(0.37376)	0.06617	(0.43993)	0.19353	0.13970	-
Res_{42}	0.43436	(0.37376)	0.80812	0.65306	0.18867	+
Res_{43}	0.25006	0.43436	(0.18430)	0.03397	0.06253	+
Res_{44}	0.83239	0.25006	0.58233	0.33911	0.69287	+
Res_{45}	0.10257	0.83239	(0.72982)	0.53264	0.01052	+
Res_{46}	(0.00541)	0.10257	(0.10798)	0.01166	0.00003	-
Res_{47}	(0.87597)	(0.00541)	(0.87056)	0.75787	0.76732	-

	Res	Res (-1)	D=Res-Res(-1)	D^2	Res^2	Sign
Res_{48}	(0.35929)	(0.87597)	0.51668	0.26696	0.12909	-
Res_{49}	(0.80009)	(0.35929)	(0.44080)	0.19430	0.64014	-
Res_{50}	0.41898	(0.80009)	1.21907	1.48613	0.17554	+
Res_{51}	3.37910	0.41898	2.96012	8.76231	11.41832	+
Res_{52}	1.00200	3.37910	(2.37710)	5.65060	1.00400	+
Res_{53}	(0.75642)	1.00200	(1.75842)	3.09204	0.57217	-
Res_{54}	(1.56360)	(0.75642)	(0.80718)	0.65154	2.44484	-
Res_{55}	(2.44700)	(1.56360)	(0.88340)	0.78040	5.98781	-

The Runs Test or the Geary Test

To supplement the graphical evidence, which suggests that there might be (positive) autocorrelation in the interest rate regression, we can make use of a formal test to confirm the result. An examination of the residuals given in Figure 11 and Table 14, shows a number of positive residuals followed by a bunch of negative ones and then again by a bunch of positive ones. Such pattern can be checked by the so-called 'runs' test to detect the presence of autocorrelation.

The runs test involves noting down the sign (+ or -) of the residuals from the interest rate regression given in column 7 of Table 14. These signs can be reproduced in slightly different form as:

(+)(- - - - - - - - -)(+ + + + + + + + + + + + + + +)(- - - - - - - - - - - - - -)(+)(-)
(+ + + +)(- - - -)(+ + +)(- - -).

Thus, there is 1 positive residual followed by 9 negative residuals, followed by 15 positive residuals, followed by 14 negative, 1 positive, 1 negative, 4 positive, 4 negative, 3 positive and finally 3 negative for a total of 55 residuals. In the sequence above, there are 10 runs (a run being defined as an uninterrupted sequence of one symbol or attribute, such as + or -) and a run of 1 plus (i.e. of length 1), a run of 9 minus (i.e. of length 9), a run of 15 pluses (i.e. of length 15) and so on. The length of a run is thereby defined as the number of elements in the run.

By examining how runs behave in a strictly random sequence of observations, a test of randomness of runs can be derived. The question here is: Are the 10 runs observed in a sample of 55 observations too many or too few as compared with the number of runs expected in a strictly random sequence of 55 observations? If there are too many runs, it means that the residuals change sign frequently, thus suggesting negative serial correlation. Similarly, if there are too few runs, it suggests positive autocorrelation.

Let n = Total number of observations = $n_1 + n_2$

n_1 = Number of '+' symbols (i.e., + residuals)

n_2 = Number of '-' symbols (i.e., - residuals)

k = Number of runs

To test the hypothesis whether the successive outcomes (residuals) are independent, Swed and Eisenhart's special Table of critical values of the runs expected in a random sequence of n observations are used.

However, since the number of observations is big and the Swed and Eisenhart's Table is appropriate only when n_1 or n_2 is smaller than 20, we shall test the hypothesis of the randomness in the runs by making use of the following decision rule, adapted from Gujarati (1995: 420):

Decision Rule: Do not reject the null hypothesis of randomness with 95 *percent* confidence if $[E(k) - 1.96\sigma_k \leq k \leq E(k) + 1.96\sigma_k]$; reject the null hypothesis if the estimated k lies outside these limits.

Under the null hypothesis that successive residuals are independent, and with $n_1 > 10$ and $n_2 > 10$, the number of runs is distributed (asymptotically) normally with

$$\text{Mean: } E(k) = \frac{2 n_1 n_2}{n_1 + n_2} + 1$$

$$\text{Variance: } \sigma_k^2 = \frac{2 n_1 n_2 (2 n_1 n_2 - n_1 - n_2)}{(n_1 + n_2)^2 (n_1 + n_2 - 1)}.$$

If the hypothesis of randomness is sustainable, we should expect k, to lie between $[E(k) \pm 1.96\sigma_k]$ with 95 *percent* confidence. In the interest rate regression equation (9), $n_1 = 24$ and $n_2 = 31$ Therefore, we obtain $E(k) = 28.05$.

$$\sigma_k^2 = 13.05$$

$$\sigma_k = 3.61$$

Hence the 95 *percent* confidence interval is $[\ 28.05 \pm 1.96\ (3.61)] = (\ 20.97,\ 35.13)$.

Since the number of runs is 10, it clearly falls outside this interval. Therefore, we reject the hypothesis that the observed sequence of residuals from Figure 11 is random with 95 *percent* confidence interval, and thereby, conclude that our model of the equation (9) is beset by the autocorrelation problem.

The Durbin-Watson *d* Test

Another test that can be used to support the runs test for detecting autocorrelation is the Durbin-Watson d statistic. As defined below, it is simply the ratio of the sum of squared differences in successive residuals to the residual sum of squares. (Note the numerator of the d statistic, the sample size is $(n-1)$ because one observation is lost taking successive differences. For e_t, we use the variable 'Res' from Table14.

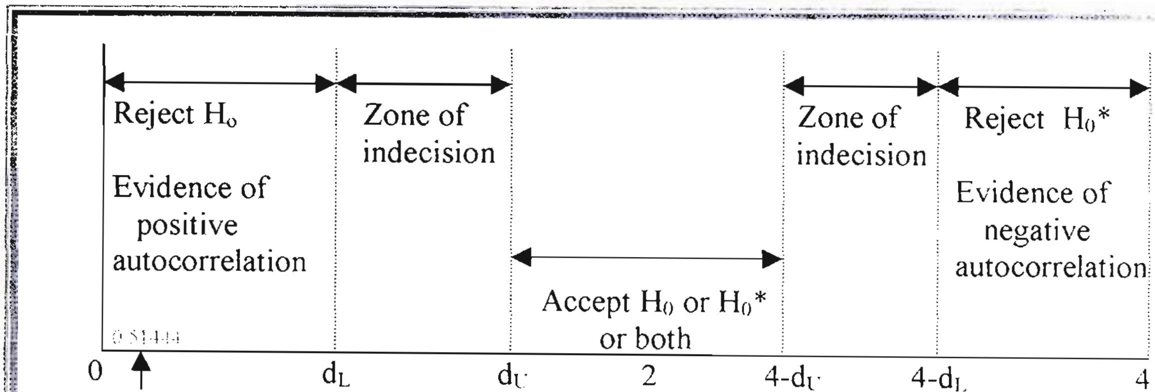
$$d = \frac{\sum_{t=2}^{n} (e_t - e_{t-1})^2}{\sum_{t=1}^{n} (e_t)^2}$$

For the interest rate regression, we can easily compute the d statistic from the data given in Table 14. First, the numerator of the d statistics, $\sum_{t=2}^{n} (e_t - e_{t-1})^2$ is presented as D^2 and is computed in column 5, by subtracting the lagged 'Res(-1)' given in column 2 of the

Table 14, from the 'Res' given in column 1 and then sum the squared the difference. Then, divide the sum by the sum of squares $\sum_{t=1}^{n} (e_t)^2$ presented as (Res^2) in column 6. So the computed *d* is 0.5144 (55.99915 divided by 108.85618).

The computed *d* value must lie between 0 and 4. As a general rule, if the computed *d* value is closer to zero, then there is evidence of positive autocorrelation, but if it is closer to 4, there is evidence of negative autocorrelation. And the closer the *d* value is to 2, the more the evidence is in favor of no autocorrelation.

In our case, the computed *d* being 0.51444 is indicative of positive autocorrelation, however, to get a definitive indication of autocorrelation, one needs to get the "critical" *d* values in terms of a lower and upper limit as shown in the diagram below.



At 5% Significance	1.334	1.814	2.186	2.666

Legend: H_0: No Positive Autocorrelation and H_0*: No Negative Autocorrelation

Source: Gujarati (1999:389)

The d_L and d_U are the lower and upper critical d values. They depend upon the number of observations, *n*, and on the number of explanatory variables, *k*, and they are obtained from the Durbin-Watson *d* statistic Table. For *n*=55 and *k*=6, the lower limit of the d statistics is 1.334 while the upper limit is 1.814 at the 5 *percent* significance level.

Since the computed d of 0.51444 is well below the lower bound value of 1.334, following the decision rules given in the diagram above, we conclude that there is positive autocorrelation in the interest rate regression residuals.

Remedial Measures

On the basis of all these tests conducted, we have reached the conclusion that the residuals of the regression equation (9) based on the Mehra's model are auto-correlated. Since the consequence of autocorrelation can be very serious, it is crucial to have a regression without the problem of autocorrelation. The Cochrane-Orcutt procedure can be used as a remedial measure to solve this problem.

The Cochrane-Orcutt Procedure

This procedure involves a series of iterations, each of which produces a better estimate of the autocorrelation coefficient ρ than the previous one. Using the data in Table 14 and the

$$\rho = \frac{\sum_{t=2}^{n} e_t e_{t-1}}{\sum_{t=1}^{n} e_t^2}$$

formula for above, ρ has the value of 0.71304.

The value of ρ can also be computed from the following approximate relationship between the d statistic and ρ:

$$d \approx 2(1-\rho)$$

From which we can obtain

$$\rho \approx 1 - d/2$$

The Cochrane-Orcutt method uses the notion that ρ is a correlation coefficient associated with errors of adjacent time periods. To transform the regression (9) so that in the transformed model the error terms are not auto-correlated, the first step is to write the regression with a one-period lag as:

$$i_{t-1} = (1/(1 - T)) [A_0 + A_1 X_{t-1} + A_2 SS_{t-1} + A_3 LIQ_{t-1} + A_4 Z_{t-1} + A_5 PE12_{t-1}] \ldots\ldots (11)$$

Multiply the regression (11) by ρ on both sides to obtain

$$\rho i_{t-1} = (1/(1 - T)) [\rho A_0 + \rho A_1 X_{t-1} + \rho A_2 SS_{t-1} + \rho A_3 LIQ_{t-1} + \rho A_4 Z_{t-1} + \rho A_5 PE12_{t-1}] \ldots\ldots (12)$$

Then, subtract Equation (12) from (9), to yield

$$(i - \rho i_{t-1}) = (1/(1 - T)) [A_0(1- \rho) + A_1 (X_t - \rho X_{t-1}) + A_2 (SS_t - \rho SS_{t-1}) + A_3 (LIQ_t - \rho LIQ_{t-1}) + A_4 (Z_t - \rho Z_{t-1}) + A_5(PE12_t - \rho PE12_{t-1})] + V_t \ldots\ldots (13)$$

Since the error term added in Equation (13) satisfies the standard CLRM assumption, it provides the transformation needed to give a model free from serial correlation. We can write Equation (13) as:

$$i^* = (1/(1 - T)) [A_0^* + A_1^* X + A_2^* SS + A_3^* LIQ + A_4^* Z + A_5^* PE12] \ldots\ldots (14)$$

Where $i^* = (i - \rho i_{t-1})$

$A_0^* = A_0(1- \rho)$

$A_1^* X = A_1 (X_t - \rho X_{t-1})$

$A_2^* SS = A_2 (SS_t - \rho SS_{t-1})$

$A_3^* LIQ = A_3 (LIQ_t - \rho LIQ_{t-1})$

$A_4^*Z \quad = A_4 (Z_t - \rho Z_{t-1})$

$A_5^*PE12 = A_5 (PE12_t - \rho PE12_{t-1})]$

When the transformed variables i^* to PE12 are estimated using the least squares, the estimator is called generalised least squares (GLS). The results of the transformed regression (14) are presented in next section.

3.4.2 Regression Results

Table 15 below reports estimates of the regression equation (14), covering the period from the first quarter of 1986 to the forth quarter of 1999 (refer Appendix E for the transformed data used and for the regression results). The explanatory variables have the expected sign as shown in Table 4 and reproduced below.

Co-efficient	Expected Sign	Actual Sign
A_1	+	+
A_2	Any	-
A_3	-	-
A_4	Any	-
A_5	+	+

A rise in expected inflation (PE12) and the exogenous component of demand (X), raises interest rates so their expected co-efficients are greater than zero. The positive supply shocks (SS), increases in the money growth rates (LIQ) and a rise in the lagged real income growth (Z) are expected to lower the rate of interest.

TABLE 15: **Estimates of the Coefficients of the Interest Rate Regression Equation (14)**

Sample Period	X	SS	LIQ	Z	PE12	R^2	SER
1986 to 1999	1.48	-0.05	**-0.79**	-0.02	0.06	0.10	0.79
t-ratio	(0.58)	(-1.83)	**(-1.05)**	(-0.52)	(0.46)		

Table15 - Cont'd

Level of Significance	**0.01**	**0.05**	**0.10**
Calculated t for LIQ	-1.05	-1.05	-1.05
Critical t	-2.704	-2.021	-1.684

The estimation presented in Table 15 above corrects for the presence of first-order serial correlation. . The parentheses contain t-values.

The parameter of interest is A_3 (coefficient on LIQ in Table 15). It is the coefficient measuring the effect of higher money growth rates on the nominal interest rate. As expected it is negative but since the 'calculated t' is less than the 'critical t' at 1 *percent*, 5 *percent*, and 10 *percent* level of significance, the coefficient of the LIQ is therefore statistically insignificant at the different significance levels. The estimates based on the full sample period 1986 to 1999 thereby do not support the presence of a statistically significant liquidity effect after correcting for autocorrelation.

3.5 Accounting for the Inflationary Period

In order to separate the low-inflation periods from the high-inflation periods, the full sample period is split into several sub-period samples. Table 16 reports estimates of the coefficient and the 't' statistics of the nominal interest rate equation (14) over various sub-periods.

TABLE 16: **Estimates of the Coefficients of LIQ in the Interest Rate Equation (14) over various sub-periods**

Sample Period	**Average Quarterly Inflation Rate**	**Coefficient of LIQ**	**T - Statistics**	**T - Critical at 5%**
1986 II to 1992 III	3.48 %	0.047260	0.051319	2.064
1992 IV to 1999 III	1.86 %	-1.4559	-1.1535	-2.052
1994 IV to 1998 II	1.77 %	-1.1298	-1.6037	-2.145
1996 IV to 1998 II	1.69 %	-0.58367	-3.0691	-2.447

Rows 2 to 4 show that in the low-inflation periods, the interest rate falls with increases in money growth, for example, in Row 2, a one percent positive deviation in the money growth rate reduces the nominal interest rate by 1.46 basis points. The estimate and the 't' statistic from Row 4 clearly implies the existence of a statistically significant liquidity effect, that is, we **reject** the null hypothesis that changes in the monetary growth rate does not have an effect on the nominal interest rate. However, the positive coefficient obtained for the high inflation period (Row 1) implies the complete disappearance of this liquidity effect. It is unfortunate that this result is not statistically significant but the observed trend moving from Row 4 to Row 1 is informative. There is a drastic reduction in the size of the liquidity effect parameter. This implies that for a change in the growth rate of the money supply, the interest rate will rise instead of falling, thereby confirming the vanishing liquidity effect. These results together then imply that the liquidity effect is not temporally stable; there does not appear to exist a significant liquidity effect over the high inflation period.

3.6 Conclusion

This Chapter reports the empirical results concerning the existence, magnitude, and temporal stability of the liquidity effect using the Melvin and Mehra model applied to South African data.

It was found that with the use of a Monte Carlo study, the stylized pattern of the effect of higher monetary growth on the nominal interest rate as depicted by the Melvin (1983) model, (that is an initial fall and then rise in the interest rate following an increase in the growth rate of money supply) was apparent with the South African data. Figure 4 shows that the interest rate declines for a period of about 3 to 4 months following an increase in the growth rate of money supply and rises thereafter.

Section 3.4 of this chapter investigates the issue of whether a significant liquidity effect of money on the interest rate exists, using the interest rate regression adapted from Mehra (1985). One main problem with the empirical estimation was the presence of autocorrelation in the residuals of the initial interest rate regression. Once this problem is overcome by the transformation of the data using the Cochrane-Orcutt procedure, estimation of the interest rate regression in which money growth appears as one of the right-hand side regressors is possible using ordinary least squares.

The empirical results reported imply the following conclusions:

- ✓ First, there was no sign of a statistically significant liquidity effect when the whole sample from 1986 (I) to 1999 (III) was estimated.
- ✓ Second, the sample was split in terms of high and low inflationary periods. In the low-inflation period, with an average quarterly inflation rate of 1.69 percent, there is a statistically significant liquidity effect. This effect vanishes the periods of high-inflation, and the interest rate rises (but not by a large amount) for an increase in the money growth variable (LIQ). This is weak evidence for the expectations effect but only in the period of high inflation.

The liquidity effect of money on the interest rate is therefore shorter-lived in the high inflationary period of the late 1980's and early 1990's. In a high-inflation period, inflationary expectations may adjust rapidly and become more sensitive to higher money growth, justifying the vanishing liquidity effect.

CHAPTER 4

SUMMARY AND IMPLICATION FOR CURRENT MONETARY POLICY

Announced changes to the money supply affects the interest rate by changing the information sets of economic actors, and this in turn alters expectations of inflation. One change is to the real rate of interest if expectations adjust slowly. If actual changes in the money supply affect the ex-ante real rate of interest, then announced changes will also have an impact, if they alter how individuals anticipate and respond to the future change before it is implemented. However, it is possible (if expectations adjust quickly) that the nominal rate of interest rate rises if inflationary expectations increase. The extent of the rise is open to question. Sargent (1972, 1973 and 1976) argues that the interest rate rises by less than the expected rate of inflation because the magnitude of the response to anticipated inflation depends on the structural parameters within the economic model. We use two models: one with limited structure and another with more.

One aim of Chapter 3 is to implement the Melvin technique so as to obtain the change in the interest rate over time after an increase in the money supply. The small sample properties of the economic model underlying the time path of the interest rate are examined using the Monte Carlo method. Using South African data, given an increase in the money supply growth rate, the interest rate does fall initially, and then rises after one quarter. Thus we have achieved the first objective of the thesis as outlined in Chapter One. There is some evidence that inflationary expectations raise the rate of interest prior to the liquidity effect. Our pattern for the interest rate does conform to patterns observed in earlier empirical work. We also examine the robustness of the time path of the interest rate by changing the nature of the error term and the distributional assumptions on which it is based. We find that our results are unchanged.

Another aim of the third chapter is to apply the Mehra (1985) model to South African data. Part of the reason for doing so is the identification difficulties inherent in the Melvin (1983) model. Before actual estimation, this thesis undertakes a lengthy examination of the data so as to differentiate itself from the 'collect data and estimate' strategy of much research.

From the regression results it appears that inflationary expectations have a strong impact on the interest rate, although this effect is not statistically significant. We then broke up our sample into three sub-samples grouping the data into high, moderate and low inflationary periods. It is during periods of high inflationary expectations that the liquidity effect becomes statistically insignificant. In times of high inflation the liquidity effect does not operate. Thus we achieve the second objective of the thesis.

The empirical work this dissertation presents has a number of weaknesses. In the application of the Melvin model, the number of observations is large and covers a long time period. We correct for this shortcoming when estimating the Mehra model by breaking the second sample into periods of high, moderate and low expectations of inflation. Another problem with our application of the Melvin model is one of identification. Ideally one would like to estimate supply and demand separately. Melvin's model does not do this and thus estimates may be a mixture of equilibria from supply and demand shifts. To some extent our estimates using Mehra's model overcomes the identification problem as there are a sufficient number of exogenous variables to allow the effect of inflationary expectations on the interest rate to be identified. However, each short coming - too long a sample period and identification - suggests two fruitful avenues of further research in the area of the interest rate response to changing monetary conditions. Also another item for future research is to examine the stationarity problem in more detail.

The current monetary policy's goal for inflation is within a band 3 to 6 percent. This policy recognizes that the Reserve Bank must avoid sharp swings in money supply growth rates. In other words the money supply is adjusted so as to keep inflation between the moderate levels implied by the range or band for inflation, given its current goal.

A widely held view within monetary theory is that an increase in the money stock reduces interest rates. In addition, one of the controversial and pressing questions of monetary policy is the nature and length of the lag between the execution of monetary changes and the effect on output and employment. While monetary theory suggests many possible reasons for such a lag, there is no general agreement on its length. However, it is widely accepted that a delayed response of spending to interest rate changes is the main reason for a lag in monetary policy (Cagan, 1969: 278). The results here show support for this view, and serves to vindicate current South African monetary policy, as the liquidity effect is of such short duration. However, as inflationary expectations decline with the Reserve Bank's successful implementation of its inflation goal, the liquidity effect may become a viable route for the monetary authorities in the event of say an adverse supply shock. Our results show the liquidity effect having an impact in periods of low inflation. Thus we see the policy of inflation targeting as having a secondary goal: improving the transmission of monetary policy.

In terms of policy implications, earlier research indicates that the monetary authorities can induce falling interest for up to two quarters by increasing the growth of the money supply. The results here indicate that the lowering of the interest rate is so short lived that the short-run political, as well as the economic benefits from a monetary expansion aimed at lowering interest rates tend to be negligible as the effect seems to only last one quarter. Considering the increased inflation purchased with the higher money growth rate, the evidence this dissertation presents casts doubt on the notion that the interest rate can be lowered for a considerable period of time by increasing the money growth rate, unless inflationary expectations are low.

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Appendix A - Monthly Data used for Regression Equation (8)

Year		Change in Interest	Change in Money
1977	Jul	-	-
	Aug	-	0.82
	Sep	(0.25)	2.82
	Oct	0.76	(3.12)
	Nov	-	2.13
	Dec	(0.25)	3.49
1978	Jan	0.51	(5.79)
	Feb	0.13	0.73
	Mar	0.38	1.74
	Apr	-	1.33
	May	-	(1.40)
	Jun	0.13	6.36
	Jul	-	(0.36)
	Aug	(1.13)	0.08
	Sep	(3.16)	(1.49)
	Oct	(0.92)	1.00
	Nov	(2.51)	4.47
	Dec	(0.41)	3.57
1979	Jan	0.14	(5.63)
	Feb	(6.24)	2.35
	Mar	(7.67)	5.52
	Apr	(11.91)	0.52
	May	(1.96)	0.40
	Jun	(2.18)	3.05
	Jul	(5.01)	(0.22)
	Aug	(10.55)	0.31
	Sep	(5.02)	1.82
	Oct	(9.20)	(0.50)
	Nov	(2.53)	5.51
	Dec	5.71	6.53
1980	Jan	2.95	(5.59)
	Feb	1.67	0.26
	Mar	(1.41)	9.18
	Apr	2.62	(3.28)
	May	4.64	2.81
	Jun	2.22	8.35
	Jul	(2.39)	4.17
	Aug	(1.78)	(0.46)

Year		Change in Interest	Change in Money
1989	Jan	(0.72)	(6.47)
	Feb	1.38	3.09
	Mar	3.97	8.57
	Apr	1.06	(6.63)
	May	5.14	2.93
	Jun	1.00	3.10
	Jul	-	(6.89)
	Aug	(0.12)	7.84
	Sep	(0.12)	1.04
	Oct	3.74	6.79
	Nov	1.35	(0.16)
	Dec	-	(1.82)
1990	Jan	-	7.39
	Feb	0.06	(2.34)
	Mar	(0.39)	7.02
	Apr	0.33	(4.93)
	May	-	(1.35)
	Jun	(0.11)	3.48
	Jul	(0.95)	(7.44)
	Aug	(0.79)	2.52
	Sep	(1.08)	(1.30)
	Oct	0.57	0.31
	Nov	0.40	7.45
	Dec	(1.47)	5.43
1991	Jan	(0.52)	(5.84)
	Feb	(0.98)	13.44
	Mar	(1.17)	(0.79)
	Apr	(0.83)	(2.90)
	May	(0.66)	4.44
	Jun	0.06	0.96
	Jul	0.06	0.54
	Aug	(0.18)	2.70
	Sep	(0.66)	(2.29)
	Oct	(1.09)	0.67
	Nov	(2.32)	6.86
	Dec	0.94	(2.51)
1992	Jan	(0.93)	(4.62)
	Feb	-	6.10

Year		Change in Interest	Change in Money
1980	Sep	4.75	6.05
	Oct	3.02	2.50
	Nov	12.79	5.87
	Dec	10.04	2.21
1981	Jan	9.63	1.27
	Feb	15.41	1.32
	Mar	1.07	0.30
	Apr	2.38	8.10
	May	10.84	(1.22)
	Jun	8.38	4.48
	Jul	13.32	1.44
	Aug	6.92	1.17
	Sep	0.18	1.81
	Oct	2.30	2.71
	Nov	5.88	4.42
	Dec	10.13	4.24
1982	Jan	6.82	(4.88)
	Feb	6.53	(0.13)
	Mar	3.06	11.10
	Apr	(0.51)	(2.84)
	May	1.08	(1.67)
	Jun	1.38	5.32
	Jul	1.92	1.30
	Aug	(1.34)	2.74
	Sep	0.49	1.87
	Oct	(3.56)	(2.28)
	Nov	(5.92)	5.58
	Dec	(2.77)	-
1983	Jan	(10.51)	1.07
	Feb	(19.28)	(3.17)
	Mar	(2.79)	6.26
	Apr	11.00	2.93
	May	1.07	4.48
	Jun	11.75	5.31
	Jul	9.25	(3.69)
	Aug	11.51	1.07
	Sep	(2.92)	10.79
	Oct	1.34	(0.40)
	Nov	3.83	2.79
	Dec	10.55	5.33
1984	Jan	1.72	4.32
	Feb	(0.11)	0.97
	Mar	0.34	3.20

Year		Change in Interest	Change in Money
1992	Mar	-	4.13
	Apr	-	(4.88)
	May	-	(0.49)
	Jun	-	5.25
	Jul	(15.81)	(0.22)
	Aug	(5.57)	7.05
	Sep	(5.19)	4.71
	Oct	0.25	(1.77)
	Nov	(0.58)	2.85
	Dec	0.17	(0.95)
1993	Jan	(1.50)	(7.13)
	Feb	(3.96)	5.85
	Mar	(0.44)	0.69
	Apr	(1.76)	0.57
	May	3.23	(1.31)
	Jun	3.30	0.97
	Jul	(1.01)	(5.52)
	Aug	(0.60)	5.45
	Sep	(0.68)	1.09
	Oct	(2.76)	(2.20)
	Nov	(9.57)	6.09
	Dec	(0.20)	2.98
1994	Jan	(0.39)	1.87
	Feb	0.10	6.87
	Mar	(0.30)	1.71
	Apr	1.78	1.69
	May	3.69	6.24
	Jun	1.50	(0.44)
	Jul	(0.83)	(2.23)
	Aug	(0.09)	0.68
	Sep	0.84	0.64
	Oct	8.67	(0.57)
	Nov	3.48	2.66
	Dec	2.30	2.72
1995	Jan	1.84	(6.34)
	Feb	1.50	5.43
	Mar	0.93	0.04
	Apr	(0.38)	0.82
	May	5.86	4.19
	Jun	0.66	(0.00)
	Jul	1.23	(2.78)
	Aug	(0.79)	2.55
	Sep	0.87	3.89

Year		Change in Interest	Change in Money
1984	Apr	0.28	3.58
	May	0.06	0.22
	Jun	(0.73)	3.03
	Jul	5.26	1.13
	Aug	16.83	2.58
	Sep	0.18	3.72
	Oct	(0.05)	2.32
	Nov	(3.13)	5.14
	Dec	(1.66)	(0.02)
1985	Jan	3.86	2.01
	Feb	1.11	1.24
	Mar	(0.46)	0.17
	Apr	(3.37)	(0.44)
	May	(6.49)	(0.16)
	Jun	(13.23)	0.76
	Jul	(4.00)	1.27
	Aug	1.16	0.86
	Sep	(8.61)	(7.75)
	Oct	(5.84)	(6.15)
	Nov	(8.59)	(1.81)
	Dec	(0.31)	3.05
1986	Jan	(6.11)	(4.03)
	Feb	(1.23)	2.30
	Mar	(0.08)	1.54
	Apr	(5.17)	0.34
	May	(3.61)	(2.01)
	Jun	(1.28)	9.76
	Jul	(2.13)	(2.04)
	Aug	(6.99)	0.89
	Sep	(7.92)	1.67
	Oct	0.99	1.15
	Nov	(4.15)	(0.22)
	Dec	(4.21)	3.41
1987	Jan	4.88	(0.75)
	Feb	(0.57)	3.96
	Mar	(3.08)	3.31
	Apr	1.18	3.56
	May	1.98	(1.07)
	Jun	(1.60)	3.01
	Jul	1.74	0.76
	Aug	(1.59)	(0.37)
	Sep	0.23	5.17
	Oct	0.46	0.34

Year		Change in Interest	Change in Money
1995	Oct	(1.14)	(3.21)
	Nov	(1.45)	6.38
	Dec	2.27	7.77
1996	Jan	0.57	(6.07)
	Feb	(0.71)	6.21
	Mar	1.58	5.42
	Apr	1.13	0.74
	May	10.98	1.93
	Jun	(0.44)	3.65
	Jul	(4.94)	(2.73)
	Aug	5.73	4.81
	Sep	(3.78)	3.26
	Oct	(1.70)	1.53
	Nov	1.60	3.91
	Dec	4.39	5.29
1997	Jan	1.88	(5.17)
	Feb	(2.71)	3.84
	Mar	0.13	6.12
	Apr	(0.25)	(5.07)
	May	(0.57)	0.37
	Jun	(1.40)	2.26
	Jul	(2.46)	(2.74)
	Aug	(1.92)	4.62
	Sep	(0.47)	7.48
	Oct	(1.09)	1.09
	Nov	(0.07)	4.13
	Dec	0.69	0.06
1998	Jan	(1.50)	(0.66)
	Feb	(2.84)	3.82
	Mar	(5.71)	(0.76)
	Apr	(2.42)	3.50
	May	0.93	0.97
	Jun	23.20	9.83
	Jul	18.39	1.07
	Aug	3.95	6.87
	Sep	9.52	(0.03)
	Oct	(10.04)	(4.23)
	Nov	(8.69)	2.77
	Dec	(3.15)	(1.02)
1999	Jan	(4.65)	(1.92)
	Feb	(5.24)	(2.28)
	Mar	(5.92)	5.42
	Apr	(5.95)	(1.71)

Year		Change in Interest	Change in Money
1987	Nov	(0.34)	5.95
	Dec	4.15	6.53
1988	Jan	4.10	(0.49)
	Feb	3.09	(0.61)
	Mar	7.74	8.64
	Apr	2.20	(2.51)
	May	7.87	0.31
	Jun	2.95	7.13
	Jul	2.28	(4.36)
	Aug	4.21	1.57
	Sep	1.82	4.42
	Oct	3.65	2.15
	Nov	9.30	(0.37)
	Dec	4.87	5.07

Year		Change in Interest	Change in Money
1999	May	(1.67)	0.43
	Jun	(1.92)	3.31
	Jul	(8.75)	0.16
	Aug	(3.47)	3.05
	Sep	(4.37)	0.63
	Oct	(3.67)	4.07
	Nov	(0.46)	7.16
	Dec	(0.09)	1.17
2000	Jan	(5.05)	(4.70)
	Feb	(3.74)	4.37
	Mar	0.72	(1.57)
	Apr	0.30	1.34

The change in interest rate and change in money are computed as in the examples given below:

Year		Interest Rate Treasury Bills	Money (M1) (Millions)	Change in Interest Rate	Change in Money
1981	Jan	6.49	8,530	-	-
	Feb	7.49	8,643	15.41	1.32
		....	....	....	....
1983	Jan	12.86	13,264	-	-
	Feb	10.38	12,843	(19.28)	(3.17)

Appendix B - Quarterly Data used for Regression Equation (9)

Year		i x (1-T)	X	SS	LIQ	Z	PE12
1986	I	6.99	-0.95	89.33	-0.04	1.66	3.82
	II	6.41	-0.89	81.50	0.21	-3.77	3.68
	III	5.71	-0.85	70.06	0.09	0.20	3.47
	IV	5.09	-0.94	77.54	-0.07	1.56	3.35
1987	I	5.05	-0.97	78.90	0.19	1.74	2.56
	II	5.03	-1.02	78.98	0.09	-1.20	2.96
	III	5.04	-1.08	78.05	0.09	1.43	2.94
	IV	5.10	-1.07	76.16	0.14	3.92	3.37
1988	I	5.71	-1.04	72.36	0.03	0.75	3.63
	II	6.58	-1.05	67.05	0.05	-3.56	4.15
	III	7.27	-1.05	64.78	-0.15	4.58	3.36
	IV	8.35	-1.04	63.27	0.00	5.28	3.14
1989	I	9.00	-1.02	63.17	-0.05	-0.67	3.58
	II	9.73	-0.97	60.92	-0.16	-3.20	3.25
	III	9.94	-1.03	59.64	-0.08	2.66	3.15
	IV	10.39	-1.01	60.90	0.04	-0.05	3.92
1990	I	10.43	-1.06	60.32	0.19	-1.56	3.45
	II	10.43	-1.10	58.09	-0.16	-0.73	3.60
	III	10.24	-1.08	56.13	-0.17	1.73	3.83
	IV	10.18	-1.06	55.69	0.27	-1.15	4.36
1991	I	9.93	-1.16	55.37	-0.03	-1.76	3.21
	II	9.70	-1.10	54.25	-0.04	0.02	2.99
	III	9.65	-1.09	53.15	0.21	-0.11	2.91
	IV	9.43	-1.12	52.03	0.04	-0.20	1.25
1992	I	9.16	-1.16	51.29	0.02	-1.74	1.99
	II	8.40	-1.14	50.72	-0.16	-0.92	3.98
	III	7.40	-1.07	49.41	0.18	-1.46	1.67
	IV	6.99	-1.19	48.89	-0.12	-0.71	1.44
1993	I	6.69	-1.18	47.95	-0.13	0.52	2.29
	II	6.68	-1.15	45.42	-0.05	5.35	1.78
	III	6.78	-1.15	44.46	-0.05	0.38	3.43
	IV	6.12	-1.16	45.31	0.11	2.39	2.07
1994	I	5.89	-1.17	45.33	0.19	1.48	2.21
	II	6.17	-1.15	42.84	0.09	-1.15	2.46
	III	6.25	-1.13	41.67	-0.10	2.72	0.53
	IV	7.05	-1.18	41.93	0.01	-0.39	1.28
1995	I	7.46	-1.14	40.99	-0.12	0.45	2.30
	II	7.83	-1.12	38.51	0.01	1.61	1.74
	III	8.09	-1.10	39.32	-0.03	-0.17	2.16
	IV	8.00	-1.14	39.44	0.16	2.41	2.76

Year		i x (1-T)	X	SS	LIQ	Z	PE12
1996	I	8.14	-1.10	39.01	0.04	0.40	2.32
	II	8.89	-1.10	34.58	0.03	1.04	1.80
	III	8.93	-1.02	32.95	0.02	1.33	1.57
	IV	8.93	-1.03	32.11	0.12	0.93	0.65
1997	I	9.25	-1.02	34.87	-0.07	-1.42	1.34
	II	9.07	-1.04	35.42	-0.18	-0.07	1.42
	III	8.62	-1.06	34.84	0.08	1.89	4.19
	IV	8.46	-1.05	33.52	0.00	1.59	2.13
1998	I	8.06	-0.99	33.32	-0.07	-0.94	0.54
	II	8.11	-1.03	33.39	0.23	0.62	0.38
	III	11.67	-0.98	28.06	0.04	2.27	0.31
	IV	10.52	-1.05	28.55	-0.18	-2.51	0.53
1999	I	9.00	-0.96	27.76	-0.09	-0.15	1.59
	II	7.84	-1.04	28.59	-0.05	1.71	2.39
	III	6.76	-1.01	28.72	0.02	1.10	1.90

Appendix C - Regression Results - Interest Rate Regression Equation (9)

Ordinary Least Squares Estimation

Dependent variable is I

55 observations used for estimation from 1986Q1 to 1999Q3

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONSTANT	13.7474	3.3183	4.1429[.000]
X	3.2660	2.8697	1.1381[.261]
SS	-0.067663	0.017776	-3.8063[.000]
LIQ	-2.2069	1.7377	-1.2700[.210]
Z	-0.18688	0.10388	-1.7990[.078]
PE12	0.50062	0.25042	1.9991[.051]

R-Squared	.31091	R-Bar-Squared	.24059
S.E. of Regression	1.4905	F-stat. F(5, 49)	4.4216[.002]
Mean of Dependent Variable	7.9744	S.D. of Dependent Variable	1.7104
Residual Sum of Squares	108.8564	Equation Log-likelihood	-96.8158
Akaike Info. Criterion	-102.8158	Schwarz Bayesian Criterion	-108.8378
DW-statistic	.51444		

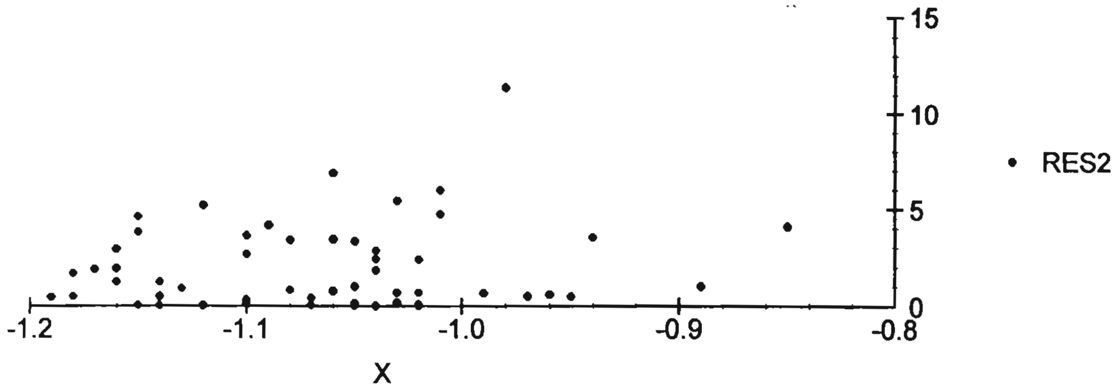
Diagnostic Tests

* Test Statistics *	LM Version	F Version
* A:Serial Correlation	*CHSQ(4)= 42.0229[.000]	*F(4, 45)= 36.4300[.000]*
* B:Functional Form	*CHSQ(1)= 4.1083[.043]	*F(1, 48)= 3.8748[.055]*
* C:Normality	*CHSQ(2)= 2.8278[.243]	* Not applicable *
* D:Heteroskedasticity	*CHSQ(1)= .0017033[.967]	*F(1, 53)= .0016414[.968]

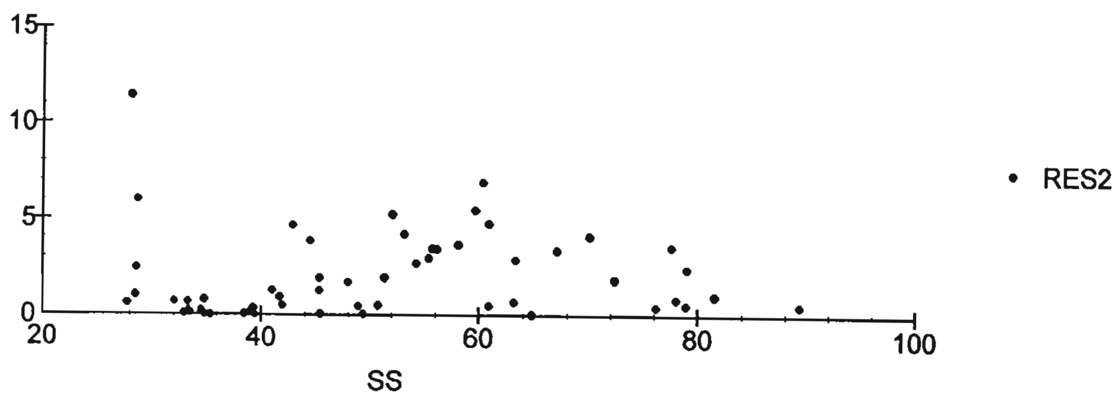
A:Lagrange multiplier test of residual serial correlation
B:Ramsey's RESET test using the square of the fitted values
C:Based on a test of skewness and kurtosis of residuals
D:Based on the regression of squared residuals on squared fitted values

Appendix D - Scatter Plot of the Residuals Squares of the Interest Rate Regression on each of the Explanatory Variables

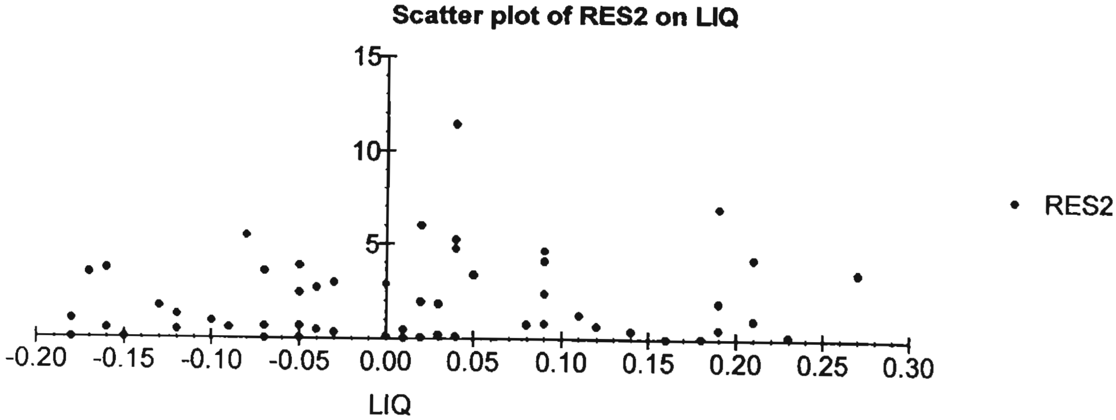
Scatter plot of RES2 on X



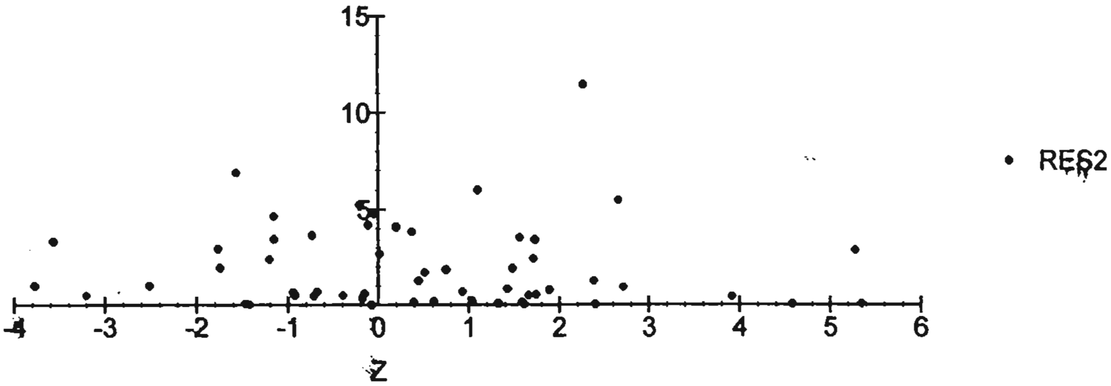
Scatter plot of RES2 on SS



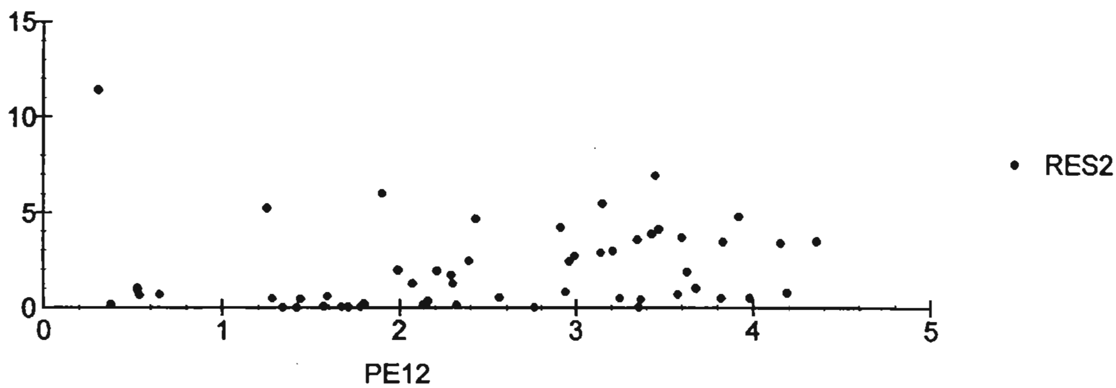
Scatter plot of RES2 on LIQ



Scatter plot of RES2 on Z



Scatter plot of RES2 on PE12



Appendix E - Box- Pierce Statistics and Ljung- Box Statistics for Variables I, X, SS and PE12

Variable I Sample from 1986Q1 to 1999Q3

Order	Autocorrelation Coefficient	Standard Error	Box-Pierce Statistic	Ljung-Box Statistic
1	.90099	.13484	44.6480[.000]	47.1284[.000]
2	.75819	.21841	76.2652[.000]	81.1319[.000]
3	.61227	.26193	96.8832[.000]	103.7324[.000]
4	.46978	.28677	109.0213[.000]	117.2985[.000]
5	.35383	.30044	115.9070[.000]	125.1481[.000]
6	.19888	.30792	118.0825[.000]	127.6788[.000]
7	.023832	.31025	118.1137[.000]	127.7159[.000]
8	-.14104	.31028	119.2077[.000]	129.0427[.000]
9	-.28832	.31144	123.7796[.000]	134.7079[.000]
10	-.41846	.31626	133.4107[.000]	146.9072[.000]
11	-.50724	.32617	147.5616[.000]	165.2391[.000]
12	-.55767	.34021	164.6665[.000]	187.9130[.000]
13	-.57889	.35644	183.0979[.000]	212.9271[.000]
14	-.57345	.37315	201.1847[.000]	238.0721[.000]
15	**-.55684**	**.38884**	**218.2389[.000]**	**262.3743[.000]**
16	-.52706	.40308	233.5174[.000]	284.7045[.000]
17	-.46429	.41542	245.3733[.000]	302.4883[.000]
18	-.38188	.42475	253.3941[.000]	314.8448[.000]

Variable X Sample from 1986Q1 to 1999Q3

Order	Autocorrelation Coefficient	Standard Error	Box-Pierce Statistic	Ljung-Box Statistic
1	.78544	.13484	33.9300[.000]	35.8150[.000]
2	.68542	.20153	59.7694[.000]	63.6046[.000]
3	.53997	.24021	75.8058[.000]	81.1829[.000]
4	.47268	.26135	88.0940[.000]	94.9168[.000]
5	.34348	.27645	94.5829[.000]	102.3142[.000]
6	.30464	.28411	99.6873[.000]	108.2519[.000]
7	.28938	.28998	104.2929[.000]	113.7210[.000]
8	.27849	.29519	108.5585[.000]	118.8942[.000]
9	.19618	.29993	110.6753[.000]	121.5173[.000]
10	.21367	.30225	113.1863[.000]	124.6979[.000]
11	.18202	.30498	115.0085[.000]	127.0584[.000]
12	.11367	.30695	115.7192[.000]	128.0004[.000]
13	.0081517	.30772	115.7228[.000]	128.0054[.000]
14	-.070357	.30772	115.9951[.000]	128.3839[.000]
15	**-.16465**	**.30801**	**117.4861[.000]**	**130.5086[.000]**
16	-.21636	.30961	120.0607[.000]	134.2715[.000]
17	-.26497	.31235	123.9221[.000]	140.0636[.000]
18	-.28807	.31641	128.4861[.000]	147.0947[.000]

Variable SS Sample from 1986Q1 to 1999Q3

Order	Autocorrelation Coefficient	Standard Error	Box-Pierce Statistic	Ljung-Box Statistic
1	.91666	.13484	46.2149[.000]	48.7824[.000]
2	.84826	.22076	85.7895[.000]	91.3438[.000]
3	.81207	.27368	122.0599[.000]	131.1017[.000]
4	.75667	.31446	153.5504[.000]	166.2970[.000]
5	.69341	.34598	179.9958[.000]	196.4447[.000]
6	.63563	.37039	202.2171[.000]	222.2940[.000]
7	.57819	.38972	220.6039[.000]	244.1284[.000]
8	.51871	.40501	235.4022[.000]	262.0752[.000]
9	.46396	.41692	247.2416[.000]	276.7458[.000]
10	.41787	.42620	256.8453[.000]	288.9105[.000]
11	.37538	.43359	264.5954[.000]	298.9504[.000]
12	.32949	.43946	270.5665[.000]	306.8655[.000]
13	.28005	.44392	274.8801[.000]	312.7196[.000]
14	.23648	.44712	277.9559[.000]	316.9958[.000]
15	**.20273**	**.44939**	**280.2163[.000]**	**320.2169[.000]**
16	.16332	.45105	281.6833[.000]	322.3610[.000]
17	.12023	.45213	282.4784[.000]	323.5536[.000]
18	.078197	.45271	282.8147[.000]	324.0717[.000

Variable PE12 Sample from 1986Q1 to 1999Q3

Order	Autocorrelation Coefficient	Standard Error	Box-Pierce Statistic	Ljung-Box Statistic
1	.62155	.13484	21.2479[.000]	22.4283[.000]
2	.43066	.17953	31.4485[.000]	33.3988[.000]
3	.39941	.19742	40.2225[.000]	43.0164[.000]
4	.25869	.21160	43.9032[.000]	47.1301[.000]
5	.33190	.21728	49.9618[.000]	54.0370[.000]
6	.43662	.22631	60.4466[.000]	66.2336[.000]
7	.42722	.24114	70.4849[.000]	78.1540[.000]
8	.38830	.25453	78.7778[.000]	88.2114[.000]
9	.29260	.26508	83.4865[.000]	94.0461[.000]
10	.25944	.27089	87.1884[.000]	98.7352[.000]
11	.22678	.27537	90.0170[.000]	102.3995[.000]
12	.099894	.27874	90.5658[.000]	103.1270[.000]
13	.14681	.27939	91.7512[.000]	104.7358[.000]
14	.17732	.28079	93.4807[.000]	107.1401[.000]
15	**.11624**	**.28282**	**94.2238[.000]**	**108.1991[.000]**
16	.16247	.28369	95.6756[.000]	110.3210[.000]
17	.091372	.28537	96.1348[.000]	111.0098[.000]
18	.3283E-3	.28591	96.1348[.000]	111.0098[.000]

Appendix F - Transformed Data According to Regression Equation (14) and Regression Results

OBS.	I3	X3	SS3	LIQ3	Z3	PE123
1986Q1	-	-	-	-	-	-
1986Q2	1.4259	-.21261	17.8041	.23852	-4.9536	.95619
1986Q3	1.1394	-.21539	11.9472	-.059738	2.8882	.84601
1986Q4	1.0185	-.33392	27.5844	-.13417	1.4174	.87575
1987Q1	1.4206	-.29974	23.6109	.23991	.62766	.17132
1987Q2	1.4291	-.32835	22.7211	-.045478	-2.4407	1.1346
1987Q3	1.4534	-.35270	21.7341	.025826	2.2856	.82940
1987Q4	1.5063	-.29992	20.5072	.075826	2.9004	1.2737
1988Q1	2.0735	-.27705	18.0549	-.069826	-2.0451	1.2271
1988Q2	2.5085	-.30844	15.4544	.028609	-4.0948	1.5617
1988Q3	2.5782	-.30131	16.9707	-.18565	7.1184	.40088
1988Q4	3.1662	-.29131	17.0793	.10696	2.0143	.74419
1989Q1	3.0461	-.27844	18.0560	-.050000	-4.4349	1.3411
1989Q2	3.3126	-.24270	15.8773	-.12435	-2.7223	.69732
1989Q3	3.0021	-.33835	16.2016	.034086	4.9417	.83262
1989Q4	3.3024	-.27557	18.3743	.097043	-1.9467	1.6739
1990Q1	3.0215	-.33983	16.8959	.16148	-1.5243	.65488
1990Q2	2.9930	-.34418	15.0794	-.29548	.38234	1.1400
1990Q3	2.8030	-.29566	14.7095	-.055914	2.2505	1.2631
1990Q4	2.8785	-.28992	15.6671	.39122	-2.3836	1.6291
1991Q1	2.6713	-.40418	15.6608	-.22252	-.94000	.10115
1991Q2	2.6195	-.27287	14.7690	-.018609	1.2750	.70114
1991Q3	2.7335	-.30566	14.4676	.23852	-.12426	.77801
1991Q4	2.5492	-.34279	14.1319	-.10974	-.12157	-.82495
1992Q1	2.4360	-.36140	14.1905	-.0085216	-1.5974	1.0987

OBS.	I3	X3	SS3	LIQ3	Z3	PE123
1992Q4	1.7135	-.42705	13.6587	-.24835	.33104	.24922
1993Q1	1.7059	-.33148	13.0895	-.044435	1.0263	1.2632
1993Q2	1.9098	-.30861	11.2297	.042695	4.9792	.14714
1993Q3	2.0169	-.33000	12.0737	-.014348	-3.4348	2.1608
1993Q4	1.2856	-.34000	13.6082	.14565	2.1190	-.37573
1994Q1	1.5262	-.34287	13.0222	.11157	-.22417	.73401
1994Q2	1.9702	-.31574	10.5179	-.045478	-2.2053	.85418
1994Q3	1.8505	-.31000	11.1234	-.16417	3.5400	-1.2027
1994Q4	2.5935	-.37426	12.2176	.081304	-2.3295	.90209
1995Q1	2.4331	-.29861	11.0922	-.12713	.72809	1.3873
1995Q2	2.5107	-.30713	9.2825	.095565	1.2891	.070008
1995Q3	2.5069	-.30140	11.8608	-.037130	-1.3180	.94070
1995Q4	2.2315	-.35566	11.4033	.18139	2.5312	1.2198
1996Q1	2.4357	-.28713	10.8877	-.074086	-1.3184	.35201
1996Q2	3.0859	-.31566	6.7643	.0014784	.75478	.14575
1996Q3	2.5911	-.23566	8.2931	-.0013912	.58844	.28653
1996Q4	2.5626	-.30270	8.6153	.10574	-.018343	-.46947
1997Q1	2.8826	-.28557	11.9743	-.15556	-2.0831	.87652
1997Q2	2.4744	-.31270	10.5563	-.13009	.94252	.46453
1997Q3	2.1527	-.31844	9.5841	.20835	1.9399	3.1775
1997Q4	2.3136	-.29418	8.6777	-.057043	.24235	-.85764
1998Q1	2.0277	-.24131	9.4189	-.070000	-2.0737	-.97878
1998Q2	2.3629	-.32409	9.6315	.27991	1.2903	-.0050416
1998Q3	5.8872	-.24557	4.2516	-.12400	1.8279	.039045
1998Q4	2.1988	-.35122	8.5421	-.20852	-4.1286	.30896
1999Q1	1.4988	-.21131	7.4027	.038347	1.6397	1.2121
1999Q2	1.4226	-.35548	8.7960	.014174	1.8170	1.2563

Ordinary Least Squares Estimation

Dependent variable is I3
54 observations used for estimation from 1986Q2 to 1999Q3

Regressor	Coefficient	Standard Error	T-Ratio[Prob]
CONSTANT	3.3293	.80228	4.1498[.000]
X3	1.4773	2.5528	.57870[.565]
SS3	-.045869	.025029	-1.8326[.073]
LIQ3	-.78893	.74889	-1.0535[.297]
Z3	-.023143	.044795	-.51665[.608]
PE123	.061283	.13229	.46325[.645]

R-Squared	.10241	R-Bar-Squared	.0089100
S.E. of Regression	.79259	F-stat. F(5, 48)	1.0953[.375]
Mean of Dependent Variable	2.2905	S.D. of Dependent Variable	.79615
Residual Sum of Squares	30.1539	Equation Log-likelihood	-60.8906
Akaike Info. Criterion	-66.8906	Schwarz Bayesian Criterion	-72.8575
DW-statistic	.92220		

Diagnostic Tests

* Test Statistics *	LM Version	* F Version *
* A:Serial Correlation	*CHSQ(4)= 17.8925[.001]	*F(4, 44)= 5.4509[.001]*
* B:Functional Form	*CHSQ(1)= .13567[.713]	*F(1, 47)= .11838[.732]*
* C:Normality	*CHSQ(2)= 36.5606[.000]	* Not applicable *
* D:Heteroskedasticity	*CHSQ(1)= 5.2264[.022]	*F(1, 52)= 5.5721[.022]*

A:Lagrange multiplier test of residual serial correlation
B:Ramsey's RESET test using the square of the fitted values
C:Based on a test of skewness and kurtosis of residuals
D:Based on the regression of squared residuals on squared fitted values