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Umit Erol
Louisiana State University and Agricultural & Mechanical College

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AN EMPIRICAL INQUIRY INTO THE VARIATION OF INTEREST RATES, 1959-1983

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AN EMPIRICAL INQUIRY INTO THE VARIATION OF INTEREST RATES, 1959-1983

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
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in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Economics

by
Umit Erol
B.S., Istanbul University, 1976
M.S., Bogazici University, 1978
December 1985

To my mother Muhibbe Erol
and to my father Adil Erol

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ABSTRACT

The empirical relationships among nominal interest rates, the inflation rate, and the money supply are examined for the period, 1959-1983. Monthly data are analyzed. The analysis of these relations specifically focuses on 1) the determination of the causal order between the variables and 2) the estimation of empirical lag distributions. The Gibson test, the Granger test, the Box-Jenkins test, and the Haugh test are used for these purposes. In addition, vector autoregressive-moving average models are estimated to determine how the variables are correlated. Finally, spectral analysis is used to determine the periodic movements of interest rates and to test if there are significant correlations with the inflation rate and the money supply along these periodic movements.

Empirical results suggest a positive response of nominal interest rates to changes in the money supply and the inflation rate. The estimated lags do not exceed one quarter in both cases. There is also a significant positive feedback from nominal interest rates to the money supply in both the short and long-run and a negative feedback from nominal interest rates to the money supply in the short-run. The statistical evidence suggests a

very quick adjustment of bond markets to innovations in money and commodity markets. This evidence casts doubt on the Fisher approach which emphasizes the importance of past inflation rates in the determination of current interest rates. The overall picture implies a response of interest rates to all kinds of information and not only to the information contained in the inflation rate series. This fact points out the highly efficient information processing character of the bond market.

Multivariate analysis further confirms this point by showing that the variables are related to each other through the innovation series and unsystematic information is utilized in the assessment of nominal interest rates.

In frequency domain, spectral analysis indicates a significant correlation between nominal interest rates and the inflation rate at the high frequency band. There is no significant correlation between the nominal interest rate and the inflation rate along the business cycles. There is, on the other hand, spectral evidence of a correlation between the money supply and interest rates along a nine-month cycle and minor business cycles. This last point suggests that the periodic movements of interest rates may be closely related to the stabilization policies pursued by the Federal Reserve.

CHAPTER 1

INTRODUCTION

Interest rates and hence the analysis of movements in interest rates have always been vitally important to macroeconomics. This can be easily seen from the major role ascribed to the interest rate sensitivity of income and other macroeconomic variables in the fiscalist/monetarist debate and can be justified since interest rates are a major signal determining the investment, savings, and portfolio decisions of economic agents in a market economy. It is not surprising then for an important part of empirical and theoretical work in economics to focus on specifying and discussing the determinants of interest rates. Several classic articles bring out the nature of the discussion regarding interest rates (Fisher, 1930; Keynes, 1937; Friedman, 1961; Sargent, 1973).

Classical theory maintains that movements in real interest rates are independent of nominal variables and are determined by the long-run movements of real forces such as investment and savings or capital productivity and thrift.

Fisher (1907; 1930) extends the classical theory substantially by making a distinction between the real and nominal components of interest rates. The real component is determined by the real forces as predicted by the classical theory but the nominal component is a direct function of inflationary expectations. The Fisher hypothesis is based on two basic arguments:

1) The real rate is constant over a relatively long period of time given the assumption that real forces which determine the real rate change slowly over time.

2) The nominal component varies with changes in anticipated inflation. There is a complete adjustment of the nominal component of interest rates to a change in anticipated inflation.[1]

This simple and powerful argument is theoretically derived from the behavior of economic agents, assuming that they are profit and utility maximizers. Lenders are not likely to lend if they are not guaranteed a nominal return which is at least equal to the real rate plus anticipated inflation since otherwise they will be losing in real terms. Borrowers can accept this nominal premium anticipating that their real burden is not increased by the premium.[2]

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[1] This argument, more precisely, also requires the implicit assumption that the real rate of interest, cost of capital to the firm, and real return to the savers are equal in the absence of taxes (Hirshleifer, 1958).

[2] An additional and more subtle assumption of the Fisher hypothesis is the homogeneity of anticipations on the part of both borrowers and lenders. Cukierman (1978) argue that people in different markets can have different expectations because they are exposed to different information.

Keynes´ contribution (Keynes, 1936; 1937) to this debate is to shift the attention to the relation between the money market and interest rates following his theory of liquidity preference. According to Keynes, interest rates are essentially determined by the supply of and demand for money in a two-asset (bond-money) world. An exogenous increase in the money supply[3] causes a decline in interest rates (liquidity effect) due to the public´s portfolio readjustments. Bond prices increase and inversely interest rates decline as the public tries to deplete its holdings of excess money by buying bonds.[4] The price effects on nominal interest rates are ignored in early Keynesian models since these models were typically working with a fixed price assumption.

The Fisher hypothesis and the importance of substitution relations between bond and commodity markets have been re-emphasized by the monetarist school. Friedman´s theory (1963) is based on a generalized portfolio including both human and non-human assets. The model allows substitution among all the major markets of the economy and does not restrict the substitution of bond-money (Keynesian approach) or bond-commodity markets (Fisher hypothesis). An exogenous increase in the money

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[3] The implicit assumption here is a stable money demand function.

[4] Neo-Keynesians (Tobin, 1947) derive the same result by adding the security market and assuming imperfect substitution between the different assets.

supply causes a short-run substitution effect in the bond and equity markets. In the long run, however, an increase in the money supply causes a fully adjusted increase in the price level as the public tries to deplete its excess supply of money in the commodity market.

Both the Fisher effect and the liquidity effect can be observed depending on the length of the observation period. An exogenous increase in the money supply can cause a temporary decline in interest rates but such an increase is also an incentive for higher expenditures. The end result is an increase in the level of aggregate demand. If the increase in the money supply is continuous, an inflationary process is started.

A relatively persistent inflation becomes the source of inflationary expectations which may trigger the inflation rate, especially if monetary authorities are reluctant to impose short-term unemployment on the economy. The economic agents eventually learn to hedge against the losses in real value by asking an inflationary premium in the transactions including the making of loans. The nominal interest rate increases in the same amount as the anticipated inflation when the process of adjustment is completed in the long-run. Nominal interest rates will increase as a result of inflationary expectations leaving the real rate of interest unchanged. This argument depends on the equivalence of real interest, the cost of capital, and real return to savers in the absence of taxes. The presence of corporate and personal income taxes can alter the effect of inflation on the capital intensity of production, the market rate of interest, and real net return to savers (Darby, 1975). The response of nominal interest rates can be substantially greater than the expected inflation in the case of income taxation because of the premium charged on interest rates with the anticipation of tax effects (Darby, 1975; Peek, 1982).

Empirical evidence regarding these hypotheses is inconclusive given the complications of modeling the hypotheses. The empirical tests of the relatively simple two-variable Fisher hypothesis are often inconclusive and inconsistent, after fifty years of empirical work. This state of affairs is further complicated by the increasingly volatile and high interest rates of the 1970's and the relatively high real rate during the past decade.

The difficulties associated with empirical tests of the Fisher hypothesis can be observed at two different levels. On the theoretical level, the problem is how to model interest rates adequately. Interest rates are the result of a very complex interaction taking place among all segments and assets of the real economy. All major macro variables including the unquantifiable expectation effects can have an impact on interest rates.[5]

In addition, interest rates are not just another price in the market economy. The long-run social costs of a very volatile interest rate can be high. This helps to explain the tendency of the Federal Reserve to intervene frequently in the bond market for interest rate stabilization purposes.[6]

The theoretical problems associated with the structural modeling of interest rates are the source of important and difficult problems at the technical level. The first such problem is the correct specification of the causal order. Interest rates can act both as an exogenous and endogenous variable in their relations with other macro variables.

The second problem is the correct identification of distributed lag relationships. Most macro-relations are not restricted to instantaneous correlation but are distributed over a time horizon. The importance of distributed lag identification for purposes of policy and

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[5] See Chamberlain and Feldstein (1973) for a general theoretical framework which includes expectations. Their reduced form equations and empirical tests are however subject to the same criticisms directed to the regression techniques that are discussed in a later chapter.

[6] The change of official policy from interest rates to targeting money supply in 1979 does not mean that the Federal Reserve has totally given up the practice of interfering in the bond market to stabilize interest rates. The minutes of the FOMC meetings after 1980 seem to support the opposite view.

and analysis is widely discussed in Friedman (1960; 1961), Culbertson (1960), and many others.[7]

A very significant part of the empirical literature on interest rate analysis uses OLS regression techniques. OLS regression is not an effective tool to cope with the problems cited above. The form of the regression equation is either assumed a priori or derived from a structural model. In both cases, the structure is specified using a priori assumptions including the a priori specification of the causal order and the distributed lag structure. The empirical literature related to the Fisher hypothesis is especially rich in the practice of specifying the distributed lags from a priori transformations and estimating the parameters via data transformations such as Koyck or Almon (Kmenta, 1971).

An alternative approach is to specify the variables a prior and then use data analysis to infer information about the causal order and distributed lag structure instead of using a priori considerations. This alternative method is commonly known as time-series analysis and it is now increasingly used in the econometric literature.

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[7] The famous debate between Friedman and Culbertson (1960; 1961) is noteworthy in underlining the issue of choosing the levels or rates of change as the relevant form of testable variables in addition to stocks versus flows argument. Technically this is an issue of stationarity versus nonstationarity which will be elaborated in this thesis. In his discussion, Friedman (1961) advocates the use of cross-spectral techniques as a tool for identification. This same approach is pursued in this thesis.

The most popular and well-known examples are Box-Jenkins univariate and multiple input transfer function models. These models seem especially well suited to the empirical determination of distributed lag structures and research continues to develop rapidly in this area.

Empirical causality detection is also an increasingly popular area following the original studies of Sims (1972) and Granger (1969). A distant cousin of these more popular time-series methods is the historically older but less popular spectral analysis. This is an effective tool for determining correlations and lags along the different cycles of the economy.

The advantages or disadvantages of regression techniques versus time series methods, to a large extent, depends on the level of a priori information available. Three such levels can be distinguished according to Liu and Hudak (Liu and Hudak, 1985):

Level 1: Only the information set (data) is known.

Level 2: The distinction between the endogenous and exogenous variables in the information set and the relevant explanatory variables are known.

Level 3: The form of the function and the structure of distributed lags are known.

OLS or other forms of regression models (econometric approach) is an effective tool for estimating parameters and testing hypotheses if level-3 knowledge is available. If only level-1 or level-2 knowledge is available, the econometric approach may not be an effective tool since the estimated parameters and the validity of hypothesis testing will depend on the model specified with inadequate prior knowledge. Time-series analysis can be an effective tool under these circumstances since only level-1 knowledge is assumed (Liu and Hudak, 1985).

The empirical literature on the analysis of interest rates suggests that the information level is restricted to level 1 knowledge. Level 2 knowledge is the basic content of the ongoing theoretical discussions. A set of relevant explanatory variables are jointly suggested by different theoretical models. The distinction however between exogenous and endogenous variables is not well determined and subject to ongoing discussion. Level-3 knowledge is not available.

According to Fisher hypothesis (Fisher, 1980); nominal interest rates are determined by past inflation rates. Sargent (1973) argues that the determination of interest rates is the result of a complex interaction among all the variables which can affect the slopes of the IS and LM curves and cites evidence of a feedback effect from interest rates to the inflation rate.

The basic feature of Keynesian IS-LM analysis is the idea that changes in the demand or supply of nominal balances can change the real rate of interest if we assume sluggish price adjustments in labor market and other non-financial markets. A particularly important nominal balance is the money supply. An increase in money supply has a negative effect on the real rate of interest. In the IS-LM framework, the real rate of interest is not constant even in the short-run while a constant real rate of interest in the short-run is one of the underlying assumptions of Fisher hypothesis. The empirical test of the assumption depends on finding an appropriate proxy for the real rate of interest. This proves to be a very difficult problem. The IS-LM framework also suggests that the interest rates can be an endogenous variable with respect to money supply (Branson, 1979). A change in interest rates can affect the level of loans supplied by the banking system and can be an important variable in determining the level of demand deposits and the money supply.

Given these considerations, the scope of this dissertation can be outlined as follows:

1) The nominal money supply and inflationary expectations are selected as explanatory variables in determining interest rates. This choice is dictated by the fact that these are the most extensively discussed variables in the IS-LM framework and the Fisher hypothesis. The analysis is restricted to nominal movements in interest rates because of the problems associated with finding a reliable proxy for the real rate of interest. It is expected that a careful analysis of distributed lag

structure and feedback effects can give additional empirical information concerning the hypotheses cited above if sufficiently robust and reliable techniques are used.[8]

2) The causal relationships between these variables and the empirical information about the endogenity or exogenity of the variables is empirically explored using a set of different tests. The empirical distributed lag structure is analyzed by the Gibson test, Granger test, Box-Jenkins filtering and Hough filtering and by estimating appropriate multivariate time-series models (vector ARMA models). The liquidity effect and the Fisher effect are discussed after examining empirical evidence.

3) The empirical evidence from the time-domain analysis is extended by the evidence gleaned from the spectral domain. A number of questions including the effects of business cycles and annual cycles on the inflation rate/interest rate and money/interest rate relationships are reconsidered by applying spectral techniques. The observation period is 1959-83, and monthly observations are used.

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[8] Another frequently used variable is income which is assumed to affect the demand side of interest rates (Gibson and Kaufman, 1968). The reason this variable is not included is technical. All other series used in the analysis are monthly and seasonally non-adjusted series. All monthly series of income, on the other hand, are seasonally adjusted. The majority of techniques used in this thesis are sensitive to biases that can be generated by seasonal adjustments. This consideration led to the omission of income in the thesis.

The following chapters are organized on the basis of this outline. Chapters 2 and 3 focus on the nominal interest rate/actual inflation rate relationship. Chapter 2 reviews the Fisher hypothesis. A number of empirical problems associated with tests of the Fisher hypothesis are pointed out. Several alternative techniques that are often used for causality detection and the identification of distributed lag structures are described. Chapter 3 presents the empirical results of these alternative techniques including the estimation of a two-variable vector ARMA model. Chapter 4 extends the analysis to the interest rate-money supply relationship. Chapter 5 re-examines these relations in the spectral domain. Chapter 6 summarizes the overall results and concludes with a theoretical re-appraisal.

CHAPTER 2

THE FISHER HYPOTHESIS AND THE EMPIRICAL EVIDENCE

Introduction

This chapter includes a brief description of the Fisher hypothesis and reviews the literature on the empirical evidence of this hypothesis. Specific problems in the testing of the hypothesis are addressed. An alternative time series approach is proposed, and the possible empirical and technical advantages of such an approach are discussed.

The Fisher Hypothesis

The Fisher hypothesis originates from the resolution of an empirical paradox. The empirical paradox is the Gibson paradox which empirically suggested a high correlation between nominal interest rates and the aggregate price level (Fisher, 1907). This observation was contrary to predictions of the classical theory which presupposes an interest rate independent of the price level and determined by the real variables of the economy. Fisher (1907) proposed his well known hypothesis to solve this paradox between the observation and theory.[1]

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[1] The paradox also attracted the attention of Keynes (1937).

According to Fisher, nominal rates of interest rise proportionally with the rate of increase in the price level because of inflationary expectations. If future inflation is anticipated by market participants, lenders expect the real value of their principal and the interest to decrease while borrowers expect to repay the loans with depreciated real value.

These anticipations cause the quantity of loans supplied to decrease and simultaneously to increase the quantity of loans demanded. Both forces work to increase nominal rates and nominal rates increase by the same amount of increase in the expected rate of inflation given a sufficiently long adjustment period. Meanwhile real interest rates, which are determined by the real factors of the economy, remain constant in line with the classical propositions.[2]

If R is the nominal rate of interest, r is the real rate of interest and E represents inflationary expectations, then,

$$1)\quad R = r + E$$

Equation (1) cannot be tested as such since both r and E are unobservable. Instead one can use the following equation:

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[2] A careful survey of the criticisms of the Fisher hypothesis shows that a substantial part of the criticism is directed to the second argument rather than the first. The possible effects of aggregate supply shocks on the real interest rate has been cited by Wilcox (Wilcox, 1983).

$$2)\quad E = \sum_{i=0}^{m} V_i \frac{\dot{P}_{t-i}}{P_{t-i}}$$

where P is the price level and $\dot{P}$ is the time derivative. The equation states that the public forms expectations on the basis of the past and actual inflation rates. The V_i's are the weights assigned to the actual and past inflation rates. The following statistically testable hypothesis can be constructed:

$$3)\quad R_t = \alpha + \beta_i \sum_{i=0}^{m} V_i \frac{\dot{P}_{t-i}}{P_{t-i-1}} + \varepsilon_t$$

where ε_t is the random error and the second term in the right hand side of the equation is a weighted sum of past inflation rates, while α is the intercept of the regression equation and is assumed to be equal to the real rate of interest. The Fisher hypothesis suggests that α is a constant over time and the coefficient β is equal to one. The first argument cannot be tested independently since the real rate of interest is not observable and does not have a universally acceptable proxy.[3]

The empirical results will critically depend on several assumptions. First, there is no significant correlation between ε_t and β_1 which is a requisite assumption for all linear regression models. Second, α is independent of the second term in Equation (3). This is a

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[3] The widely used proxy for the real rate is the difference between the actual inflation rate and the nominal rate. This measure itself depends on the validity of the Fisher hypothesis.

crucial assumption since otherwise a value of $\beta = 1$ does not necessarily prove that α is constant assuming that positive (negative) effects on the real rate are exactly compensated by underadjustment (overadjustment) of nominal rates (Gibson, 1972).

Empirical Tests of the Fisher Hypothesis

The Fisher hypothesis has been the subject of innumerable empirical studies.[4] The overall results find β to be less than one contradicting Fisher hypothesis in its classical form and β to be unstable over time (Wilcox, 1983). Fisher´s own results are also open to discussion. Fisher was able to verify his hypothesis only by assuming unrealistically long lags ranging from ten to thirty years in the formation of expectations (Sargent, 1973).

Important results of the empirical literature are presented below:

1) There is no consensus on the value of the coefficients. The cumulative value of coefficients on distributed lag is found to be equal to one as predicted by the theory in some studies such as Fama (1975) but less than one or greater than one in others such as Darby (1975), Peek (1982) and Wilcox (1983).

2) There is some evidence of a liquidity effect (Feldstein and Eckstein, 1970), and this suggests that the

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[4] See for example, Yohe and Karnosky (1969), Gibson (1970), Gibson (1972), Darby (1975), Cukierman (1978), Peek (1981), and Wilcox (1983).

interest rates are sensitive to the changes in the money market as the changes in prices.[5]

3) There is evidence that periods of large variances in the rate of inflation are associated with periods with large variances of inflationary expectations (Cukierman, 1978). This suggests the possibility that not only the inflation rate but also the variance of the inflation rate may be relevant in the formation of expectations (Carlson, 1979).

4) Darby (1976) and Tanzi (1980) have argued about the possible effects of the tax structure (especially income tax) on the estimated equation and its coefficients.

5) The price level was significant when it was included in the regression tests (Gibson, 1972), as distinct from the rate of change of the price level.

6) Aggregate supply shocks may have transient, but important, effects on the nominal rate (Wilcox, 1983).

7) The public may form their expectations by taking into account factors other than the past and actual inflation rates, for example, the past history of business cycles (Gibson, 1970; Chamberlain and Feldstein, 1973).

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[5] Feldstein and Eckstein (1972) found the liquidity effect to be more important than the inflationary expectations in the 1953-65 period.

The overall results do not give a definite answer to the validity of the Fisher hypothesis, and often they tend to be inconsistent with each other. Reasons for this inconsistency are related to the empirical tests. The tests have generally been one of the following:

1) simply regressing the nominal interest rate on the past and actual inflation rates (Gibson, 1970; Ball, 1965). This method gave statistically insignificant values for the coefficients on the distributed lag of past inflation rates.

2) regressing the nominal interest rate on the expected inflation rate after constructing and estimating a distributed lag structure such as Yohe and Karnosky (1969).

3) testing the Fisher hypothesis after correcting for the possible effects of other variables on nominal interest rates (e.g., liquidity effect, uncertainty, etc.) such as Feldstein (1970).

The possible sources of error in these approaches can be traced back to the following possibilities: 1) incorrect specification of the model; 2) inadequate specification of the distributed lag structure; and 3) statistical problems arising from the form of the function to be tested.

Model Specification Errors

A possible source of model misspecification (Sargent, 1973) is the fact that the relationships between the interest rate and inflation rate depend on the interactions of the real and financial sectors of the economy. If the hypothesis is to hold, various restrictions must be imposed on the parameters of the structural equations. Empirically, all the parameters affecting the slopes of IS and LM curves can be relevant in the evaluation of the Fisher hypothesis (Sargent, 1973). The statistically tested equation is a reduced form equation even though the true framework is a structural model. The source of model misspecification is the fitting of a single equation system without appropriate restrictions. This type of error can explain the capricious change in the coefficients of the variables other than inflationary expectations, and these changes are not easily distinguished from a measurement error when using regression techniques.

A typical example is the possible interaction between the independent and dependent variables. Testable regression equations assume a unidirectional causality from the independent variable to the dependent variable. If feedback effects are important, this may affect both the parameter estimates and significance tests.[6]

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[6] This is the problem of correctly identifying the endogenous and exogenous variables in a structural model.

Specification Errors Due to Misspecification of the Lag Structure

The expected inflation rate is not an explicitly observable variable. There are two methods commonly used to deal with this problem. The first method uses the Livingston survey data or some other survey data. However these surveys are not completely adequate. They reflect the expectations of only certain groups in the market and this does not necessarily coincide with the overall expectations.[7] The second alternative is to estimate the expected inflation by using past and actual inflation rates.[8] The proxy for the inflationary expectations is constructed by using

$$Y_t = \alpha + \beta_0 X_t + \beta_1 X_{t-1} + \cdots + \beta_m X_{t-m} + \varepsilon_t$$

with the constant $\sum_{i=0}^{m} \beta_i < \infty$.

The estimation of the parameters in this equation is affected by multicollinearity since the coefficients of the adjacent lags are highly correlated. This has a detrimental effect on the standard errors of the estimated

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[7] Another practical problem is the time-limits. The popular Livingston survey data start in 1949 and is given semi-annually. This limits its use with monthly and quarterly data. Recent literature also suggests that Livingston survey data are biased upward and do not reflect the rational expectations of market participants (Pesando, 1975; Pearce, 1979).

[8] Money growth, business cycles and the variance of past inflation rates are cited as other factors that may affect the expectations (Carlson, 1972; Cukierman, 1978).

coefficients and also affects the significance tests negatively. Meiselman (1963) and Gibson (1972) were unable to find statistically significant coefficients when regressing the nominal interest rate on past and actual inflation rates. Their results may be explained by this statistical problem.

A solution to the multicollinearity is to put restrictions on the regression coefficients $_0$, $\beta_1, \ldots,$ β_n. A frequently used form is a geometric lag distribution defined as

$$Y_t = \alpha_0 + \beta_0 (X_t + \lambda X_{t-1} + \lambda^2 X_{t-2} + \ldots) + \varepsilon_t$$

with the restriction that $0 \leq \lambda < 1$.

Geometrically declining weights impose a geometrical decay on the coefficients. Most of the empirical results using geometrically declining weights gave long lags (Yohe and Karnosky, 1969). The method however has the technical advantage of reducing multicollinearity and has a logical explanation if it is assumed that the expectations are formed adaptively. These expectations are formed by modifying previous expectations in the light of current observations. There are, on the other hand, two statistical problems associated with the use and estimation of geometrically declining weights.

The first is the autoregressive structure of the error terms. If the derived regression equations are estimated under the assumption of independent disturbance terms, while there is a significant correlation, the acceptance levels of the significance tests will be narrower than the specified level of significance. This affects the validity of the hypothesis testing.

Studies acknowledging this problem have used two-step full transform (Cochrane-Orcutt) method. This method is restricted to first-order correlation and does not generalize to higher order autocorrelation. This a priori assumption of first order autocorrelation and its compatibility with the true order of the process is open to discussion.[9]

The second problem is that the geometric lag model in its original form is not suitable for estimation since it includes an infinite number of regressors and must be transformed using a Koyck transformation (Kmenta, 1971). The Koyck transformation causes a spurious correlation between the first order lag of the dependent variable and the error term leading to inconsistent estimates of coefficients. Consistent estimates can be obtained by using instrumental variables and a two-stage estimation procedure.

The instrumental variable technique suggests the use of a new variable uncorrelated with the noise term and

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[9] The empirical results show strong seasonal autocorrelations in addition to first order autocorrelation. This suggests that the use of first order autocorrelation can be a good approximation for seasonally adjusted data but not seasonally unadjusted data.

highly correlated (preferably perfectly correlated) with the explanatory variable. The instrumental variable method will not produce good second-stage estimates if the goodness of fit for the instruments is poor (Hanssens and Liu, 1983). The instruments are created from the exogenous variables and their lags. The consistent estimators satisfying all these conditions are not easy to find in the domain of the Fisher hypothesis.[10]

This discussion and review of the empirical literature underlines the demands for a coherent empirical analysis between nominal interest rate and inflation. The first is the correct identification of the endogenous and exogenous variables. In the domain of the Fisher hypothesis, this amounts to determining the causal order between the inflation rate and the interest rate. The second is the empirical determination of the order of autocorrelations between the error terms. The third is the empirical determination of the distributed lag structures. This information can either be descriptive or used as an initial step in the building of regression models or

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[10] Another frequently used method is the Almon lag. This approach suggests that the weights follow a polynomial of a given degree. The problem with this approach is the correct identification of the degree of the polynomial. Also, Almon lags have a chance of benefiting from an infinite number of transformations until one finds the best while the linearly introduced variables do not have the same chance. This fact can distort our judgment when we compare the significance of the Almon lag variable with the other variables unless the latter are also transformed over polynomials of same degree (Roll, 1972).

time series models. The next section describes several methods that are designed to satisfy these demands.

Empirical Methods of Identifying Causal Order and Distributed Lags

The identification of causality received increasing popularity following the work of Granger (1969). The Granger causality criterion depends on the notion of predictability. This criterion states that a variable X causes another variable Y if the use of the past history of X allows a more accurate prediction of Y in comparison to using only the past history of Y (Feige and Pearce, 1979). Thus if $\overline{Y}_t$ and $\overline{X}_t$ are past values of the variables Y and X respectively, then Y causes X if $O^2(X_t|\overline{Y}_t,\overline{X}_t) < O^2(X_t|\overline{X}_t)$ where O^2 is the minimum predictive error variance conditional on the information set of past values. The variables X and Y are independent of each other if neither causes the other in the sense above and there is feedback if X causes Y and Y causes X simultaneously.

In a strict sense, the use of the term "causality" implies that all other variables in the system are identified and none of them has an effect on X or Y (Peirce and Haugh, 1977). If there is another variable in the system that causes both X and Y, then there may be a spurious correlation between Y and X due to the joint dependence of both series on a third series. Granger causality as defined above is a measure of linear correlation rather than causality if the structural model is not completely identified.[11]

An empirical test of Granger causality requires regressing X on both its own lagged values and the lagged values of Y (Pierce and Haugh, 1977). If Y does not Granger-cause X then the coefficients on the lagged values of Y are jointly equal to zero in the estimated equation. The test of reverse causation (feedback from X to Y) requires regressing Y on its own lagged values and the lagged values of X. This method has been used to test the order of causality in several studies, including Sargent (1976), and Porter and Offenbacher (1983). The pattern of the significant coefficients gives empirical information about the distributed lag structure of the variables.

A similar and popular causality test is the Sims' test (Sims, 1972). In this test X is regressed on the past, present and future values of Y in a two-sided regression. The null hypothesis of no causality from X to Y requires that the coefficients on the future values of Y (negative lags) are equal to zero (Sims, 1972).

A number of statistical problems prevent the use of either one of these two techniques as an effective tool for causality detection. The first is the possibility

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[11] A good review of the causality concept and empirical tests is given in Pierce and Haugh (1977). Se Geweke (1982) for an extensive discussion of feedback and its measures.

that the error terms are highly correlated. A second and more serious problem is the possibility of severe multicollinearity due to the high correlation between the coefficients at adjacent lags. The test of joint significance of coefficients is possible. The test, however, gives information only about the degree of multicollinearity. The reduction of multicollinearity itself poses a much more difficult and serious problem if the available data are limited (Kmenta, 1971). The use of specifically designed filters to reduce multicollinearity is a promising area of research (Granger, 1973). This approach, however, needs more exploration regarding the statistical properties associated with the estimation problem. A third problem in causality detection is the possibility of spurious correlations if the error terms are autocorrelated. An alternative method is to derive the cross-correlation function, but this method easily leads to spurious cross-correlations arising from the autocorrelations of the individual series if applied without prewhitening.[12]

These statistical considerations led to the application of certain filters designed to transform the individual series into white noise. Sims (1972) applied an ad hoc filter of the form $(1-0.75\mathbf{B})^2$ to both series in order

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[12] Even if the autocorrelations of the two series are known, it is still difficult to interpret unfiltered cross-correlations due to complicated interaction effects.

to transform one of the series into white noise and eliminate the spurious correlation. Subsequent research (Feige and Pearce, 1979) has raised serious doubts about the effectiveness of this filter and the practice of using ad hoc filters.

The univariate time series analysis developed by Box and Jenkins (Box and Jenkins, 1976) enables the identification of appropriate filters from the empirical data. Box and Jenkins (1976) used this approach to define a new causality detection technique which can also be used as an empirical tool of distributed lag identification. The validity of the method depends on the following assumption. If two series X and Y are not correlated, and if one of the series is white noise and the other is not, the pattern of cross-correlations between these series is similar to the autocorrelation function of the unfiltered series (Stokes and Neuburger, 1979). If X and Y are correlated under the same conditions, and the pattern of cross-correlations is different than the autoregressive pattern of cross-correlations, the sample cross-correlation pattern is an unbiased estimate of the true population cross-correlation.

The estimated sample pattern reflects the dynamic relation between the two series. The absence of any significant spikes in a given direction implies the absence of a causal relation in that direction. This approach is called Box-Jenkins filtering.

The method however has been criticized on the ground that this type of filter does not remove all the autocorrelations in the series and can lead to spurious correlation (Pierce and Haugh, 1977). This criticism led Haugh to propose a slightly different approach which is called Haugh filtering or double filtering. This method cross-correlates the two series after filtering both of them with their appropriate univariate filters. Although any possibility of spurious correlation is effectively eliminated by the Haugh test, the cross correlations are biased in the direction of not finding a relationship between X and Y (Sims, 1977; Geweke, 1983).[13]

The considerations above and the absence of a method which is unanimously accepted in the literature led to the use of three methods instead of one in Chapters 3 and 4. The methods used to derive the dynamic relationships between the variables are the Granger method, Box-Jenkins filtering and Haugh filtering.[14]

The Fisher hypothesis is important enough to test because it is the best conceptual tool in explaining the

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[13] In a recent study, Geweke, Dent and Meese (1983) compare the performance of various techniques such as Granger method, Sims method and a variety of others (LaGrange, Wald and Hannan techniques) on the basis of Monte-Carlo experiments. They report that Granger and Sims´ methods perform better than the others. The Box-Jenkins and Haugh tests mentioned above are not included in this study.

[14] Sims´ criteria is not pursued since empirical research in both the time-domain and frequency-domain did not support Sims´ ad hoc filter.

relation between the commodity markets and financial markets. The new tests that avoid the above mentioned problems can clarify the empirical issues and enable us to test the hypothesis without imposing a priori restrictions.

CHAPTER 3

THE EMPIRICAL RELATION BETWEEN INTEREST RATES AND INFLATION RATE

Introduction

The purpose of this chapter is to analyze the empirical relation between nominal interest rates and the inflation rate using empirical methods such as Granger causality, Box-Jenkins filtering, and Haugh filtering. The observation period is 1959-1983. A stochastic independence test (Haugh test) is applied to determine the causal order of the series. This prior information is ultimately used to derive a multivariate time-series model.[1]

There are two related objectives of this chapter. The analytical objective is to derive empirical information about the causal order, feedback effects, and distributed lag structure between nominal interest rates and the inflation rate. This empirical information is used to evaluate two hypotheses: 1) Is there any evidence confirming the Fisher hypotheses? and 2) Is there a feedback from interest rates to the inflation rate? Empirical

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[1] The approach used in this study is technically similar to the study by Stokes and Neuburger (1979) who used these techniques to analyze the money supply and nominal interest rate relation in 1947-1978 period.

findings will be related to other developed relationships between nominal interest rate and inflation, such as the Fama effect.[2]

The technical objective is to compare the results of the different methods and evaluate the performance of these methods. Each technique has been used and criticized by different writers such as Sims (1972), Sargent (1976; 1979), Haugh (1976) and Pierce and Haugh (1977). The technical part is similar to the study undertaken by Feige and Pearce (1978) who compared the performance of the above mentioned techniques in explaining the money-income relation.[3]

Univariate Models for the Interest Rate and Inflation Rates

The data for interest rates are 90-day treasury-bill yields with monthly observations from 1959 to 1983. Initially, the observation period was to begin in 1953. Earlier periods were not considered because of interest rate pegging until 1951. The observation period was reconsidered after analyzing the data plots. The sequence plots, after stationarity inducing transformations, showed

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[2] Fama (1975; 1976) proposed that nominal interest rates carry information about the future movements in prices.

[3] Feige and Pearce (1979) compared the performance of Sims´ method, Granger´s method and the Haugh test in examining the money-income relation. Sims´ method is replaced by the method proposed by Box and Jenkins due to reasons cited in Chapter 2.

an unstable variance in the 1953-1959 period. This source of nonstationarity can negatively affect the empirical results.[4] A linear operation such as first differencing cannot transform the data into stationary form if there is a sudden change in the slope of the trend (Granger and Hatanaka, 1964). One proposed solution is to use nonlinear methods or other methods such as complex demodulation (Bloomfield, 1969). However the statistical properties of these methods have not been explored in detail. In addition, the focus in this dissertation is on the behavior of interest rates in the more recent period. A better approach is to omit the few years after 1953 which could also have a bias due to the persisting effects of pegging the interest rates until 1951. This also solves the problem of nonstationarity mentioned above. These considerations led to the omission of 1953-59 period from the analysis.

The inflation rate is derived from the consumer price index (CPI) with base year 1967. The inflation rate series is constructed by taking the first difference of the natural logarithm of the CPI.[5] Further information about this series is given in the section that describes the inflation rate.

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[4] The lagged adjustment of interest rates to the elimination of pegging may be the source of the unstable variance in the 1953-1959 period.

[5] First differencing corresponds to the time derivative of a discretized variable.

The Nominal Interest Rate

The identification of univariate Box-Jenkins models is a required step in the derivation of Haugh and Box-Jenkins filters.

An important class of univariate models is a stochastic difference equation of the form (Box and Jenkins, 1976),

$$1)\quad \Phi_p(B)\, z_t = \theta_q(B)\, a_t$$

with $\Phi_p = (1 - \Phi_1 B - \cdots - \Phi_p B^p)(1-B)^d$, $\theta_q(B) = (1 - \theta_1 B - \cdots - \theta_q B^q)$

The a´s are normally distributed random shocks with zero mean, Z_t is a stationary stochastic variable, $\Phi_p(B)$ is the generalized autoregressive operator and $\theta_q(B)$´s are the moving average operator. The model is identified using sample data and does not require prior knowledge.

An important step in the identification process is the inspection of time sequence plots and transforming the data into a stationary form.[6] The plot of interest rates (Diagram 1) shows a strong upward trend of the mean and an

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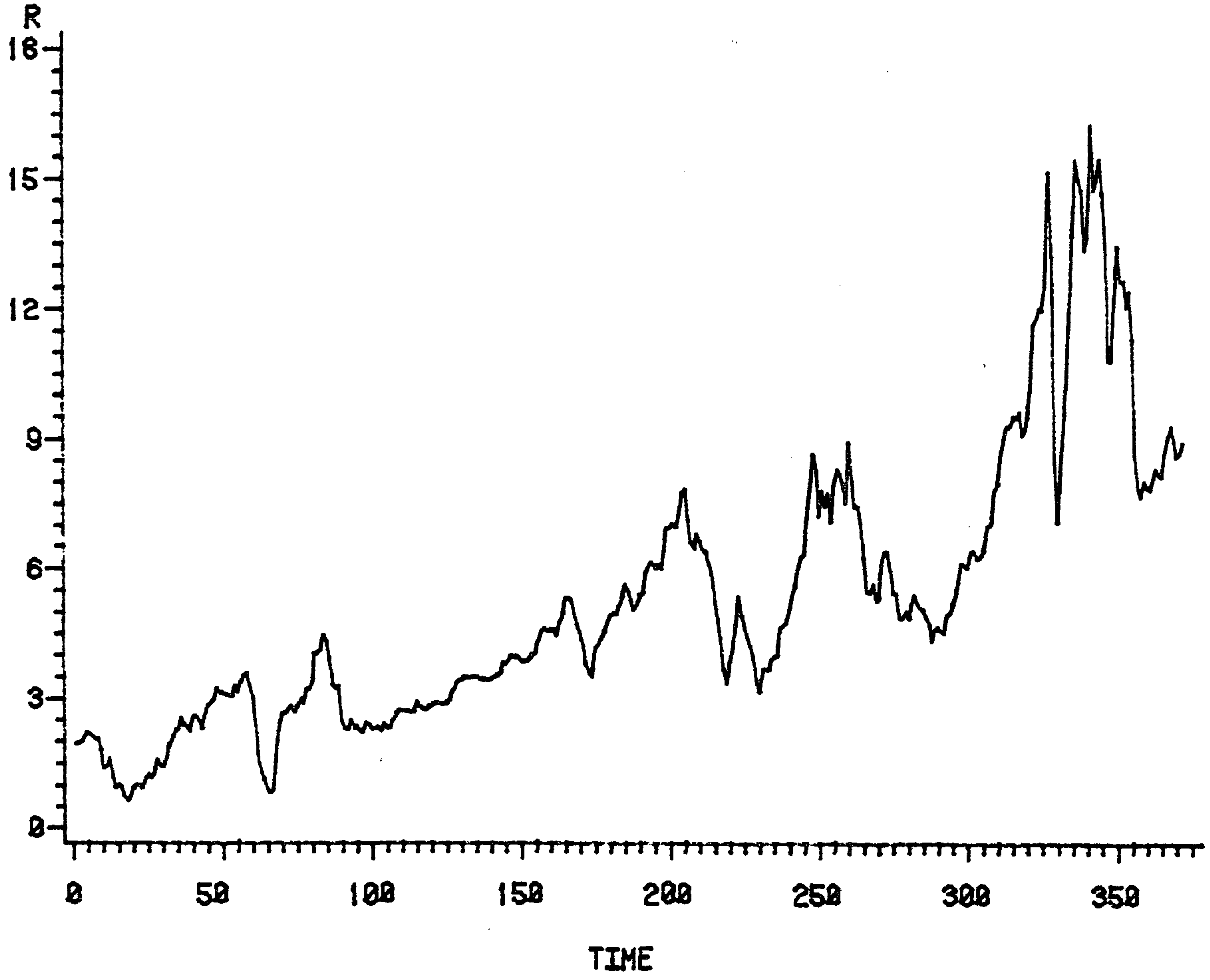
[6] The transformation of data into stationary form is a required step in time-series analysis. A covariance stationary process is characterized by a covariance which is dependent only on the time interval and not the specific dates. Most economic time series violate this assumption because of trends in mean and/or variance. An approximately stationary series can be created by taking first or second differences of the data in case of trend. A trend in variance which is another source of stationarity can be eliminated by taking the logs of the series (Box-Jenkins, 1976; Engle, 1976).

Diagram 1. The Plot of Interest Rates, 1953-1983



increasing variance over time. The trend in the variance is eliminated by applying a log transformation to the data (Diagram 2). The third plot (Diagram 3) is the final shape of the series after taking the first difference of the logs. The series, as can be seen in Diagram 3, is approximately stationary in both mean and variance except for a big spike in 1957. This outlier and its possible effects on the statistical results is not important since this observation is in the early data which was not included in the analysis. It is important to note that linear transformations such as differencing and some non-linear transformations such as log operations preserve the causal relations (Feige and Pearce, 1979).

The sample autocorrelation function of the transformed interest rates after the series is transformed into stationary form is given in Table 1. This function describes the autoregressive and moving average behavior of the series over time. The corresponding diagram is presented in Diagram 4.

The identification, estimation, and diagnostic checking based on this function suggested a model of the form $(0,0,1)x(1,0,0)_6$ as an adequate representation of the

Diagram 2. The Plot of Logarithm of Interest Rates, 1953-1983

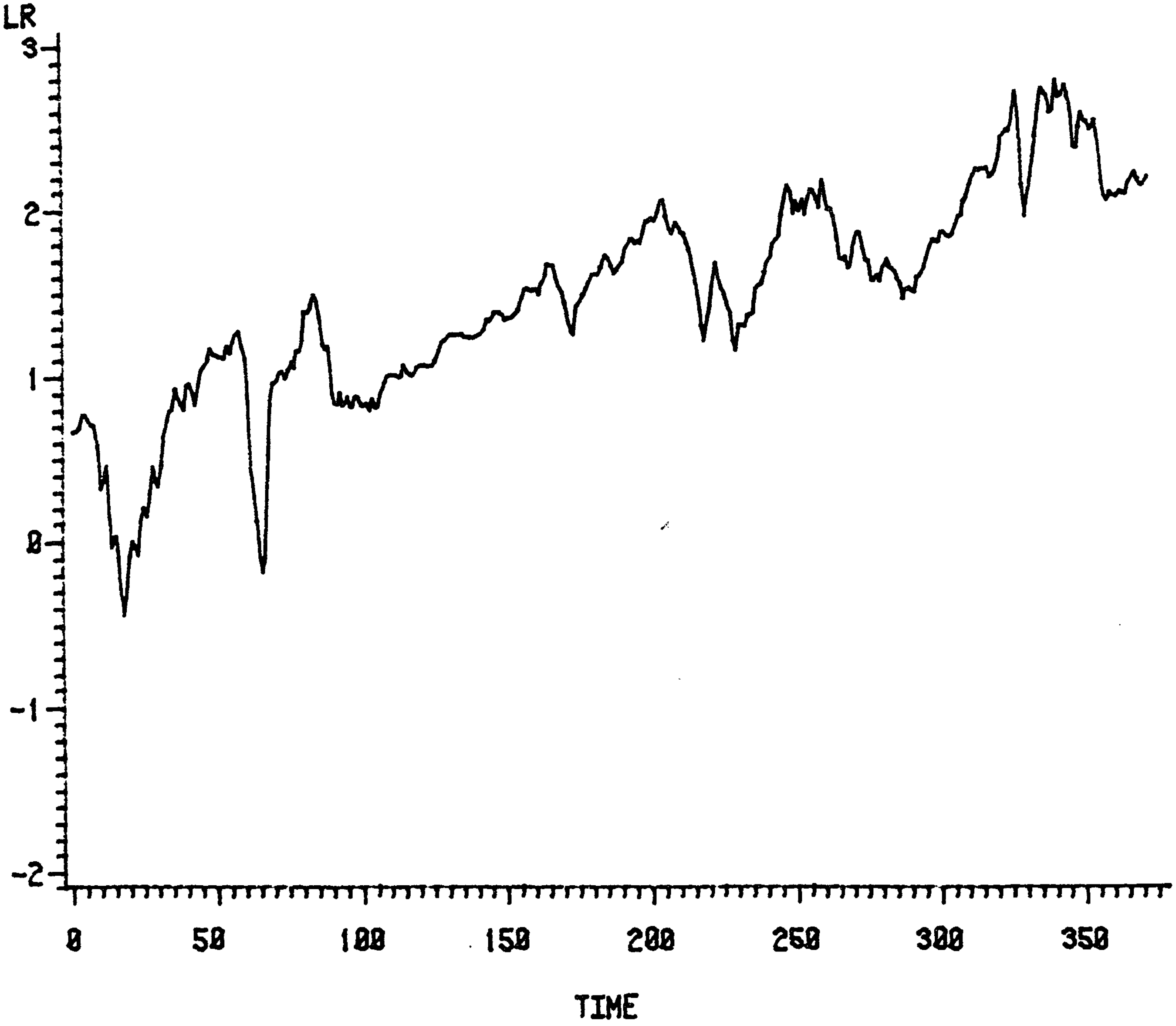


Diagram 3. The Plot of First Differences of the Logarithm of Interest Rates, 1953-1983

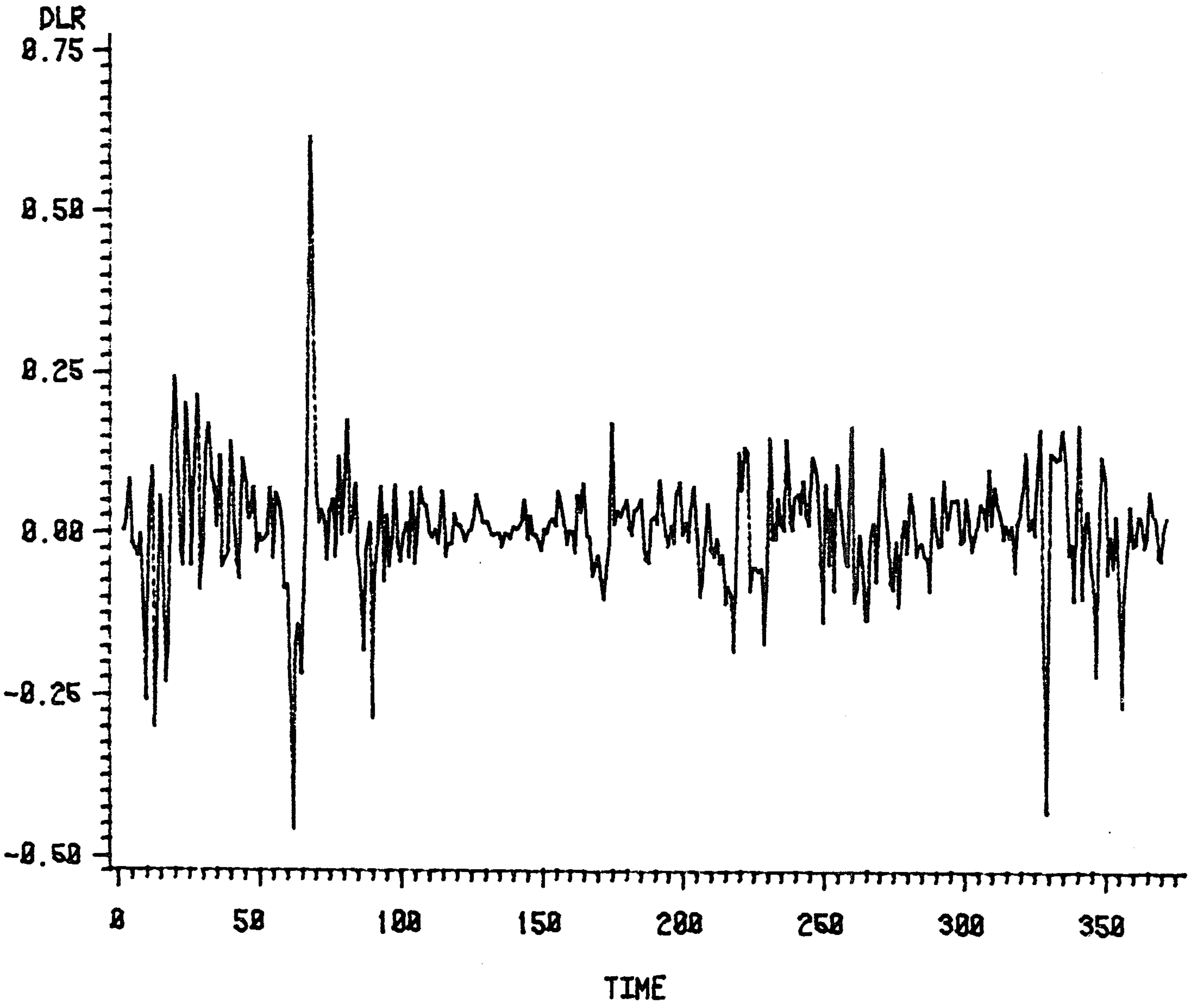


Table 1

Sample Autocorrelation Function of Interest Rates

Lag	1	0.31	13	0.06
	2	-0.12	14	0.15
	3	-0.13	15	-0.09
	4	-0.05	16	0.01
	5	0.03	17	0.09
	6	-0.24	18	0.12
	7	-0.22	19	-0.01
	8	0.09	20	-0.27
	9	0.23	21	-0.18
	10	0.09	22	-0.01
	11	-0.02	23	0.01
	12	-0.15	24	-0.02

Standard Deviation of the Series: 0.6161

Effective Number of Observations: 292

Mean of the Series: 0.0191

Standard Deviation of the Mean: 0.0361

Note: The series are nominal interest rates after taking the first difference of the natural logarithms.

Diagram 4. The Autocorrelation Function of Nominal Interest Rates for 1959-1983

```
 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.
---+----+----+----+----+----+----
                  I
               +  IXX+XXXXXXX
               +  I  +
               +  IX +
               +  IXX+
               + XI  +
           XXXX+XXI  +
             XX+XXI  +
               +  I  +
               +  IX +
               + XI  +
               +  I  +
               +  IXX+
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               +  I  +
               +XXI  +
               XXXI  +
               + XI  +
               +  I  +
               + XI  +
               + XI  +
               +  IX +
```

time-series data.[7] The statistical properties of the model and the diagnostic checking of residuals are reported in Table 2.

Inflation Rate

The time plot of inflation rate over 1953-1983 is given in Diagram 5. The autocorrelation function of the inflation rate and its time plot suggested first-order differencing to achieve stationarity. The univariate model that prewhitens the inflation rate series is given in Table 3.[8]

Empirical Results

The empirical relation between the inflation rate and the nominal interest rate has been analyzed by using these statistical methods. The first method is the direct Gibson test. In the first stage, nominal interest rates are regressed on their own lagged values and the lagged

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[7] The expression within the first parenthesis is the non-seasonal component. The first term shows the order of the autoregressive operator, the second is the order of regular or seasonal differencing and the third is the order of the moving average operator. The expression within the second parenthesis is the seasonal component of the series.

[8] The data at observation 247 of the CPI shows a very strong spike and corresponds to the 1974 oil price shock. This outlier causes a special form of non-stationarity causing a sudden change in the level of trend. Linear methods such as first differencing cannot eliminate this type of non-stationarity (Granger and Hatanaka, 1964). The data has been normalized to solve this problem and a weighted average of past values has been used to replace the outlier.

Table 2

The Prewhitening Model for Nominal Interest Rates

Observation Period: 1959-1983

The Estimated Model:

$$\underset{(0.05)}{(1 + 0.22B^6)}(1 - B)R_t = \underset{(0.05)}{(1 - 0.42B)}a_t$$

Diagnostic Checking of Residual Autocorrelations:

Lags 1-6:	-0.01	-0.02	-0.01	-0.02	0.05	0.02
6-12:	-0.12	0.02	0.12	0.13	0.01	0.09
MQ(12) = 14.7						
12-18:	-0.01	0.05	-0.07	0.02	0.01	0.04
18-24:	-0.04	-0.12	-0.08	0.00	0.00	-0.01
MQ(24) = 25.1						

Note: 1) The standard error of all the residual autocorrelations is 0.06. 2) R is the interest rate after taking the logs of series and corresponds to percentage changes in interest rates. MQ(12) and MQ(24) are modified Q-statistics for the first cumulative 12 and 24 lags respectively (Ljung and Box, 1978). MQ(k) is approximately distributed as X^2 with k-p-q degrees of freedom if the residuals follow a white noise process.

Diagram 5. The Plot of Inflation Rate for 1953-1983

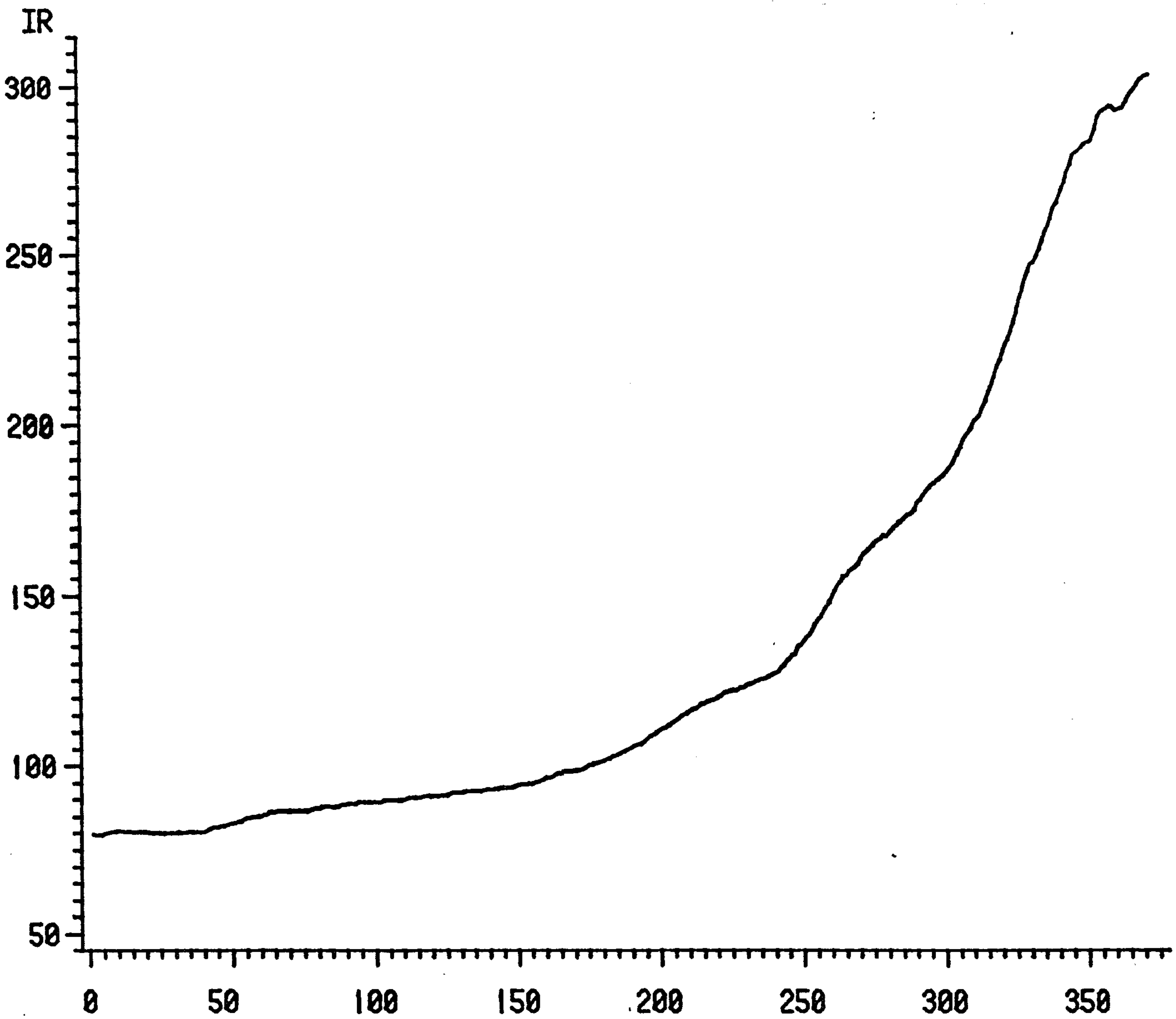

Table 3

The Prewhitening Model for the Inflation Rate

The Estimated Model:

$$(1 - B)X_t = (1 - 0.68B)(1 - \underset{(0.04)}{0.13}B^6 + \underset{(0.06)}{0.12}B^{12})a_t$$

Diagnostic Checking of the Residual Autocorrelations:

Lags	1-6:	0.12	-0.05	-0.09	-0.10	-0.07	-0.01
	6-12:	-0.05	-0.03	0.10	0.13	0.09	0.01
	12-18:	0.03	-0.04	0.08	0.04	-0.03	-0.10
	18-24:	0.09	0.10	0.00	-0.13	0.02	0.04

MQ(24) = 41.5

Note: The standard error of all the residual autocorrelations is 0.06. The confidence limits are plus/minus two times the standard error (0.12).

values of the inflation rate. Then the order is reversed and the inflation rate is regressed on its own values and the lagged values of interest rate. This type of regression is often referred to as a regression in vector autoregressive form (Sims, 1980). The maximal lag length is chosen as 36 months. The empirical analysis showed that lags beyond three years are not significant. There are two different approaches to a vector autoregressive regression. Granger (1972) suggests applying first differencing to both series in order to eliminate the non-stationarity caused by a changing mean. Gibson (1972) and others (e.g., Meiselman, 1963) regress one series or another without applying first differencing. In order to make a distinction in terminology, a vector autoregressive regression without prior differencing operations on data is called the Gibson test in this study. Vector autoregressive regression with differencing is called the Granger test. The regression results of the Gibson test with interest rate as the dependent variable are reported in Table 4. Table 5 reports the results of the Gibson test when the causal order is reversed.

Tables report both the t-statistics and F-statistics. F-tests are designed to test the joint significance of a group of lagged variables. In most cases, groups of four lagged variables are selected for the joint test of the coefficients. This choice is related to the fact that causality interpretations based on the joint significance

Table 4

Results of the Gibson Test: Interest Rate Regressed on Inflation Without Differencing the Series

Method: OLS Estimation

Dependent Variable:	Coefficients on the lagged Inflation Rate (X)			
Interest Rate	0	6.35(3.03)	19	-1.02(0.45)
	1	2.74(1.24)	20	-0.51(0.22)
	2	-5.79(2.61)	21	-0.17(0.07)
	3	0.92(0.41)	22	-0.85(0.36)
	4	-6.00(2.69)	23	-3.83(1.64)
	5	6.39(2.83)	24	-0.28(0.12)
	6	-1.82(0.79)	25	5.06(2.14)
	7	4.96(2.18)	26	-3.26(1.36)
	8	-2.28(0.99)	27	4.47(1.87)
	9	-0.19(0.08)	28	-5.18(2.17)
	10	-2.02(0.85)	29	-2.42(1.01)
	11	-0.16(0.06)	30	-1.29(0.53)
	12	-3.15(1.34)	31	0.59(0.24)
	13	3.60(1.53)	32	0.29(0.12)
	14	0.74(0.31)	33	-1.04(0.43)
	15	-3.77(1.63)	34	-0.28(0.12)
	16	3.24(1.41)	35	2.59(1.13)
	17	1.43(0.62)	36	0.07(0.03)
	18	2.83(1.24)		

$R^2 = 0.98$

F-Tests

Dependent Variable	Independent Variable	F	Causality
Interest Rate	X(4)	7.25	Accepted
	X(7)	4.78	Accepted
	X(12)	1.82	Rejected
	X(16)	1.99	Rejected
	X(20)	0.05	Rejected
	X(24)	0.01	Rejected
	X(28)	4.72	Accepted
	X(32)	0.01	Rejected

Note: 1) F-statistics are calculated for the hypothesis that all coefficients for X(k) are jointly zero. The statistics are applied to groups of four variables as mentioned in text except for the cases where the judgment about causality changes. 2) The values in parenthesis are t-statistics for testing H_o: $\beta_i = 0$.

Table 5

Gibson Test: Inflation Rate Regressed on Interest Rate

Method: OLS Estimation

Dependent Variable	Coefficients on Lagged Interest Rate Without Differencing			
Interest Rate	1	0.002 (1.18)	19	-0.001(0.56)
	2	0.0006(0.21)	20	0.002(0.69)
	3	0.001 (0.45)	21	0.001(0.41)
	4	-0.003 (0.92)	22	-0.004(1.57)
	5	0.002 (0.83)	23	0.005(1.81)
	6	-0.004 (1.30)	24	-0.006(2.01)
	7	0.004 (1.28)	25	0.002(0.66)
	8	-0.0009(0.27)	26	0.001(0.16)
	9	-0.001 (0.46)	27	0.004(1.57)
	10	0.003 (0.98)	28	-0.004(1.36)
	11	-0.003 (0.95)	29	0.001(0.50)
	12	-0.0001(0.03)	30	-0.001(0.46)
	13	0.002 (0.65)	31	0.002(0.67)
	14	-0.002 (0.91)	32	-0.001(0.27)
	15	0.0007(0.24)	33	-0.001(0.60)
	16	-0.001 (0.58)	34	0.005(1.79)
	17	0.002 (0.68)	35	-0.004(1.71)
	18	0.0002(0.06	36	0.001(0.90)

$R^2 = 0.71$

F-tests

Dependent Variable	Independent Variable	F	Causality
Inflation Rate	X(4)	0.860	Rejected
	X(7)	1.637	Rejected
	X(12)	0.001	Rejected
	X(16)	0.346	Rejected
	X(20)	0.478	Rejected
	X(24)	4.065	Accepted
	X(27)	2.476	Accepted
	X(34)	3.223	Accepted

Note: 1) F-values have been calculated for groups of four variables to check the hypothesis that all coefficients for X(k) are jointly zero. 2) The values in parenthesis are the t-statistics for testing H_o: $\beta_i = 0$.

of the coefficients have been found to be better reflected by this choice.[9]

The results of Tables 4 and 5 suggest a short-run response of nominal interest rates to changes in the inflation rate, but neither the t-statistics nor F-statistics give any evidence of a feedback effect in the Gibson test. The results of Granger test are reported later in this chapter after examining the results of alternative techniques based on filtering.

The second method used to test causality is Box-Jenkins filtering (Box-Jenkins, 1976). This method proceeds through the following steps:

1) One of the series in the analysis is prewhitened using an appropriate univariate model. In this study the inflation rate is chosen as the variable to be prewhitened.[10]

2) The other series (interest rates) is filtered by using the same prewhitening filter. The resulting

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[9] F-tests are compiled from a more extensive table which tests the joint significance by adding one variable each time.

[10] Box and Jenkins (1976) suggest prewhitening the input series. The question of which series are the input series is not, as yet, clearly determined. The choice of inflation rate as the input series is a tentative decision following from the theoretical form of the Fisher hypothesis. The choice, theoretically, does not affect the final outcome (Box and Jenkins, 1976). A matter of terminology also needs to be clarified. Prewhitening implies an operation that transforms a given series into white-noise form. The filtering operation also affects the distribution characteristics of a series but does not necessarily transform a series into white noise form.

residual series generally does not follow a white noise process.

3) The sample cross-correlations are estimated, in both directions, by relating filtered interest rates to the prewhitened inflation rate and then relating the prewhitened inflation rate to the filtered interest rates.

4) The coefficient at lag k is statistically significant if the value of the coefficient is at least equal to two times the standard deviation of the coefficient.[11]

The sample cross-correlation pattern estimated using a Box-Jenkins filter is presented in Table 6. The pattern indicates short-term positive causality and negative feedback between the inflation rate and interest rates.

The third method to examine the empirical relationship between interest rates and inflation rate is a procedure advocated by Haugh (1976) and Pierce (1977) to test the independence between the variables. The method uses a two-step approach. Each of the series is prewhitened by their own univariate models in the first stage. The residual series, which are approximately white noise, are cross-correlated in the second stage. The results of Haugh-Pierce two-filter test are given in Table 7.

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[11] Stokes and Neuburger (1979) suggest the com-parison of the sample cross-correlation pattern with the residual pattern of the filtered interest rate series. They argue that an economic meaning cannot be ascribed to sample cross-correlation if the patterns are identical. In the case above, the inspection of patterns showed a sufficient non-similarity between the series.

Table 6

Sample Cross-Correlation Function Using Box-Jenkins Filter

Series 1: Inflation Rate prewhitened by:

$$(1 - B)X_t = (1 - 0.68B)(1 - 0.13B^6 + 0.12B^{12})a_t$$

Series 2: Interest Rate filtered by:

$$(1 - B)R_t = (1 - 0.68B)(1 - 0.13B^6 + 0.12B^{12})a_{12}$$

Series 2 on lags of Series 1:

0*	0.24	13	-0.04	25	0.00
1*	0.27	14	-0.05	26	-0.01
2*	0.12	15	-0.08	27	0.05
3	0.06	16	0.00	28	0.02
4	-0.04	17	0.06	29	-0.04
5	0.00	18	0.08	30	-0.06
6	0.03	19	0.04	31	-0.07
7	0.09	20	0.00	32	-0.07
8	0.08	21	0.02	33	0.05
9	0.07	22	-0.02	34	-0.05
10	0.07	23	-0.07	35	-0.04
11	0.04	24	0.08	36	-0.01
12	-0.01				

Series 1 on lags of Series 2:

0*	0.24	13	-0.04	25	-0.21
1*	0.19	14	-0.06	26	-0.06
2*	0.16	15	-0.04	27	-0.01
3	0.08	16	0.00	28	0.01
4	0.05	17	0.04	29	0.00
5	0.03	18	0.01	30	-0.02
6	0.02	19	-0.03	31	-0.03
7	0.03	20	-0.01	32	-0.03
8	0.03	21	-0.06	33	-0.09
9	0.05	22*	-0.12	34*	-0.12
10	0.09	23*	-0.17	35*	-0.19
11	0.04	24*	-0.26	36*	-0.15
12	-0.02				

Note: The coefficients with an asterisk are statistically significant. The standard error of all the coefficients is 0.06.

Table 7

Cross-Correlation Function Estimated by Using Double Filter

Series 1: Inflation Rate prewhitened by:

$$(1 - B)X_t = (1 - 0.68B)(1 - 0.13B^6 + 0.12B^{12})a_t$$

Series 2: Interest Rate prewhitened by:

$$(1 + 0.22B^6)(1 - B)R_t = (1 - 0.42B)a_t$$

Series 2 on lags of Series 1:

0*	0.15	13	-0.02	25	0.09
1*	0.14	14	-0.04	26	-0.07
2*	-0.16	15	-0.05	27	0.12
3	0.00	16	0.09	28	-0.07
4	-0.12	17	0.06	29	-0.07
5	0.11	18	0.05	30	-0.01
6	0.03	19	-0.01	31	0.05
7	0.11	20	-0.04	32	0.02
8	0.01	21	0.05	33	0.00
9	0.07	22	-0.07	34	-0.03
10	0.03	23	-0.08	35	-0.01
11	0.00	24	-0.02	36	0.02
12	-0.04				

Series 1 on lags of Series 2:

0*	0.15	13	-0.03	25*	-0.26
1	0.07	14	-0.05	26	0.08
2*	0.17	15	-0.04	27	-0.03
3	0.07	16	0.06	28	0.00
4	0.05	17	0.05	29	0.01
5	0.02	18	0.07	30	-0.02
6	0.01	19	-0.08	31	0.02
7	-0.03	20	0.04	32	0.03
8	0.03	21	-0.05	33	-0.04
9	-0.05	22	-0.06	34	0.03
10	0.07	23	0.08	35	-0.07
11	0.08	24*	-0.14	36*	-0.21
12	0.02				

Note: The lags marked with asterisks are statistically significant and exceed two standard error limits. The standard deviation for all coefficients is 0.06.

The distributed lag pattern estimated by using the Box-Jenkins filter is similar to the pattern estimated by the double filter. The pattern, in both, suggests a short-term (one-quarter) lag when interest rates lag the inflation rate. The statistically significant spikes in the reverse order imply a feedback from interest rates to the inflation rate. The statistical significance of the feedback is examined by using a test devised by Haugh.

Haugh (1976) proposed a statistical procedure to test the independence of the two series. Haugh (1972) showed that, under the null hypothesis of independence, the statistic

$$S = N\sum_{k=-M}^{M} \hat{r}_{ij}(k)$$

is asymptotically distributed as $X^2(2M+1)$ where M is the maximal lag length.[12] If the S-statistic exceeds the critical value, the hypothesis of independence is rejected. The statistic can also be used on one vector testing the significance of an assumed causal direction (Pierce, 1977). The results of the Haugh test are reported in Table 8.

---

[12] N is the number of observations and equal to 292. M is the maximal lag length. $r_{12}(k)$ is the sample cross-correlation between the prewhitened interest rate series and the prewhitened inflation rate at lag k. The Monte Carlo experiments verify the validity of the test procedure for series of N = 50,100 and 200 (Haugh, 1976).

Table 8

Haugh-Pierce Test of Independence

1) The test of X ---> R (The lead of inflation rate over interest rate)

Lags	S-statistic	X-statistic	Stochastic Dependence
6	21.9	12.6	Accepted
12	26.9	21.0	Accepted
24	31.5	36.4	Rejected
36	43.6	43.8	Rejected

2) The test of R ---> X (The lead of interest rate over inflation rate)

Lags	S-statistic	X-statistic	Stochastic Dependence
6	12.17	12.6	Rejected
12	16.8	21.0	Rejected
24	33.2	36.4	Rejected
36	70.6	43.8	Accepted

Comparison of Results

The economic interpretation of the statistical results requires a careful approach since there are no precise guidelines and no universally accepted method. In the widely investigated relationship of money and income, for example, different methods and fleters led to radically different conclusions about the independence and the causal order of the variables (Feige and Pierce, 1978).

The results expected from the application of these techniques are indications about the true generating mechanism rather than a very precise description of the distributed lag patterns. The results are encouraging when they are interpreted with this point of view. The similarity between the cross-correlation patterns of the Box-Jenkins and Haugh filters is especially encouraging since different filtering criteria are used. This similarity is illustrated in Diagrams 6 and 7. The Haugh filter is slightly biased downward as expected[13] while the Box-Jenkins filter does not show any explicit evidence of spurious correlation when it is compared with the findings of other techniques.[14]

---

[13] See Chapter 2.

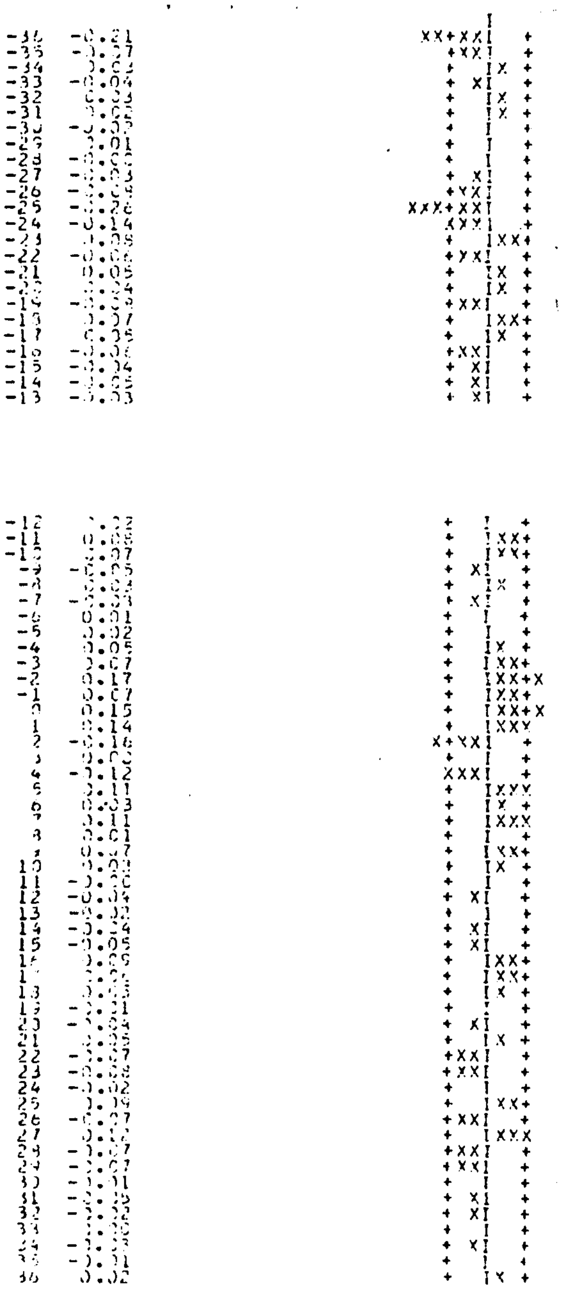
[14] The possibility of spurious correlation is mentioned in the literature as a weak point of Box-Jenkins filter (Haugh and Pierce, 1977). A sign of spurious correlation will be the observation of spikes not confirmed by other more conservative techniques such as the Haugh filter.

Diagram 6. The Cross-Correlation Function after Using Box-Jenkins Filter

```
                                  I
-36  -0.15                 X+XXI  +
-35  -0.18                XX+XXI  +
-34  -0.12                  XXXI  +
-33  -0.10                  XXXI  +
-32  -0.08                  +XXI  +
-31  -0.04                  + XI  +
-30  -0.02                  +  I  +
-29  -0.02                  + XI  +
-28  -0.00                  +  I  +
-27  -0.02                  + XI  +
-26  -0.06                  +XXI  +
-25  -0.19                XX+XXI  +
-24  -0.25               XXX+XXI  +
-23  -0.18                 X+XXI  +
-22  -0.14                  XXXI  +
-21  -0.09                  +XXI  +
-20  -0.04                  + XI  +
-19  -0.05                  + XI  +
-18  -0.00                  +  I  +
-17   0.05                  +  IX +
-16  -0.02                  +  I  +
-15  -0.05                  + XI  +
-14  -0.06                  + XI  +
-13  -0.03                  + XI  +
-12  -0.02                  +  I  +
-11   0.04                  +  IX +
-10   0.07                  +  IXX+
 -9   0.04                  +  IX +
 -8   0.03                  +  IX +
 -7   0.04                  +  IX +
 -6   0.04                  +  IX +

 -5   0.03                  +  IX +
 -4   0.07                  +  IXX+
 -3   0.12                  +  IXXX
 -2   0.20                  +  IXX+XX
 -1   0.21                  +  IXX+XX
  0   0.23                  +  IXX+XXX
  1   0.25                  +  IXX+XXX
  2   0.12                  +  IXXX
  3   0.10                  +  IXXX
  4  -0.01                  +  I  +
  5   0.03                  +  IX +
  6   0.02                  +  I  +
  7   0.09                  +  IXX+
  8   0.07                  +  IXX+
  9   0.06                  +  IXX+
 10   0.05                  +  IX +
 11   0.02                  +  IX +
 12   0.00                  +  I  +
 13  -0.05                  + XI  +
 14  -0.05                  + XI  +
 15  -0.07                  +XXI  +
 16  -0.00                  +  I  +
 17   0.04                  +  IX +
 18   0.06                  +  IXX+
 19   0.03                  +  IX +
 20   0.00                  +  I  +
 21   0.01                  +  I  +
 22  -0.01                  +  I  +
 23  -0.04                  + XI  +
 24  -0.07                  +XXI  +
 25   0.00                  +  I  +
 26  -0.01                  +  I  +
 27   0.03                  +  IX +
 28   0.01                  +  I  +
 29  -0.05                  + XI  +
 30  -0.05                  + XI  +
 31  -0.06                  +XXI  +
 32  -0.07                  +XXI  +
 33  -0.06                  + XI  +
 34  -0.05                  + XI  +
 35  -0.05                  + XI  +
 36  -0.03                  + XI  +
```

Diagram 7. The Cross-Correlation Function after Using Haugh Filter



The Gibson test which is based on OLS estimation gives results inconsistent with the other techniques concerning the signs of the coefficients and the feedback effect. The Gibson test, though widely used in 1960's (Meiselman, 1963; Gibson, 1972), is more open to misjudgment resulting from statistical problems. A typical problem is multicollinearity. The scope of this problem is demonstrated in Table 9 which represents the correlation matrix of the independent variables. The table, for the sake of brevity, is limited to the first six coefficients. The rest of the table (not reported here) shows a similar picture.

A high degree of multicollinearity among the coefficients is shown in Table 9. A comparison of the F-tests also suggests a serious underestimation of the individual coefficients.[15]

The findings suggest that a test of dependence and feedback between the series is beset with statistical problems which render a meaningful economic interpretation very difficult if a Gibson type approach is pursued. More robust techniques such as the Haugh and Box-Jenkins filters which effectively cope with the problems of multicollinearity and spurious correlation look much more promising.

---

[15] The underestimation problem is more severe in the test of causal feedback from interest rates.

Table 9

The Correlation Matrix

	1	2	3	4	5	6
1	1.00					
2	0.72	1.00				
3	0.64	0.72	1.00			
4	0.61	0.64	0.72	1.00		
5	0.57	0.61	0.64	0.72	1.00	
6	0.55	0.57	0.61	0.65	0.72	1.00

Note: The (k,k+j) th element of the table gives the degree of correlation between the estimate of inflation rate lagged k months and the estimate of inflation rate lagged k+j months.

The finding that the Gibson test can lead to serious problems of underestimation and bias raises an important problem. As mentioned in Chapter 2, the possible statistical sources of bias can be related either to multicollinearity (the correlation between the explanatory variables) or spurious correlations caused by the autocorrelation structure of error term. Another possible source of bias may be the non-stationarity of the series involved. The Granger test uses first-differenced data to overcome the problem of non-stationarity. The results of the Granger test in both causal directions are reported in Tables 10 and 11. In Table 10 nominal interest rates are regressed on the inflation rate after first differencing the logarithms of both series. The logarithmic transformation is included to eliminate non-stationarity that might be caused by a variance changing over time. Table 11 presents the results of reversing the causal order. The t-statistics point out to a considerable difference between the results of the Granger test and the Gibson test. Table 10 indicates a relatively strong correlation between the interest rate and one-month lagged inflation rate. The remaining significant correlations between nominal interest rates and seven, eighteen and twenty-seven month lagged inflation rates reflect either a genuine property of the population structure or spurious correlations. The fact that these correlations are not observed in both the Box-Jenkins and Haugh tests supports

Table 10

Results of the Granger Test: Interest Rate Regressed on Inflation After First Differencing Both Series

---

Method: OLS Estimation

Dependent Variable	Coefficients on the Lagged Inflation Rate (X)			
Interest Rate	0	6.12(2.92)	19	7.07(2.02)
	1	8.74(3.38)	20	6.60(1.87)
	2	3.09(1.08)	21	6.40(1.82)
	3	3.91(1.27)	22	5.52(1.57)
	4	-2.61(0.65)	23	1.80(0.51)
	5	4.15(1.19	24	1.50(0.42)
	6	2.23(0.62)	25	6.47(1.84)
	7	7.15(1.99)	26	3.34(0.93)
	8	4.81(1.30)	27	7.78(2.14)
	9	5.08(1.36)	28	2.45(0.67)
	10	3.04(0.83)	29	0.00(0.00)
	11	2.69(0.76)	30	-1.43(0.40)
	12	-0.55(0.16)	31	-0.93(0.27)
	13	3.19(0.95)	32	-0.93(0.28)
	14	3.94(1.19)	33	-2.05(0.67)
	15	0.29(0.08)	34	-2.28(0.78)
	16	3.79(1.11)	35	0.23(0.08)
	17	5.17(1.50)	36	0.15(0.07)
	18	8.10(2.33)		

$R^2 = 0.43$

Note: The values in parenthesis are t-statistics for testing H_0: $\beta_i = 0$.

Table 11

Results of the Granger Test: Inflation Rate Regressed on Interest Rates After Differencing Both Series

Method: OLS Estimation

Dependent Variable		Coefficients on Lagged Interest Rates		
Interest Rate	0	0.006(2.92)	19	-0.002(1.06)
	1	0.002(1.20)	20	0.002(1.35)
	2	0.004(2.12)	21	0.001(0.56)
	3	0.001(0.73)	22	-0.001(0.86)
	4	0.002(1.13)	23	0.001(0.90)
	5	0.001(0.86)	24	-0.002(1.10)
	6	0.001(0.79)	25	-0.001(0.72)
	7	0.001(0.66)	26	-0.001(0.53)
	8	0.002(1.18)	27	0.001(0.53)
	9	-0.002(1.01)	28	-0.0009(0.47)
	10	0.003(1.67)	29	-0.0004(0.21)
	11	0.0006(0.30)	30	-0.001(0.52)
	12	0.0008(0.40)	31	-0.0008(0.41)
	13	0.0005(0.23)	32	0.001(0.65)
	14	-0.0006(0.31)	33	-0.002(1.48)
	15	-0.003(1.43)	34	0.003(1.66)
	16	-0.001(0.71)	35	-0.002(1.05)
	17	-0.001(0.49)	36	-0.002(1.42)
	18	0.0006(0.31)		
	$R^2 = 0.55$			

Note: The values in parenthesis are the t-statistics for testing H_o: $\beta_i = 0$.

the second possibility.[16] All the significant coefficients are positive as theoretically expected.[17] The results of Table 11 indicate a significant correlation between the inflation rate and two month lagged interest rates. The empirical lag distributions derived by the Granger test are more similar to the empirical distributions derived by filtering techniques than that of the Gibson test. This conclusion strongly suggests that the problems associated with the Gibson test are at least partially related to the use of non-stationary series.

The improvement in the statistical results of the Granger test with respect to the Gibson test can be related to a reduction of multicollinearity as a result of differencing operations. Table 12 presents the correlation matrix of the first six lagged variables of the Granger test.

The comparison of Table 12 with Table 9 shows a substantial reduction in the correlations of lagged variables after differencing the data. This result strongly suggests the use of prior differencing operations in vector autoregressive operations to reduce the problems associated with multicollinearity.

---

[16] Only the correlation between nominal interest rates and the inflation rate is significant at 99% level of significance. All other correlations are significant at 95% level of significance.

[17] Gibson test gives coefficients with negative signs. lagged variables after differencing the data.

Table 12

The Correlation Matrix of Lagged Independent Variables for the Granger Test

	1	2	3	4	5	6
1	1.00					
2	0.32	1.00				
3	-0.02	0.31	1.00			
4	-0.02	-0.02	0.31	1.00		
5	0.00	-0.02	-0.02	0.31	1.00	
6	-0.01	-0.01	-0.01	-0.02	0.02	1.00

Note: The (k,k+j) th element of the table gives the degree of correlation between the estimate of inflation rate lagged k months and the estimate of inflation rate lagged k+j months.

Interpretation of the Results

The significance of lags according to four alternative causality detection techniques is summarized in Table 13. The table shows a close similarity between the empirical lag structures of the Haugh and Box-Jenkins methods. The empirical lag distribution found by the Granger test is more similar to the lag distributions found by using filters in comparison with the Gibson test. The feedback from interest rates to the inflation rate is underestimated in both regression-based methods with respect to filter-based methods.

Ascribing economic significance to the statistical results is another step that requires careful consideration. Mechanical interpretation of the results can lead to erroneous judgments given the difficulties of distinguishing the true population structure from the sample fluctuations. Since none of the methods can claim to be completely satisfactory in this regard, the application of the following guidelines can decrease the possibility of such erroneous judgments:

1) The first step is to compare the findings suggested by different techniques. If different techniques lead to similar conclusions and sample patterns, the sample properties reflect the properties of the population with a higher likelihood.

2) Second, one of the techniques can lead to markedly different conclusions due to the specific

Table 13

Significant Lags Estimated by Different Techniques

Causal Direction: Inflation Rate ---> Interest Rate

Method	Significant Lags
Box-Jenkins	0(+),1(+),2(+)
Double Filtering	0(+),1(+),2(-)
Gibson Test	2(-),4(-),5(+),28(+)
Granger Test	1(+),17(+),18(+),27(+)

Causal Direction: Interest Rate ---> Inflation Rate

Box-Jenkins	1(+),2(+),23(-),24(-), 25(-),34(-),35(-),36(-)
Double Filtering	2(+),35(-),36(-)
Gibson Test	24(-)
Granger Test	2(+)

statistical problems associated with the use of this technique. An important step is to identify these statistical problems if one of the techniques gives results substantially different from the others.

3) Finally, the empirical results must be related to a priori economic theory. This is a particularly important requirement in time series analysis since the observed properties can merely reflect the data properties or an inadequate fit of the proposed models. If however a certain hypothesis or theory is consistently rejected by different techniques, this might suggest the inadequacy of the hypothesis to explain the empirical reality.

A short-term response of interest rates to changes in the actual inflation rate is supported by all the different statistics and techniques considered here, including the S-statistics and F-tests. The response of interest rates to a change in actual inflation rate damps out quickly. The lag does not exceed one quarter using the Haugh and Box-Jenkins methods and barely extends into the second quarter using the Granger method. None of the tests show a significant response beyond two quarters.

The signs of the coefficients do not satisfy the consistency criteria. The more robust Box-Jenkins filter suggests a positive response function as would be expected by the Fisher hypothesis. The Gibson test finds a mixed but mostly negative response. A more thorough statistical analysis of this method is suggested following criteria (2). The negative signs of the coefficients may be the result of a significant negative correlation between the regression coefficients in the case of the Gibson test. The correlation between the regression coefficients is presented in Table 14 to analyze this possibility. The significant negative correlations between the coefficients observed in Table 11 support this argument.

The sample cross-correlation functions estimated after applying both the Box-Jenkins and Haugh filters indicate a short-run positive feedback from interest rates to the inflation rate in the first quarter. The coefficients on the first and second months are significant and positive in both methods. This short-run positive feedback is partially confirmed by the Granger test but not with the other methods.[18] A possible explanation for this inconsistency is given in the conclusion section of this chapter. The intermediate period between two and eight quarters is characterized by a typical pause in all methods. This pause is followed by a long-run negative effect, and it is confirmed by all the methods, including the F-tests of the Gibson approach.[19]

---

[18] Neither the F-statistic nor the S-statistic confirm the short-run positive feedback. The S-statistic however is very close to the boundary of the rejection region.

[19] The negative feedback follows a typical pattern in Box-Jenkins method and implies a possible seasonal correlation.

Table 14

The Correlation Between the Estimated Regression Coefficients (First 6 Lags) in the Gibson Test

	1	2	3	4	5	6
1	1.00					
2	-0.19	1.00				
3	-0.14	-0.20	1.00			
4	-0.03	-0.14	-0.20	1.00		
5	0.02	-0.03	-0.11	-0.21	1.00	
6	-0.02	0.05	-0.07	-0.11	0.25	1.00

Estimation of Multivariate Models

Box and Jenkins (1976) advocated the estimation of a transfer function in order to derive the response pattern of output to a given change in input. This approach can be applied if there is no feedback from the output to the input series (Hanssen and Liu, 1983). More generalized methods which do not require a priori restrictions must be used if feedback effects are allowed. These methods are commonly known as multivariate time series analysis and include vector autoregressive (VAR) and vector autoregressive-moving average (VARMA) models. The models require only level 1 knowledge (see Chapter 2) and can be used to test different hypotheses simultaneously (Stokes, 1983).

The multivariate models represent two or more time series as a vector stochastic process (Jenkins and Alavi, 1981). The models, technically, are the generalizations of univariate ARMA models to k series allowing feedback among the series. The models are written in the general form (Quenoille, 1957) as

$$2)\quad \underline{\phi}(B)\,\underline{\Phi}(B^s)\,\underline{z}_t = \underline{\theta}(B)\,\underline{\Theta}(B^s)\,a_t$$

where

$$3)\quad \underline{\phi}(B) = I - \underline{\phi}_1 B - \ldots - \underline{\phi}_p B^p\,;\quad \underline{\Phi}(B^s) = I - \underline{\Phi}_1 B^s - \ldots - \underline{\Phi}_p B^{ps}$$

and

$$4)\quad \underline{\theta}(B) = I - \underline{\theta}_1 B - \ldots - \underline{\theta}_q B^q\,;\quad \underline{\Theta}(B^s) = I - \underline{\Theta}_1 B^s - \ldots - \Theta_Q B^{qs}$$

The B´s are backward shift operators, $\underline{\phi}(B)$ is the autoregressive operator and $\underline{\theta}(B)$ is the moving average operator. $\underline{\phi}$ and $\underline{\Theta}$ are matrix polynomials in B with kxk matrices, $\bar{Z}_t$ is the vector of time series and $\bar{O}_t$ is a vector of random shocks.

An appropriate multivariate model is a model which transforms the original sample matrices of auto and cross-correlations into white noise. The roots of $\underline{\phi}(B)$ and $\underline{\Theta}(B)$ must be outside the unit circle to satisfy the initial conditions of stationarity and invertibility (Box and Tiao, 1981). The determination of the model follows the identification and diagnostic checking stages as in the case of univariate Box-Jenkins methods.

In this chapter, a multivariate model with the inflation rate and interest rate series is estimated for the 1959-83 period. All the series are expressed in log form and transformed into stationary form by the difference operators. The maximum lag length for identification is 36 months. The sample cross-correlation matrices before fitting the model are given in Table 15. The diagonal elements of the matrices show the autocorrelation structure of the series and the off-diagonal elements given the cross-correlations between the different series.

The identification and estimation stages suggested the following model

$$4) \quad (I - \underline{\phi}_1 B^6)\, \underline{Z}_t = (I - \underline{\Theta}_1 B^1 - \underline{\Theta}_2 B^2)\, \vec{a}_t$$

as the most adequate and parsimonious model on the basis of diagnostic checking. $\underline{\phi}_1$, Θ_1 and $\underline{\Theta}_2$ are 2x2 matrices,

Table 15

The Sample Cross-Correlation Matrices Before Fitting the Model

---

Series 1: Inflation Rate

Series 2: Nominal Interest Rate

Eigenvectors of the Covariance Matrix

$$\begin{matrix} 1.000 & -0.001 \\ 0.001 & 1.000 \end{matrix}$$

Behavior of the values in the (i,j) th position of the sample cross-correlation matrix over all outputted lags when series J leads series I

	1	2
1	- . . . . +	. . . .
1	. . + . . . - . . - . .	. . . . -
2	. . . -	+ . . + . - - . . . . +
2	. . . . -	. . . . . - - . . - . +

Note: + denotes a value greater than $2n^{-1/2}$, - denotes a values less than $-2n^{-1/2}$ and . denotes a non-significant value based on the above criterion. Both series have been prewhitened by using the univariate models of interest rate and inflation rate to make the identification easier.

Z_t is a 2x1 vector with inflation rate and nominal interest rate as the elements of the series and a_t is 2x1 vector of independently distributed random shocks. The parameters were estimated by the conditional likelihood method in the first stage. The parameters estimates of the model are given in Table 16.

Tiao and Box (1983) argue that the conditional likelihood method can give unstable and biased estimates of coefficients in the moving average operator. An exact likelihood function is proposed (Ansley, 1979; Ljung and Box, 1978) as an alternative algorithm of deriving more efficient estimates of coefficients in the moving average operator. Table 17 reports the results of the exact likelihood method and gives the sample matrices after fitting the model for the purpose of diagnostic checking. The parameters found to be nonsignificant in the first stage conditional likelihood are constrained to be equal to zero.

Diagnostic checking confirms that the model is adequate and transforms almost all the sample cross-correlation matrices into white noise. The few spikes remaining in the correlation functions can be safety ignored if we do not want to sacrifice the parsimony.[20] The exact likelihood method proves to be effective in

---

[20] The spikes in lags 25 and 36 reflect the long-run negative feedback which is also indicated by other methods in the earlier part of this chapter.

Table 16

Parameter Estimation for the Multivariate Model

Series 1: Inflation Rate

Series 2: Nominal Interest Rate

Estimation Method: Conditional Likelihood

Model: $(I - \underline{\phi}_1 B^6)\underline{z}_{1t} = (I - \underline{\theta}_1 B^1 - \underline{\theta}_2 B^2)\underline{a}_t$

Matrix Estimates:

PHI 6

$$\begin{bmatrix} \overset{*}{-0.183} & 0.0052 \\ (0.057) & (0.001) \\ -1.813 & \overset{*}{-0.168} \\ (1.171) & (0.055) \end{bmatrix}$$

THETA 1

$$\begin{bmatrix} \overset{*}{0.611} & -0.0002 \\ (0.058) & (0.002) \\ -4.396 & -0.410 \\ (1.759) & (0.060) \end{bmatrix}$$

THETA 2

$$\begin{bmatrix} 0.161 & -0.003 \\ (0.057) & (0.002) \\ 3.953 & -0.003 \\ (1.797) & (0.061) \end{bmatrix}$$

Note: Standard errors are reported below the coefficients. The coefficients marked with asterisk are statistically significant at 95% level.

Table 17

Final Form of the Multivariate Model

Series 1: Inflation Rate

Series 2: Interest Rate

Estimation Method: Exact Likelihood

Model: $(I - \underline{\phi} B^{6}) \underline{Z}_t = (I - \underline{\theta}_1 B^{1} - \underline{\theta}_2 B^{2}) \underline{a}_t$

Matrix Estimates:

PHI 6

$$\begin{bmatrix} -0.216 & 0 \\ (0.057) & \\ 0 & -0.170 \\ & (0.055) \end{bmatrix}$$

THETA 1

$$\begin{bmatrix} 0.763 & -0.004 \\ (0.040) & (0.002) \\ -5.174 & -0.412 \\ (1.761) & (0.054) \end{bmatrix}$$

THETA 2

$$\begin{bmatrix} 0 & 0 \\ 3.53 & 0 \\ (1.76) & \end{bmatrix}$$

Table 17 (continued)

Diagnostic Checking of the Residuals

```
Lags 1 through 6

     . .    . .    . .    . .    . .    . .
     . .    . .    . .    + .    . .    . .

Lags 7 through 12

     . .    . .    . .    . .    . .    . .
     . -    . .    . .    . .    . .    . .

Lags 13 through 18

     . .    . .    . .    . .    . .    . +
     . .    . .    . .    . .    . .    . .

Lags 19 through 24

     - .    . .    . .    . .    . .    . .
     . .    . -    . .    . .    . .    . .

Lags 25 through 30

     - -    . .    . .    . .    . .    . .
     . .    . .    . .    . .    . .    . .

Lags 31 through 36

     . .    . .    . .    . .    . .    . -
     . .    . .    . .    . .    . .    . .
```

reducing the standard errors of the oefficients in the moving average operator.

The generating mechanism can be better described by writing the model in the following explicit form:

5) $(1+0.21B^6)\ln X_t = (1-0.76B)a_{1t}-5.76a_{2(t-1)}+3.53a_{2(t-2)}$

6) $(1+0.17B^6)\ln R_t = (1+0.048)a_{2t}-0.41a_{1(t-2)}$

R_t is the first difference of the nominal interest rate. X_t is the first difference of actual inflation rate, a_{1t} is the innovation term driving the inflation rate and a_{2t} is the innovation driving nominal interest rates.

The model confirms the short-run positive and negative feedback found in the previous section. Inflation rate is driven by its own present and lagged innovations, suggesting both a first-order and seasonal autocorrelation of the residuals. The more important outcome is the fact that the inflation rate is also driven by the innovations of the interest rate. The random factors which affect interest rates one month ago and two months also play a significant role in the determination of present inflation rates.

The interest rate is similarly determined by its own present and lagged innovation terms with an autoregressive order of 1 and 6. It is also determined by the one month lagged innovations of the inflation rate.

The most important result of the model is the fact that the short-run cross-correlations in the data are most adequately represented by a moving-average form rather than an autoregressive form. There is an important conceptual distinction between a moving average and autoregressive representation. The autoregressive representation relates the current values of the dependent variable to the value of its own lags or the lagged values of other independent variables (Box-Jenkins, 1976).

An equivalent way to present the model is to use the moving average representation. The disturbance term in any regression equation reflects the fact that the independent variables of the equation do not explain the dependent variable perfectly at each observation (Porter and Offenbacher, 1983). This disturbance is the innovation for the variable under consideration. The moving average representation expresses the current values of the dependent variables in terms of current and lagged values of innovations (Porter and Offenbacher, 1983).

Given that a moving average representation is a legitimate model form, it may be used to explain the short-run cross-correlations in both directions. This suggests a possible explanation about the mechanism that generates the correlations. It indicates that the observed linear correlation in the short term (in one to two months) is best represented by cross-correlation between the innovations that drive the variables rather than a direct linear relation between the variables. The theoretical significance of this argument will be explored.

Conclusions

The statistical results so far support three arguments: 1) the nominal interest rates respond positively and quickly to a change in the actual inflation rate, and the lag does not exceed two months; 2) there is a short-run positive feedback from interest rates to the inflation rate, and this feedback takes place within two months; and finally, 3) there is a long-run negative feedback from interest rates to the inflation rate. The appropriate lag for the long-run effect is almost 8 to 9 quarters.

The last observation of long-run negative feedback is consistent with an explanation which takes income effects into consideration. An increase in interest rates lowers aggregate demand by causing a decline in investment causing a portfolio adjustment between the expenditures on goods and expenditures on financial assets. The decline in the level of aggregate demand acts as a brake on the rate of price changes and causes a decline in the inflation rate, given a sufficiently long period of adjustment. This explanation is consistent with both the observed negative sign and the sufficiently long adjustment period of 8 quarters observed empirically.

The long-run negative feedback is also consistent with a monetarist explanation in a policy environment characterized by interest rate stabilization. The increase in nominal rates leads the Federal Reserve to reduce the money supply in order to keep the rates under control. The long-term effect of restrictive money supply is a lowering of the inflation rate consistent with the monetarist approach. There is no way to distinguish which effect is more important in the limited context of two-variable analysis.[21]

The second observation of short-run positive feedback from interest rates is more difficult to be reconciled within the basic framework of conventional theories. Most of the conventional approaches do not give much emphasis to the possibility of significant feedback. Regression analysis, the commonly used statistical method, starts with a priori assumptions about the causal order and does not allow an explicit observation of feedback if other tests such as the ones used here are not considered.[22] There is however a theory proposed by Fama which considers the possibility of a short-run positive feedback from interest rates to inflation.

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[21] The empirical evidence on this point is reconsidered in Chapter 4 which analyzes the money-interest rate relation.

[22] Sargent (1973) also found a significant feedback from interest rates to inflation rate by using the Sims criteria.

Fama (1975; 1977) proposed a relationship between the nominal interest rates observed at time t and the rate of inflation observed one period ahead. This relation will be observed in an efficient market if the real rate does not change to exactly offset the changes in the expected rate of inflation.[23]

According to Fama's hypothesis, the market is efficient and correctly uses all information about the future inflation rates in setting nominal interest rates. The fly in the ointment, however, is the way the agents form their expectations in the bond market.

Fama argues that the information used in assessing the nominal interest rate is the information contained in the time-series of past inflation rate. The statistical evidence seems to confirm the Fama hypothesis. A careful appraisal, however, of the evidence raises questions concerning the explanation given by Fama. The Fama argument is open to two criticisms. It does not explicitly distinguish if the information used by agents is primarily focused on the changes in the inflation rate or past observed trends in the inflation rate.

This distinction is especially important in the context of aggregate supply shocks. An aggregate supply

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[23] The theory will hold if the real rate of interest is constant in the short-run. Fama's (1975) original formulation requires a weaker condition. It only requires that changes in real rates do not exactly offset changes in expected inflation and do not impose an a priori requirement of constant real rates.

shock or a radical policy change would normally alter the actual rate of inflation. The effect of such a policy change[24] is a radical deviation from the past observed trends of the actual inflation rate. If the effect of a supply shock or policy change is short-run and transient, the overall trend is not affected. If the effect is long-run and permanent[25], the trend will be affected. The actual change in the slope or level of the trend and its observation by market participants requires time and a period of adjustment.

Two different possibilities must be considered in the case of temporary deviations from the trend. Either the market also responds to temporary aggregate shocks (or unannounced policy changes) in which case nominal interest rates are good predictors of inflation at every point over the observation point, or the market does not respond to the temporary shocks and continues to form its expectations on the basis of observed past trends. In the latter case, nominal rates are good predictors of the inflation rate at the points characterized with the absence of deviations but not a good predictor at the points where there are deviations from the trend. This

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[24] An unannounced fiscal policy change by government or an unannounced change in monetary policy are two possible examples.

[25] Wilcox (1983), among others, mentions the possibility of long-run and persistent effects of aggregate supply shocks.

last case will be compatible with an increasing gap between the inflationary expectations and the nominal interest rate and a variable real rate.

Regression analysis cannot distinguish between these two different possibilities.[26] If most of the period is characterized by a movement along the trend, the regression analysis will confirm the Fama effect due to aggregation over time even though the Fama effect does not hold at all points of observation. Additional sources of information are needed.

One such piece of information is the observation of very short lags concerning the response of nominal interest rates to a change in the actual inflation rate. The positive sign of the response appears to suggest a Fisher effect. There are however two apparent paradoxes in this interpretation.

The first is the length of the lag between the actual inflation rate and the nominal interest rate. The effect of the inflation rate on the interest rate is strongest in the first month and partially carries over into the second month. There is not any statistically significant effect of actual inflation rates on interest rates for three months and beyond. In addition, there is an instantaneous and positive correlation between the actual inflation rate

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[26] Such a change in trend is actually observed in the inflation rate series in 1974 following the oil price shock.

and nominal interest rates. This is very hard to explain since the price index is reported with at least one month lag after the actual price movements (Roll, 1972).

The second paradox is the incompatibility of this result with most of the findings in the empirical literature relating to the Fisher hypothesis. Most of these studies found very long lags. The majority of these studies (Meiselman, 1963; Cagan, 1965; Friedman and Schwartz, 1963) regress nominal rates on current and lagged rates of price change using either unconstrained or geometrically decaying lags. The reported mean lags vary from seven to thirty years.[27]

It is not likely that investors have such far reaching horizons in forming their expectations. The empirical results are caught in a bind of either too long (according to other studies) or too short lags (according to this study).

A possible solution is indicated by the results of the multivariate estimation. The multivariate model suggested that the moving average form is the most adequate and parsimonious representation in explaining the cross correlations in the short run. The fact that a moving average representation, rather than an autoregressive representation, is more parsimonious is not just a minor technical point.

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[27] Friedman and Schwartz (1963) and Fisher found lags extending from ten to thirty years.

The first problem is the type of mathematical relation that holds between two representations. According to a duality theorem, a finite MA (moving average) has an autocorrelation function which is zero beyond a certain point and is equivalent to an infinite autoregressive process. The autocorrelation function of a moving average process is infinite in extent if it is written in terms of autoregressive operators instead of moving average operators (Box and Jenkins, 1976).

In time series analysis, very long lags are represented by a sample autocorrelation function which does not die off rapidly. Such a pattern can be generated in two ways. First, it can indicate nonstationarity in the data. The regression studies which use levels instead of rates of change can generate very long lags as a result of nonstationarity in the data. The operations, such as differencing, eliminate the trend and nonstationarity. Gibson (1970) and others report the finding of long lags after the trend is removed by first differencing. These long lags found by regressing rates of change on rates of change led to the belief that the observed lags were reflecting a genuine character of the economy.

The argument of this thesis is that this may still reflect a statistical problem. The observation of very long lags even by de-trended data is the result of fitting an autoregressive representation to a process whose parsimonious representation is a moving average form. The result is inefficient estimation due to the large number of parameters that must be estimated. Also, the researcher must a priori specify the order of the autoregressive polynomial. The multivariate model estimated in the previous part suggested that the short run correlations between the inflation and interest rates is parsimoniously represented by a moving average form. Theoretically, we would expect to observe very long lags if this moving average form is written in the vector autoregressive form. The result, in fact, depends on how fast the weights converge. However, if the data are monthly and seasonal, there should be significant weights at long lags. The regression equations used in the test of Fisher hypothesis, in the way they are written, are an example of vector autoregressive form.

Summing up, the regression results are biased to finding very long lags in tests of the Fisher hypothesis, and this does not necessarily reflect the properties of the true generating mechanism. If levels are regressed on levels, the source of very long lags is the trend in the series which generates non-stationarity. If the data is in stationary form (using rates of change instead of levels which corresponds to applying first differencing to the series), very long lags may be observed due to estimating an autoregressive process instead of a moving average form.

A moving average representation signifies either an autocorrelation or a cross correlation between the innovations driving the variables. An innovation is a multitude of random effects that affect a given variable. This fact is used below for a re-appraisal of the Fisher hypothesis within a rational expectations context.

This context can be summarized in terms of four related statements:

STATEMENT ONE: The markets are efficient in the sense that market agents utilize all publicly available information in forming their expectations. The assumption is based on the risk-minimizing and rational behavior of market participants. A risk-averse market participant tries to minimize losses due to unanticipated changes by using all available information.

STATEMENT TWO: The best forecast of future movements of economic variables are the recently observed trends in these variables in the absence of sudden shocks to the economy. This argument follows from the fact that (1) Recent trends are the best indicators of future movements in variables if there are not innovations strong enough to cause the variables to deviate from their past trend and (2) The use of trends in the absence of shocks minimizes cost in terms of search time and money.[28]

The first argument depends on the fact that the past history of a series is a good predictor of future in the absence of marked deviations from the past behavior. An economic time series can be decomposed into four components: a) trend, b) seasonal movements, c) movements along the business cycles, and d) short-run cycles. If the seasonal cycles are relatively unimportant most of the past behavior is summarized in the trend component in the absence of substantial short-run fluctuations.[29]

Speaking in the context of the Fisher hypothesis, the nominal component of interest rates is determined on the basis of recently observed trend in the inflation rate. The expected rate of inflation is a function of lagged values of past and actual inflation rates in a Fisherian sense since it is a direct function of observed trend in the actual inflation rate. A more or less complete adjustment of the nominal component to the weighted average of past and actual inflation rates depends, to a large extent, on the predictive content of trend. The adjustment is complete, implying a coefficient of unity,

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[28] This simply indicates the fact that extrapolating a trend into the future is a much simpler and cheaper method than the utilization of complicated multivariate models and computer packages.

[29] This argument is tested in Chapter 5.

if there are no deviations from the trend. If there are deviations from the trend at particular points of the observation period, the coefficient is unstable as observed in most empirical studies.

STATEMENT THREE: If there are marked deviations from the trend due to an unanticipated supply shock or policy announcement, market participants use a broaa spectrum of signals in order to assess the magnitude and direction of the deviation.

This statement depends on the following facts. The cost of not using additional information can be substantial in the periods of deviation from the trend. The problem is the fact that the source of the shock and the way its effects are distributed throughout the economy is unanticipated and unknown. In addition to that, the shocks tend to distort the variables in the past and decrease the informative content of the theoretical models.

A rational investor, under these circumstances, will prefer to use a broad spectrum of signals utilizing all types of available information in the different markets (or at least the markets by which he is acquainted) rather than one single model or the past history of the series. This information is utilized to assess the deviation of the actual variables from the trend. In behavioral terms, the market participants develop a short-run expectational behavior distinct from the long-run behavior which exclusively depends on trend. This short-run expectational behavior is a temporary and flexible adjustment in response to unanticipated shocks.

This broad spectrum of signals which includes the policy announcements, the behavior of the stock market and other factors, such as mass psychology variables (Keynes, 1936) statistically corresponds to the innovations of economic time series.

STATEMENT FOUR: The short-run expectational behavior determines the behavior of agents not only in one market (e.g., the bond markets), but it determines the behavior and decisions of economic agents in all the major markets simultaneously.

In statistical terms, this corresponds to the fact that the innovations are not only autocorrelated, but also cross-correlated. The cross-correlations of the innovations between different markets is observed as the short-run (one to two months) simultaneous positive and negative feedback between the different markets. The observed cross-correlations between the inflation rate and nominal interest rates can be interpreted as the same short-run expectational behavior that determines the decisions of market participants in both the commodity and bond markets. This explains the short-run feedback and the instantaneous correlation between variables. If the argument is as general as statement four implies, we expect to see a similar relation between money and interest rates. This hypothesis is tested in the next chapter.

The advantage of this explanation is its ability to explain both the results of this chapter and the long lags found in other studies on the basis of a simple assumption. The short-run changes of real rates can also be explained within this framework.

A rational investor uses a reference basis around which the expected deviations are assessed. This reference base is the recently observed trend of the variable(s). The use of recently observed trends as the reference basis of short-run expectational behavior in the initial periods of aggregate supply shocks is a rational decision due to the impossibility of distinguishing a transient shock from a permanent shock.

If the supply shock is transient, the variable moves back to a movement along the trend as the effect of the shock subsides. The picture is radically different if the supply shock is permanent and changes the long-term trend of the variable. It may take a long time to determine that there has actually been a change in trend. There is an intermediate period characterized by a change in the trend of the actual variable and a lagged adjustment of the long-term expectation. The market participants continue to make adjustments on the basis of the pre-shock trend rather than adjusting their expectations to incorporate the information about the after-shock trend. The intermediate period can be relatively long due to the difficulty of distinguishing the permanent shocks from the transient ones. Future movements of the variables are continuously underestimated due to the difference between the actual after-shock trend and the expectations based on the pre-shock trend. The adjustment of the nominal component is less than complete and the gap between the nominal interest rate and inflationary expectations widens, even if the genuine real rate is constant. The result is a change in the observed real rate. The observed rate will return to previous levels only in the long-term as the permanent supply shock and its effect on the trend is incorporated into the expectations and long-run behavior of market participants. This mechanism can explain the empirically observed fact of a real rate which is stable in the long-term but variable in the short-term.

CHAPTER 4

THE EMPIRICAL RELATION BETWEEN THE MONEY SUPPLY AND INTEREST RATES

Introduction

The focus of Chapter 4 is on the empirical relation between the money supply and nominal interest rates. This relation is analyzed by using Box-Jenkins methods, the Haugh test, the Gibson test, and the Granger test. Similar methods and the same observation period (1959-1983) are selected to compare the results of Chapter 3 with the results of this chapter. The multivariate model in Chapter 3 is extended by including a money supply series and estimating a three variable vector autoregressive-moving average (VARMA) model. The conclusion reconciles and interprets the statistical results.

The Money Supply

The money supply series is the M1 series published by the Federal Reserve. The problem of determining the best proxy for the money supply is not a completely resolved issue. The empirical literature uses both the M1 and M2 definitions of money. The majority of the empirical studies (e.g., Gibson and Kaufman, 1968) use the narrow (M1) definition of money. Friedman defends the use of M2 series as the proper money supply variable and a number of studies including Cagan (1965) and Stokes and Neuburger (1979) used M2 in their empirical work.[1] The decision to use the Ml series in this study is the result of two considerations. The first is the fact that this study analyzes the relation between the money supply and interest rates. The M2 definition of money includes interest-bearing components such as small time and savings deposits. The substitution relations between the interest-bearing and non interest-bearing components of the money supply can add an additional complication to the interpretation of the results. The second consideration is the fact that the emphasis in this study is on the effects of monetary policy followed by the Federal Reserve. Changes in Ml are controlled more effectively by the Federal Reserve´s policy instruments. Given these considerations, this study uses the Ml definition of money and excluding all interest-bearing assets. Thus the Ml series used in this study includes only the currency held by public and the checking accounts in the commercial banks. Interest-bearing ATS and NOW accounts are also excluded and the definition used here technically

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[1] The analysis of Stokes and Neuburger (1979) covers the partially overlapping time period of 1947-1979. The use of Ml instead of M2 permits us to compare the relative performance of the two proxies. Stokes and Neuburger found no significant correlation between M2 and nominal interest rates with the exception of a negative instantaneous relation by using the Box-Jenkins filtering methods and transfer function analysis.

corresponds to M1A definition of money. The observation period is 1959 to 1983. Monthly and seasonally nonadjusted nominal M1 series are used. The real M1 series is used in the end of the study to compare the effects of nominal money supply versus the real money supply on nominal interest rates. The nominal interest rate series is the yield on 90-day T-bills as in Chapter 3.

Inspection of the sample paths and the sample autocorrelation function of the nominal M1 series shows an unstable and increasing variance over time, strong seasonality and a strong upward trend. The data is transformed into an approximate stationary form by using a logarithmic transformation, first differencing, and seasonal differencing.[2]

The univariate model that prewhitens the nominal money supply series is presented in Table 18. The successive stages of identification, estimation, and diagnostic checking has suggested the following model as the

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[2] The series with strong periodic movements have a trend in the seasonal component (Granger and Hatanaka, 1964). This non-stationarity is removed by applying seasonal differencing to the data (Box and Jenkins, 1976). A seasonal component suggests a significant correlation between the current value and the twelve month lagged value. The trend in the seasonal component is indicated by a series of spikes at seasonal terms which do not die off. Seasonal differencing is a linear operation to remove this source of non-stationarity. It is the subtraction of the twelve month lagged value of the variable from the current value if monthly series have a trend in the annual cycle.

Table 18

The Prewhitening Model for Nominal Money Supply (Ml)

The Model:

$$(1-\underset{(0.05)}{0.14}B)(1-B)(1-B^{12})\ M_t = (1+\underset{(0.05)}{0.26}B)(1+\underset{(0.04)}{0.08}B^9-\underset{(0.06)}{0.65}B^{12})a_t$$

Diagnostic Checking of the Model:

Lags 1-6:	0.01	0.06	0.04	-0.05	0.00	0.00
St. Est.:	0.06	0.06	0.06	0.06	0.06	0.06
Lags 6-12:	-0.18	0.04	0.11	-0006	-0.04	-0.03
St. Est.:	0.06	0.06	0.06	0.06	0.06	0.06

MQ(12) = 16.6

Lags 12-18:	-0.07	0.10	-0.03	-0.01	0.14	0.07
St. Est.:	0.06	0.06	0.06	0.06	0.06	0.07
Lags 18-24:	-0.07	0.10	-0.03	-0.01	0.14	0.07
St. Est.:	0.07	0.07	0.07	0.07	0.07	0.07

MQ(24) = 38.3

Note: 1) M is the natural logarithm of nominal Ml. 2) Standard error estimates are listed below the coefficients. 3) The difference function $(1-B)(1-B^{12})$ transforms the series into a stationary form. 4) MQ(12) and MQ(24) are modified Q-statistics for the first 12 and 24 autocorrelations of the residuals.

best model that represents the behavior of nominal M1 over time.

$$1)\quad (1-0.14B^6)(1-B)(1-B^{12})M_t = (1+0.26B)(1+0.08B^9-0.65B^{12})a_t$$

The terms (1-B) and $(1-B^{12})$ are the first differencing and seasonal differencing (twelve month) operators which are used to transform the data into stationary form. The remaining expression on the lefthand side of the equation (1) suggests a significant correlation between the current M1 and six-month lagged M1. The moving average operators on the righthand side of the equation imply a significant correlation of current innovation terms driving M1 with the innovation terms nine (B^9) and twelve (B^{12}) months ago. The B term reflects the existence of an annual cycle. This cycle is later confirmed by spectral analysis in Chapter 5. It is difficult to assign an economic interpretation to the B^9 term. The term, however, was included in the equation since the fit of the model has substantially improved in terms of residual autocorrelations and modified Q-statistics. It may indicate a temporary nine-month cycle of money supply which is created as a result of the Federal Reserve´s stabilization policies. This possibility is explored further in Chapter 5.

The Empirical Relation Between the Money Supply and Interest Rates

The empirical relation between the nominal M1 and nominal interest rates is initially analyzed using the Gibson test. As explained in Chapter 3, the Gibson test regresses the level of an independent variable on the levels of independent variables without prior differencing operations on data. Table 19 presents the results of regressing nominal interest rates on the current and lagged money supply series. The maximal lag is 36 months. The lags beyond 36 months are found to be insignificant. Table 20 reverses the order and presents the results of regressing the level of nominal M1 on current and lagged nominal interest rates. The data are not differenced in both variables.

The t-statistics suggest a short-term effect starting in the second month and slowly dying off in the end of the third quarter. The response of interest rates to the changes in the money supply peaks in the fifth month.

The regression coefficients of the Gibson test change sign frequently. The unstable and erratic behavior of the signs of the coefficients does not permit clearly distinguishing the positive and negative effects of the money supply on interest rates. The statistical evidence based on t-statistics in Table 20 suggests rejection of the hypothesis of causal feedback from interest rates to the money supply.

Table 19

Results of the Gibson Test

Dependent Variable	Coefficients on Lagged M1			
Interest Rate	0	6.25(3.04)	19	-3.64(1.03)
	1	-3.46(1.02)	20	0.61(0.17)
	2	-8.40(2.49)	21	0.11(0.03)
	3	6.40(1.88)	22	-0.88(0.25)
	4	-6.94(2.02)	23	-2.97(0.83)
	5	12.11(3.50)	24	3.30(0.93)
	6	-7.87(2.24)	25	5.31(1.49)
	7	6.68(1.89)	26	-8.36(2.35)
	8	-7.17(2.01)	27	7.34(2.04)
	9	2.46(0.67)	28	-9.40(2.60)
	10	-2.09(0.57)	29	2.49(0.68)
	11	1.91(0.52)	30	1.04(0.28)
	12	-2.95(0.81)	31	1.88(0.51)
	13	-6.46(1.76)	32	-0.27(0.07)
	14	-2.59(0.72)	33	-1.46(0.40)
	15	-4.44(1.24)	34	0.58(0.16)
	16	-1.60(0.44)	35	2.63(0.74)
	17	-1.60(0.44)	36	-1.39(0.62)
	18	1.53(0.43)		
			$R^2 = 0.98$	

Note: The values in parentheses are t-statistics for testing H_o: $\beta_i = 0$.

Table 20

Testing Causal Feedback by the Gibson Method

Method: OLS Estimation

Dependent Variable

M1

Coefficients on Lagged Interest Rate

0	0.006(3.042)	19	-0.003(0.902)
1	-0.003(0.970)	20	0.004(0.004)
2	0.002(0.535)	21	-0.001(0.387)
3	-0.003(0.870)	22	-0.003(0.918)
4	0.001(0.312)	23	0.003(1.090)
5	0.0009(0.25)	24	-0.004(1.256)
6	0.0002(0.07)	25	0.001(0.308)
7	-0.0006(0.17)	26	-0.0002(0.08)
8	0.0015(0.14)	27	0.003(0.921)
9	-0.004(1.213)	28	-0.002(0.779)
10	0.004(1.336)	29	0.001(0.368)
11	-0.003(0.870)	30	-0.0009(0.27)
12	0.001(0.030)	31	0.0004(0.14)
13	0.0003(0.10)	32	0.0007(0.23)
14	-0.001(0.280)	33	-0.002(0.879)
15	-0.002(0.630)	34	0.005(1.680)
16	0.001(0.355)	35	-0.005(1.837)
17	0.0007(0.20)	36	0.002(1.837)
18	0.001(0.529)		

$R^2 = 0.99$

Note: The values in parenthesis are t-statistics for testing H_0: $\beta_i = 0$.

This outcome is subject to scrutiny because of the problems associated with the Gibson test as mentioned in Chapter 3. The instability of the signs and the observed absence of feedback can be related to problems of multicollinearity and its effect on the t-tests. The sample correlations between the regression coefficients for six lags are presented in Table 21.

The correlation matrix indicates significant correlation between the coefficients at adjacent lags. This could seriously distort the signs of the coefficients and the significance tests.

The overall results and the knowledge of problems associated with multicollinearity suggest the use of more robust techniques such as a Box-Jenkins filter or a Haugh filter. As mentioned in Chapter 2, the advantage of these methods is their ability to reduce multicollinearity and spurious correlations. In Chapter 3 it was also pointed out to the significant effects of differencing operations on the sample distributed lags and the degree of multicollinearity. The use of non-stationary series instead of stationary series was one of the important reasons for the biased results in the case of the inflation rate-interest rate relationship. The same biases can also be expected when analyzing the money supply-interest rate relationship if proper differencing operations are not used. As mentioned in Chapter 3, Granger test differences the data

Table 21

The Correlation Between the Regression Coefficients

	1	2	3	4	5	6
1	1.00					
2	-0.87	1.00				
3	0.07	-0.54	1.00			
4	0.06	0.05	-0.53	1.00		
5	0.05	-0.01	0.02	-0.54	1.00	
6	-0.04	0.07	-0.02	0.03	-0.56	1.00

and transforms the series into an approximate stationary form prior to regressing the series on other series. the sample cross-correlation functions are estimated by applying the Haugh and the Box-Jenkins filters; then the results of the Granger test are reported and compared with the results of the Gibson test. The sample cross-correlation function estimated after applying the Box-Jenkins filter is presented in Table 22. The sample cross-correlation function estimated after applying the Haugh filter is reported in Table 23.

The cross-correlation functions estimated by these two filters are similar. This similarity is better illustrated visually in Diagrams 8 and 9. The Haugh filter has a downward bias in the estimation of the coefficients as noted in Chapter 3. The comparison of these cross-correlation patterns with the results of the Gibson test indicates a significant underestimation of causal feedback by the Gibson method. This underestimation is related to the statistical problems mentioned above. Also the peak value at the fifth month found in the regression of interest rates on the money supply is not confirmed by the other filtering methods and suggests a spurious correlation due to correlation between the vectors of coefficients in different causal directions.

The empirical lag structure suggested by the Gibson test is radically different than the empirical lag

Table 22

Sample Cross-Correlation Function After Using the Box-Jenkins Filter

Series 1: Nominal money supply prewhitened by:

$$(1-0.14B^{6})(1-B)(1-B^{12})M_{t} = (1+0.26B)(1+0.08B^{9}-0.65B^{12})a_{t}$$

Series 2: Nominal Interest Rate filtered by:

$$(1-0.14B)(1-B)(1-B^{6})M_{t} = (1+0.26B)(1+0.08B^{9}-0.65B^{12})a_{t}$$

	Series 2 on Lags of Series 1		Series 1 on Lags of Series 2	
Lag	0	0.15*	0	0.15*
	1	0.29*	1	-0.11
	2	0.14*	2	-0.24*
	3	-0.01	3	-0.06
	4	-0.02	4	-0.09
	5	0.09	5	-0.16*
	6	0.07	6	-0.12*
	7	0.03	7	0.05
	8	-0.05	8	0.15*
	9	0.08	9	0.07
	10	0.18*	10	0.02
	11	-0.01	11	-0.02
	12	-0.06	12	-0.01
	13	-0.17*	13	0.04
	14	-0.01	14	-0.06
	15	0.13*	15	0.03
	16	-0.01	16	0.00
	17	-0.01	17	-0.01
	18	0.17*	18	0.00
	19	0.22*	19	-0.02
	20	0.05	20	-0.08
	21	-0.01	21	0.00
	22	-0.14	22	0.02
	23	0.06	23	-0.10
	24	-0.09	24	0.06
	25	-0.07	25	0.03
	26	-0.01	26	0.05
	27	0.05	27	0.09
	28	0.01	28	-0.09
	29	-0.04	29	0.04
	30	-0.01	30	-0.04

Note: The coefficients marked with asterisks are statistically significant at the 95% level. The standard deviation of all the coefficients is 0.06.

Table 23

Sample Cross-Correlation Function After Using the Haugh Filter

Series 1: Money supply prewhitened by:

$$(1-0.14B^6)(1-B)(1-B^{12})M_t = (1+0.26B)(1+0.08B^9-0.65B^{12})a_t$$

Series 2: Interest Rate prewhitened by:

$$(1+0.22B^6)(1-B)R_t = (1-0.42B)a_t$$

	Series 2 on Lags of Series 1		Series 1 on Lags of Series 2	
Lags	0	0.10	0	0.10
	1	0.29*	1	-0.08
	2	0.09	2	-0.20*
	3	-0.07	3	-0.06
	4	-0.06	4	-0.08
	5	0.07	5	-0.22*
	6	0.03	6	-0.20*
	7	0.01	7	0.04
	8	-0.06	8	-0.16*
	9	0.07	9	0.05
	10	0.18*	10	-0.02
	11	0.00	11	-0.01
	12	-0.04	12	-0.05
	13	-0.08	13	0.06
	14	0.01	14	-0.04
	15	0.15*	15	0.03
	16	0.07	16	0.01
	17	0.00	17	-0.06
	18	0.15*	18	-0.01
	19	0.14	19	-0.04
	20	0.00	20	-0.08
	21	-0.09	21	-0.02
	22	-0.12	22	-0.04
	23	0.09	23	-0.06
	24	-0.05	24	0.00
	25	0.03	25	0.03
	26	0.02	26	-0.01
	27	0.08	27	0.07
	28	0.02	28	-0.09
	29	0.00	29	0.02
	30	-0.03	30	-0.03

Note: The coefficients marked with asterisks are statistically significant at 95% level. The standard deviation of all the coefficients is equal to 0.06.

Diagram 8. The Cross-Correlation Function after Applying Box-Jenkins Filter

```
                                I
 -36   0.01            +  I  +
 -35  -0.05            + XI  +
 -34  -0.05            + XI  +
 -33   0.02            +  IX +
 -32   0.04            +  IX +
 -31  -0.05            + XI  +
 -30  -0.04            + XI  +
 -29   0.04            +  IX +
 -28  -0.09            +XXI  +
 -27   0.09            +  IXX+
 -26  -0.05            + XI  +
 -25   0.03            +  IX +
 -24   0.06            +  IX +
 -23  -0.10            XXXI  +
 -22   0.02            +  IX +
 -21   0.00            +  I  +
 -20  -0.08            +XXI  +
 -19  -0.02            +  I  +
 -18   0.00            +  I  +
 -17  -0.01            +  I  +
 -16  -0.00            +  I  +
 -15   0.03            +  IX +
 -14  -0.06            + XI  +
 -13   0.04            +  IX +
 -12  -0.01            +  I  +
 -11  -0.02            + XI  +
 -10   0.02            +  IX +
  -9   0.07            +  IXX+
  -8   0.15            +  IXX+X
  -7   0.05            +  IX +
  -6  -0.12            XXXI  +
  -5  -0.16           X+XXI  +
  -4  -0.09            +XXI  +
  -3  -0.06            + XI  +
  -2  -0.24         XXX+XXI  +
  -1  -0.11            XXXI  +
   0   0.15            +  IXX+X
   1   0.25            +  IXX+XXX
   2   0.14            +  IXX+X
   3  -0.01            +  I  +
   4  -0.02            +  I  +


   5   0.09            +  IXX+
   6   0.07            +  IXX+
   7   0.03            +  IX +
   8  -0.05            + XI  +
   9   0.08            +  IXX+
  10   0.18            +  IXX+X
  11  -0.01            +  I  +
  12  -0.06            +XXI  +
  13  -0.17           X+XXI  +
  14  -0.01            +  I  +
  15   0.13            +  IXXX
  16  -0.01            +  I  +
  17  -0.01            +  I  +
  18   0.17            +  IXX+X
  19   0.22            +  IXX+XXX
  20   0.05            +  IX +
  21  -0.11            XXXI  +
  22  -0.14            XXXI  +
  23   0.06            +  IXX+
  24  -0.09            +XXI  +
  25  -0.07            +XXI  +
  26  -0.01            +  I  +
  27   0.05            +  IX +
  28   0.01            +  I  +
  29  -0.04            + XI  +
  30  -0.01            +  I  +
  31  -0.05            + XI  +
  32   0.05            +  IXX+
  33  -0.02            +  I  +
  34   0.04            +  IX +
  35  -0.06            +XXI  +
  36   0.04            +  IX +
```

Diagram 9. The Cross-Correlation Function after Applying Haugh Filter

```
                                   I
 -36  -0.02                  +   XI  +
 -35  -0.10                  +    I  +
 -34  -0.08                  +XX I  +
 -33  -0.01                  +    I  +
 -32   0.06                  +    IX +
 -31  -0.06                  +   XI  +
 -30  -0.06                  +   XI  +
 -29   0.02                  +    IX +
 -28  -0.09                  +XXI    +
 -27   0.06                  +    IXX+
 -26  -0.03                  +   XI  +
 -25   0.02                  +    IX +
 -24  -0.00                  +    I  +
 -23  -0.07                  +XXI    +
 -22  -0.04                  +   XI  +
 -21  -0.01                  +    I  +
 -20  -0.06                  +XXI    +
 -19  -0.03                  +   XI  +
 -18  -0.00                  +    I  +
 -17  -0.05                  +   XI  +
 -16   0.02                  +    I  +
 -15   0.02                  +    I  +
 -14  -0.06                  +XXI    +
 -13   0.05                  +    IX +
 -12  -0.06                  +   XI  +
 -11  -0.02                  +   XI  +
 -10  -0.03                  +   XI  +
  -9   0.06                  +    IX +
  -8   0.18                  +    IXX+XX
  -7   0.05                  +    IX +
  -6  -0.19                XX+XXI    +


  -5  -0.21                XX+XXI    +
  -4  -0.08                  +XXI    +
  -3  -0.05                  +   XI  +
  -2  -0.19                XX+XXI    +
  -1  -0.08                  +XXI    +
   0   0.10                  +    IXX+
   1   0.30                  +    IXX+XXX
   2   0.09                  +    IXX+
   3  -0.07                  +XXI    +
   4  -0.06                  +XXI    +
   5   0.07                  +    IXX+
   6   0.05                  +    IX +
   7   0.02                  +    I  +
   8  -0.06                  +   XI  +
   9   0.08                  +    IXX+
  10   0.18                  +    IXX+XX
  11   0.00                  +    I  +
  12  -0.05                  +   XI  +
  13  -0.09                  +XXI    +
  14   0.01                  +    I  +
  15   0.16                  +    IXX+X
  16   0.06                  +    IXX+
  17  -0.00                  +    I  +
  18   0.16                  +    IXX+X
  19   0.14                  +    IXX+X
  20  -0.00                  +    I  +
  21  -0.05                  +XXI    +
  22  -0.13                  XXXI    +
  23   0.09                  +    IXX+
  24  -0.05                  +   XI  +
  25   0.03                  +    IX +
  26  -0.00                  +    I  +
  27  -0.05                  +    IXX+
  28   0.02                  +    I  +
  29  -0.00                  +    I  +
  30  -0.02                  +   XI  +
  31  -0.08                  +XXI    +
  32   0.07                  +    IXX+
  33  -0.05                  +   XI  +
  34   0.03                  +    IX +
  35  -0.07                  +XXI    +
  36   0.06                  +    IX +
```

structure suggested by filtering techniques. A similar conclusion was noted in Chapter 3 in the analysis of the nominal interest rates-inflation rate relationship. The use of differencing operations on both series yielded an empirical lag structure more similar to the one derived by the use of filtering techniques. The validity of the same approach in the case of the money-interest rate relationship is tested by using the Granger test. Interest rates are first differenced. Nominal money supply is transformed into an approximate stationary form by both first and seasonal differencing. The use of seasonal differencing is suggested by the application of univariate time-series analysis to the nominal money supply series. This analysis indicated a seasonal non-stationarity as a result of the trend in the seasonal correlations of nominal money supply. Logarithmic transformations are also applied to both series to transform the data into variance-stationary form. Table 24 presents the results of regressing nominal interest rates on the current and lagges values of nominal money supply after transforming both series into a stationary form by the aforementioned operations. Table 25 reverses the causal order and regresses the nominal money supply on current and lagged values of nominal interest rates. The comparison of empirical lag distributions estimated by the Gibson test, the Granger test, the Haugh filter and the

Table 24

Results of the Granger Test

Dependent Variable		Coefficients on Lagged M1		
Interest Rate	0	1.30(1.73)	19	2.10(2.27)
	1	3.18(4.13)	20	-0.36(0.38)
	2	-0.42(0.53)	21	-0.77(0.82)
	3	-2.16(2.73)	22	0.04(0.05)
	4	-0.02(0.02)	23	2.44(2.57)
	5	1.69(2.13)	24	-1.43(1.42)
	6	-0.34(0.42)	25	0.21(0.25)
	7	-0.40(0.49)	26	0.38(0.45)
	8	-0.04(0.05)	27	0.60(0.71)
	9	1.77(2.17)	28	-0.17(0.20)
	10	1.10(1.34)	29	-0.11(0.13)
	11	-0.58(0.70)	30	0.15(0.18)
	12	0.55(0.57)	31	1.17(1.40)
	13	0.54(0.58)	32	0.09(0.10)
	14	-0.25(0.28)	33	-1.10(1.28)
	15	-0.23(0.26)	34	0.16(0.19)
	16	0.51(0.56)	35	0.86(1.00)
	17	-0.19(0.20)	36	0.21(0.24)
	18	0.67(0.72)		
	$R^2 = 0.43$			

Note: The values in parenthesis are t-statistics for testing H_O: $\beta_i = 0$.

Table 25

Testing Causal Feedback by the Granger Method

Dependent Variable		Coefficients on Lagged Interest Rate		
M1	0	0.010(1.73)	19	0.003(0.60)
	1	-0.008(1.31)	20	-0.005(1.04)
	2	-0.024(3.93)	21	-0.010(1.89)
	3	-0.002(0.33)	22	-0.003(0.60)
	4	-0.008(1.39)	23	0.001(0.12)
	5	-0.016(2.55)	24	-0.011(1.95)
	6	-0.011(1.80)	25	-0.002(0.42)
	7	0.007(1.13)	26	-0.001(0.28)
	8	-0.007(1.06)	27	0.001(0.16)
	9	-0.007(1.16)	28	-0.008(1.56)
	10	0.006(1.04)	29	0.001(0.23)
	11	-0.007(1.12)	30	-0.007(1.29)
	12	-0.008(1.46)	31	-0.001(0.32)
	13	0.001(0.08)	32	0.004(0.90)
	14	-0.002(0.44)	33	-0.009(1.76)
	15	0.004(0.74)	34	-0.004(0.84)
	16	-0.010(1.90)	35	-0.001(0.18)
	17	-0.011(1.97)	36	-0.003(0.62)
	18	0.001(0.14)		
	$R^2 = 0.75$			

Note: The values in parenthesis are t-statistics for testing H_o: $\beta_i = 0$.

Box-Jenkins filter are presented in Table 26. The table reports the significant correlations between the current values of the dependent variable and the lagged values of independent variables at 95% level of significance. The signs in parenthesis are the observed signs of correlation between the variables.

The results indicate a relatively close similarity between the empirical lag distributions estimated by the Box-Jenkins filter, the Haugh filter and the Granger test. The minor differences concerning the signs or the location of significant lags may be related to the remaining spurious correlations or sample fluctuations. The Granger test gives more compatible results with the other filtering techniques than the Gibson test. This result can be related to a decrease in the degree of multicollinearity when stationary data are used. The correlation coefficients of the first six lagged variables are presented in Table 27 to test this hypothesis.

A comparison of Table 27 with Table 21 clearly illustrates a substantial reduction in the correlations between the coefficients following the use of proper differencing operations in the vector autoregressive regressions.

Another important technical question is the possible effect of the seasonal differencing operation on the empirical distributed lag structure. First differencing is a frequently used operation in the empirical literature

Table 26

Significant Lags

Causal Direction: M ---> R

Gibson test:	0(-),2(-),4(-),5(+),6(-),8(-),26(-),27(+),28(-)
Granger test:	1(+),3(-),5(+),9(+),19(+),23(+),36(+)
Box-Jenkins:	0(+),1(+),2(+),10(+),13(-),18(+),19(+),22(-)
Haugh:	1(+),10(+),15(+),18(+),19(+),22(-)

Causal Direction: R ---> M

Gibson test:	2(+)
Granger test:	2(-),5(-),17(-),24(-)
Box-Jenkins:	2(-),5(-),6(-),8(+)
Haugh:	2(-),5(-),6(-),8(+)

Table 27

Correlation Coefficients of the Granger Test

	1	2	3	4	5	6
1	1.00					
2	0.05	1.00				
3	0.04	0.28	1.00			
4	-0.01	-0.04	0.28	1.00		
5	-0.05	-0.02	0.03	0.28	1.00	
6	0.00	-0.05	-0.02	0.04	0.28	1.00

Note: The remaining lags show a similar correlation structure. Only the first six lags are reported.

On the other hand, seasonal differencing is rarely used in the regression studies and its effects on the empirical lag structure is a relatively unexplored area. Table 28 compares the empirical lag distributions estimated by the Granger test using seasonal differencing with the Granger test not using seasonal differencing.

The correlation coefficients of the first six lags associated with the Granger test without seasonal differencing are reported in Table 29.

Table 28 illustrates the difference between the empirical lag distributions. The fact that this difference in empirical lag distributions may be related to a different correlation structure between the lagged variables is evident when Table 29 is compared with Table 27. The lag structure estimated without using seasonal differencing shows a recurrent pattern with the significant lags located two months apart. The fact that this pattern can be related to spurious correlations receives additional support from the analysis of Table 29. The highest correlations between the variables in Table 29 is not between the lagged variables at adjacent lags as in the other cases but between the lagged variables located two months apart. The available evidence supports the hypothesis that this fact is the result of a bias introduced by the trend in the seasonal terms.

These results strongly indicate that the use of vector autoregressive regressions may lead to similar

Table 28

The Effect of Seasonal Differencing on Lag Structure

Causal Direction: M ---> R

Granger with seasonal differencing:	1(+),3(-),5(+),9(+),19(+),23(+),36(+)
Granger without seasonal differencing:	1(+),3(-),5(+),9(+),13(-),15(+),17(-),19(+),21(-),23(+),24(-),35(-),36(-)

Causal Direction: R ---> M

Granger with seasonal differencing:	2(-),5(-),17(-),24(-)
Granger without seasonal differencing:	2(-),5(-),30(-)

Table 29

Correlation Coefficients Without Seasonal Differencing

	1	2	3	4	5	6
1	1.00					
2	0.05	1.00				
3	-0.35	0.05	1.00			
4	0.24	-0.35	-0.05	1.00		
5	-0.14	0.24	-0.35	-0.05	1.00	
6	-0.17	-0.14	0.24	-0.35	0.05	1.00

results with the filtering methods regarding the direction of causality and the empirical lag structure if the proper differencing operations are used. The incompatibility between the results of these techniques reported in the literature, as in the case of money-income studies, may be due to shortcomings in the transformation of the data into stationary form. The increasing similarity between the empirical lag distributions when the data is properly transformed into stationary form is encouraging from the viewpoint of empirical consistency between the results.

The empirical results obtained so far use nominal money supply. An important question is the response of nominal interest rates to a change in the real money supply instead of the nominal money supply. This question is analyzed below. The real money supply series is constructed by dividing the nominal money supply by the price index of the same month. The cross-correlation pattern is estimated by using a Box-Jenkins filter. The empirical results are presented in Diagram 10.[4] A comparison of Diagram 10 with Diagram 8 clearly illustrates the similarity of the empirical lag distributions in case of using real money supply versus the nominal money supply. This similarity is better illustrated in Table 30.

---

[4] Other methods have also been used for empirical analysis. The reported results are restricted to Box-Jenkins filter only for the sake of brevity but the results of the other methods are not different than the conclusions reported here.

Diagram 10. The Cross-Correlation Function Between Nominal Interest Rates and Real Money Supply after Using Box-Jenkins Filter

```
                                     I
-36   0.05                          +  IX +
-35  -C.03                          + XI  +
-34  -0.05                          + XI  +
-33   0.04                          +  IX +
-32   0.02                          +  IX +
-31  -0.C4                          + XI  +
-3C  -0.04                          + XI  +
-29   0.05                          +  IX +
-28  -0.08                          +XXI  +
-27   0.11                          +  IXXX
-26  -0.05                          + XI  +
-25   0.06                          +  IXX+
-24   0.08                          +  IXX+
-23  -0.16                         X+XXI  +
-22   0.03                          +  IX +
-21  -0.C3                          + XI  +


-20  -0.11                          XXXI  +
-19  -0.01                          +  I  +
-18  -0.02                          +  I  +
-17  -0.02                          + XI  +
-16   0.0C                          +  I  +
-15   0.03                          +  IX +
-14  -0.09                          +XXI  +
-13  -0.C2                          +  I  +
-12  -0.03                          + XI  +
-11  -0.08                          +XXI  +
-10  -0.C1                          +  I  +
 -9   0.06                          +  IX +
 -8   0.12                          +  IXXX
 -7   0.05                          +  IX +
 -6  -0.09                          +XXI  +
 -5  -0.15                         X+XXI  +
 -4  -0.12                          XXXI  +
 -3  -0.04                          + XI  +
 -2  -0.28                      XXXX+XXI  +
 -1  -0.11                          XXXI  +
  0   0.10                          +  IXXX
  1   0.22                          +  IXX+XXX
  2   0.21                          +  IXX+XX
  3  -0.01                          +  I  +
  4   0.02                          +  IX +
  5   0.05                          +  IX +
  6   0.07                          +  IXX+
  7  -0.02                          + XI  +
  8  -0.06                          +XXI  +
  9   0.08                          +  IXX+
 10   0.18                          +  IXX+X
 11   0.02                          +  IX +
 12  -0.00                          +  I  +
 13  -0.12                          XXXI  +
 14   0.03                          +  IX +
 15   0.14                          +  IXX+X
 16  -0.06                          + XI  +
 17  -0.03                          + XI  +
 18   0.14                          +  IXX+X
 19   0.2C                          +  IXX+XX
 20   0.05                          +  IX +
 21  -0.08                          +XXI  +
 22  -0.C9                          +XXI  +
 23   0.10                          +  IXXX
 24  -0.03                          + XI  +
 25  -0.08                          +XXI  +
 26   0.03                          +  IX +
 27   0.05                          +  IX +
 28   0.C4                          +  IX +
 29  -0.01                          +  I  +
 3C   0.01                          +  I  +
 31  -0.04                          + XI  +
 32   0.07                          +  IXX+
 33  -0.02                          +  I  +
 34   0.03                          +  IX +
 35  -0.06                          +XXI  +
 36   0.05                          +  IX +
--
```

Table 30

The Significant Lags Using Real Versus Nominal Money Supply

Causal Direction: R ---> M

Using Nominal Money Supply: 2(-),5(-),6(-),8(+)
Using Real Money Supply: 2(-),5(-),8(+)

Causal Direction: M ---> R

Using Nominal Money Supply: 0(+),1(+),2(+),10(+),13(-),15(+),18(+),19(+)
Using Real Money Supply: 1(+),2(+),10(+),15(+),18(+),19(+)

The nearly identical pattern of empirical lag structures in both causal directions is an important result since it indicates that the nominal component of the money supply does not play any significant role in the relation between the money supply and nominal interest rates.

This result suggests that changes in nominal interest rates are determined by the movements in thereal money supply and the price movements do not have any significant effect on this relation. Conversely, the changes in nominal interest rates affect the movements in both real and nominal money supply in a similar manner. These results confirm the hypothesis that the substitution relations between the bond and money markets are neutral to price movements and point out to the absence of money illusion in the portfolio decisions of economic agents.

Interpretation of the Results

Several major conclusions can be drawn from the empirical results. First, there is a significant short-run feedback from nominal interest rates to the money supply (M1). Most of the adjustment to the feedback effect takes place in the first two quarters and starts in the second month following the innovation. The sign of the coefficients suggest a negative response of M1 to past rates of change in nominal interest rates. The statistical validity of this short-run feedback is also confirmed by the results of the Haugh independence test.

The results are reported in Table 31. The results imply a long-run effect of M1 on nominal interest rates extending back to 8 quarters. There is statistically significant feedback from interest rates to M1. The feedback is significant only in the first two quarters and not beyond.

Second, the monetarist view advocates a long-term positive relation between the money supply and interest rates. According to Friedman (1961) and others, a continuous and accelerating increase in M1 is the major cause of an accelerating inflation rate. The acceleration of the inflation rate leads to an upward adjustment of inflationary expectations. This expectation of higher prices on the basis of the past movements in the price level induces market participants to put an inflationary premium on the real rates, and nominal rates increase by an amount equal to the inflationary premium. The argument is a revival of the Fisher hypothesis, but it relates the source of inflationary expectations to increases in the money supply. This explanation requires the observation of at least two statistical results. The first is the observation of a positive response of nominal interest rates to a change in the money supply. The second is a relatively long lag between money and interest rate. Both requirements are satisfied by a statistical evidence. The sample cross-correlations support the hypothesis by giving statistical evidence of a positive correlation at a six-quarter lag. The sample cross-correlation functions with

Table 31

Haugh-Pierce Test

I) Test of Ml ---> R

Lag	S-statistic	X-statistic	Stochastic Dependence
0-6	31.09	12.6	Accepted
0-12	43.55	21.0	Accepted
0-24	75.39	36.4	Accepted
0-36	84.47	43.8	Accepted
24-36	9.08	21.0	Rejected
II) The test of R ---> M			
0-6	42.88	12.6	Accepted
6-12	9.55	21.0	Rejected
12-24	13.72	21.0	Rejected
24-36	9.08	21.0	Rejected

both filters give significant spikes at eighteen and nineteen month lags. This evidence suggests a mean lag of approximately six quarters which is consistent with the findings of Friedman (1961) who found a mean lag of six quarters from money to income in testing the monetarist argument.

Finally, most of the cross-correlation pattern is dominated by short-run (one to two quarters) positive and negative feedback between M1 and nominal interest rates. This result gives additional support to the hypothesis which was put forward in Chapter 3. If short-run expectational behavior depends on a broad spectrum of signals which simultaneously affects the decisions and behaviors of market participants in all major markets, we would expect to observe short-run positive and negative feedback among all the major variables that impact these markets. The similar short-run positive and negative feedback observed in both money-interest rate and inflation rate-interest rate relationships strongly favor this hypothesis as a consistent explanation of the statistical results. A final test of the argument is to test if the cross-correlation in short-run can be explained as the cross-correlation of the innovation terms. This test is undertaken in the next section by estimating a multivariate model.

Multivariate Model

A multivariate model containing the inflation rate and nominal interest rates was presented in Chapter 3. The estimated model implied a cross-correlation between the innovations of the variables. This result was the empirical basis of the statements in the conclusion part of the chapter. A similar structure is expected in a generalized model including the money supply if the statements of Chapter 3 are valid in the money markets. If the relationship between money and interest rates is determined in the short-run in a similar manner as the relation between the inflation rate and interest rates, we expect to observe the following: (a) a very short-run response of nominal interest rates to the changes in the money supply; (b) a short-run causal feedback from interest rates to the money supply; (c) the ability to explain the observed short-run cross-correlations as the cross-correlations of innovation terms in a structural model. Observations a and b are supported by the empirical evidence in the previous section. The last observation implies that a moving average representation explains the data more adequately and parsimoniously than the autoregressive representation. This hypothesis is tested.

The estimated multivariate model is a 3x1 vector ARIMA model with inflation rate, nominal rates and real M1 included as variables.[5] The observation period is 1959-1983. All the series are transformed into a stationary form before the estimation by using the aforementioned differencing operations. The estimates are derived by the conditional likelihood method.[6] The final results and diagnostic checking are presented in Table 32. The estimated multivariate model is expected to satisfy two purposes. The first is to find the structural model that best explains the relations between the money supply, nominal interest rates, and the inflation rate. This requires a model which reduces all residual series into an approximate white-noise process. A successful model is expected to transform the residuals of all three series in vector z and also the residuals of all cross-correlations between the variables into random error form. The general form of the models can be either moving average, autoregressive, or a mixture of both. As explained in Chapter

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[5] The use of real M1 instead of nominal M1 is preferred since this distinguishes the effect of the inflation rate from the effect of M1. The cross-correlation function between real M1 and interest rates is found nearly identical to the pattern of the nominal M1-interest rate relation as mentioned before.

[6] The use of the conditional likelihood method instead of exact likelihood method is a choice dictated by cost considerations. The exact likelihood method uses much more computer time than the conditional likelihood method. The cost increases substantially as the number of parameters are increased.

Table 32

Estimation of the Extended Multivariate Model

Series 1: Actual Inflation Rate

Series 2: Nominal Interest Rates

Series 3: Real Money Supply (M1/P)

Method of Estimation: Conditional Likelihood

Matrix Estimates:

PHI 6

$$\begin{bmatrix} -0.414 & 0.001 & -0.004 \\ (0.058) & (0.001) & (0.007) \\ -1.716 & -0.058 & -0.019 \\ (1.148) & (0.054) & (0.445) \\ 0.088 & 0.015 & 0.249 \\ (0.082) & (0.004) & (0.054) \end{bmatrix}$$

THETA 1

$$\begin{bmatrix} \overset{*}{0.614} & -0.0061 & -0.018 \\ (0.060) & (0.002) & (0.016) \\ -6.780 & -0.359 & -2.572 \\ (1.658) & (0.061) & (0.547) \\ 0.044 & 0.005 & -0.309 \\ (0.109) & (0.005) & (0.058) \end{bmatrix}$$

THETA 2

$$\begin{bmatrix} 0.081 & -0.004 & -0.015 \\ (0.059) & (0.002) & (0.016) \\ -0.062 & -0.002 & -1.933 \\ (1.738) & (0.063) & (0.481) \\ 0.054 & 0.023 & -0.219 \\ (0.110) & (0.005) & (0.055) \end{bmatrix}$$

THETA 12

$$\begin{bmatrix} -0.148 & 0.0058 & -0.024 \\ (0.064) & (0.002) & (0.021) \\ -0.590 & -0.034 & 0.319 \\ (1.867) & (0.065) & (0.610) \\ 0.287 & 0.002 & 0.715 \\ (0.134) & (0.005) & (0.046) \end{bmatrix}$$

Note: The a(k) element of each matrix gives the degree of correlation between i and j when series j leads series i. The estimates marked with asterisk are statistically significant.

Table 32 (continued)

Diagnostic Checking of the Residual Cross-Correlation Matrices

---

Lags 1 through 6

```
. . .    . . .    . . .    . . .    . . .    . . .
. . .    . . .    . . .    . . .    + . .    . . .
. . .    . . .    - . .    . . -    - - .    . . .
```

Lags 7 through 12

```
. . .    . . .    . . +    + . .    . . .    . . .
. . .    . . .    . . .    . . .    . + .    . . .
. . .    . . .    . . .    - . .    . . .    . . .
```

Lags 13 through 18

```
. . .    . . +    . . .    . . .    . . .    . . .
. . .    . . .    . - .    . . .    . . .    . . .
. . .    . . .    . . .    . . .    . . .    . . .
```

Lags 19 through 24

```
. - .    + . +    . . .    . . .    . + .    . . .
. . .    . . .    . . .    . . .    . . .    . . .
. . .    . . .    . . -    . . .    . . .    . . .
```

Lags 25 through 30

```
- - .    . . .    . . .    . . .    . . .    . . .
. . .    . . .    . . .    . . .    . . .    . . .
. . .    . . .    . . .    . . .    . . .    . . .
```

Lags 31 through 36

```
. . .    . . .    . . .    . . .    . . .    . . +
. . .    . . .    . . .    . . .    . . .    . . .
. . .    . . .    . . .    . . .    . . .    . . .
```

3, a moving average form can be expressed as an infinite autoregressive process and vice versa (Tiao and Box, 1981). The second purpose is to identify the form of the model that explains the correlations more adequately. If the short-term is more adequately expressed as an autoregressive process, this indicates a structural model determined by the relations between the variables. The moving average form indicates that the observed correlations are the result of the correlations between the innovation terms. From a theoretical point of view, this may signify the existence of random-shocks which affect the commodity, bond and money markets simultaneously.

The final form of the model suggests a mixed pattern. The general form of the model is given in Equation (2) below:

$$2)\quad (I - \underline{\theta} B^{6}) \underline{Z}_t = (I - \underline{\theta}_1 B^{1} - \underline{\theta}_2 B^{2})(I - \underline{\theta}_3 B^{12})$$

The first moving average operator $(1 - B^{1}\underline{\theta}_1 - B^{2}\underline{\theta}_2)$ explains most of the short-run cross-correlations. The fitting of this operator to data transforms the cross-correlation matrices up to lag five into white noise form. The remaining spikes imply that this model is partially inadequate in explaining all the movements of data. Diagnostic checking reveals a relatively good fit in the short-lags but a partially inadequate fit in the longer lags. The inclusion of additional parameters in order to remove the remaining spikes led to an unnecessarily complicated VAR model[7] and had only a marginal effect on the residuals. The estimated VARMA (vector autoregressive-moving average) model in Table 32 has been accepted as a relatively parsimonious and adequate description of data. The remaining spikes of the correlation functions are consistent with the empirical results found in the previous sections such as the long-run negative feedback from the interest rates. The fact that the observed short-run correlations are better represented by the first moving average operator $(1 - \underline{\Theta}_1 B - \underline{\Theta}_2 B^2)$ supports the hypothesis that the observed cross-correlations among the inflation rate, the money supply and nominal interest rates are related to the simultaneous effect of shocks on the system. The explicit form of the model in Table 32 is given below.

2) $X_t = -0.61a_{x(t-1)} - 0.18a_{x(t-2)} - 0.14a_{x(t-3)} + a_{x(t)}$

3) $R_t = 6.87a_{x(t-1)} + 0.35a_{R(t-1)} + 2.57a_{M(t-1)} + 1.83a_{M(t-2)} + a_{R(T)}$

4) $M_t = 0.30a_{M(t-1)} + 0.21a_{M(t-2)} + 0.71a_{M(t-3)} + 0.28a_{x(t-2)} - 0.01R_{t-6} - 0.24M_{t-6} + a_{M(t)}$

---

[7] A VAR (vector autoregressive) model uses only autoregressive operators. This approach is suggested by some authors such as Parzen (1977) and Stokes (1983). Trial estimations with several VAR models led in each case to very complicated autoregressive operators with at least ten or more parameters. The increase in complexity can be explained by the duality theorem mentioned in Chapter 3. In addition, none of these models gave satisfactory results in terms of diagnostic checking.

X_t, R_t, M_t are the actual inflation rate, the nominal interest rate, and the real money supply respectively. $a_{R(k)}$ is the innovation of nominal interest rate and $a_{M(k)}$ is the innovation of the real money supply.

The results summarize the short-term and seasonal determinants of each variable. Equation (3) suggests that the inflation rate is exogenous with respect to the other variables in the system. The inflation rate is determined in the short-run by its own lagged innovations. The declining pattern of the coefficients suggests a typical autoregressive process. The negative signs may indicate a correlation with a variable such as the inflation rate and the innovations are consistent with an interpretation which relates short-run price movements to fluctua-tions in output and income.

Equation (4) implies significant cross-correlations among the innovations of all three variables. This result is consistent with the arguments presented in Chapter 3. It suggests that market participants utilize the signals that also affect the money supply and the inflation rate. This result is expected considering the high-cost of non-adjustment and not utilizing available information quickly in the financial markets. If that is so, this can imply a rational expectation on behalf of market participants which relates the short-run price movements to fluctuation in income rather than the fluctuations in the bond and money markets.

Equation (5) suggests a relatively complicated mechanism that determines the movements in the real money supply. The money supply (M1) is probably not an exogenous variable determined only by the monetary authorities. The lagged innovations that drive the interest rates and the inflation rate play a significant role in determining the short-run movements in the real money supply and suggest a close similarity between the way interest rates and money supply are determined in the short-run. The model also suggests a seasonal correlation between the money supply and the inflation rate at the annual cycle.

Conclusion

The conclusions of this chapter can be summarized in two separate groups. The technical results imply that there are important problems associated with the use of the Gibson test in the determination of causal order. The significant correlations among the regression coefficients and high multicollinearity can lead to serious misjudgments about the population structure. The statistical results indicate that this method can seriously underestimate the extent of the feedback between the series. The estimate of the coefficients in the vector autoregressive regression can however be improved to a great extent by taking the proper steps to transform the data into stationary form. The Granger test gives empirical lag distribution similar to the ones estimates by Haugh and Box-Jenkins filters if appropriate differencing operations are used.

The analytical results suggest that movements in M1 play a significant role in determining nominal interest rates in both the short-run and long-run. The observation of a short-run effect with positive and negative feedback is consistent with Statements Three and Four in Chapter 3. This explanation assumes that aggregate supply shocks can have similar effects on both the bond and money markets. One possible explanation of the short-run cross-correlation between the innovations of M1 and interest rates may be the utilization of the same signals and information in simultaneously determining the short-run behavior in bond and money markets in response to supply shocks. The historical record for the observation period suggests that an important role must be played by the Federal Reserve in determining the short-run behavior. Most of the observation period from 1959 to 1983 is characterized by the interest rate stabilization policies pursued by the Federal Reserve. The statistical results can indirectly indicate such interventions in bond markets. An important result in this regard is the positive short-run response of nominal interest rates to a change in M1. This result is not consistent with either a liquidity effect (Feldstein and Eckstein, 1970) or an overshooting effect (Friedman, 1961) since both explanations require a negative sign. A more consistent explanation can be given by allowing the effects of stabilization policies in the model.

An increase in interest rates causes an intervention by the Federal Reserve in the bond market to stabilize interest rates. The goal of stabilization policy is to exert downward pressure on interest rates. Stabilization can be most effectively achieved through a purchase of bonds in order to put upward pressure on bond prices (and downward pressure on interest rates) in a short period of time. The side effect of bond purchases in the money market is a temporary expansion of the money supply if not encountered by the use of other policy tools such as an offsetting discount rate policy. Even if the other offsetting policies are used, their offsetting effect can be expected to actualize with a longer lag.

The decrease in interest rates as a result of stabilization policy will, on the other hand, change the optimum portfolio of investors and induce them to shift their assets from the bond market to the money market. This creates upward pressure on interest rates through falling demand in the bond market. In other words, there is a lagged short-run crowding out of the demand for bonds by private investors as a result of stabilization policy.

These bits of information can now be put in a more consistent framework in order to explain the short-term positive effect of the money supply on interest rates and the short-run negative feedback from interest rates.

Assume that an initial increase in interest rates is generated by exogenous causes such as aggregate supply shocks or movements in international capital markets. If the Federal Reserve follows an interest rate stabilization policy and decides to prevent the increase and interferes in the bond-market through a purchase of bonds, this can be expected to have an immediate effect on the bond market and cause a decline in interest rates. The purchase of bonds however results in two consecutive effects. The first is the creation of new money through the purchase of bonds by the Federal Reserve which explains the short-run negative correlation (the immediate downward effect on interest rates followed by an increase in the money supply).

The second is the portfolio adjustment effect causing an upward pressure on interest rates. The correlation between an increase in the money supply followed by an increase in interest rates in the short-run can be justified by the upward pressure on interest rates caused by portfolio adjustments. All that is needed to assume theoretically is a portfolio adjustment taking place in a very short period of time. The statistical evidence seems to support such short-run portfolio adjustments and gives short-run correlations between the variables consistent with this approach. This framework can also explain the persistence of short-run lags during the observation period. If the Federal Reserve reinterferes in the bond market to prevent increases in interest rates caused by the portfolio adjustment, the process described above takes a repetitive and self-perpetuating character. This repetitive process, if true, must lead to a short-run periodic cycle of interest rates as a result of stabilization policies and a significant correlation between the interest rates and the money supply at this cycle. This hypothesis is tested in Chapter 5 by spectral techniques.

CHAPTER 5

SPECTRAL ANALYSIS OF INTEREST RATES

Introduction to Spectral Analysis

Most of the empirical work in Chapters 3 and 4 relied on the use of time-domain ARIMA models. The estimation of an ARIMA model requires the initial specification of the model's functional form. The specification process is iterative, and involves some amount of subjective judgment (Engle, 1976).

There are a number of methods, such as frequency-domain analysis, which do not require initial specification, and the estimation of the coefficients is not dependent on the form of the model. The major tool in frequency analysis is the spectrum of a given stochastic process.[1] The spectrum (spectral density function) characterizes the process in terms of the relative importance of different kinds of defining oscillations (Fishman, 1969). The idea originates from the theory of Fourier series which states that all periodic and nonperiodic functions can be expressed as an infinite sum of sine and cosine functions (Andersen, 1971).

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[1] A deterministic series can also have a spectrum. However, the emphasis of this thesis is on stochastic economic series.

Any economic time series that satisfies the condition of stationarity can be analyzed by spectral analysis. The spectral density function is a continuous function whose ordinate is spectral density and horizontal coordinate is frequency. The frequency is related to the period of oscillation by the formula $f = 2 /T$ where f is the frequency and T is the period of oscillation (Jenkins and Watts, 1968).[2]

A peak in the spectral density function corresponds to a periodic component. The spectrum, then, is a method which enables us to classify and define the cycles that contribute to the shaping of the process. A distinct peak in the spectrum identifies a reasonably regular cycle of the variable over time.

The theoretical form of the spectral density function is rarely known. It is estimated from a given sample data by an estimator function called the periodogram (Priestley, 1981). The raw periodogram has statistically undesirable properties and is an inconsistent estimator of the spectral density. The statistical literature on spectral analysis suggests the use of a truncated periodogram. The truncation point corresponds to a certain lag length chosen by the analyst and is called a

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[2] A nonstationary series can be transformed into stationary form using a number of operations such as regular differencing or a logarithmic transformation as mentioned in Chapter 3.

window. Several different kinds of windows are proposed in the literature. The empirical evidence does not decisively favor one window over the other proposed windows (Priestly, 1981). Mathematically the truncation operation is equivalent to a local approach to the global spectral density function.

The spectral density function is closely related to ARMA models. The spectral density function is mathematically related to the autocorrelation function of a series by the following relation:

$$1) \quad h(w) = \frac{1}{2\pi} \sum_{s=-\infty}^{\infty} R(s) \cos(sw)$$

where h(w) is the spectral density function and R(s) is the autocovariance function. The transformation (Fourier transform) implies that there must exist a certain consistency in the results of time-domain and frequency-domain methods (Andersen, 1971); that is, the Fourier transform of the autocovariance function yields the spectral density function.

The auto-spectrum analyzes the periodic components of a given time-series. From the viewpoint of economic analysis, a more important and interesting question is to find the periodic components of a certain relation between two series; that is, a relationship between two series can be decomposed into different periodic components. The technical tool used for this purpose is the cross-spectrum between the series.

Suppose that two variables X and Y are correlated. There is however no reason to expect that the correlation at one frequency band (corresponding to a certain period of oscillation) is exactly the same as the correlation at another frequency band. If two variables are related, then a certain periodic component at a frequency w_1 of X may be caused by a component at the same frequency w_2 of Y. For example, the annual variation in X corresponding to a frequency of 0.5 may be correlated with the annual variation of Y at the same frequency. The degree of correlation need not be the same at all different frequencies. Different components usually have different degrees of correlation. According to the Wiener theorem, the component of X at frequency w_1 can be correlated by the component of Y at w_1 but not by other periodic components of Y (at the frequency bands other than w_1). The diagram which plots the degree of correlation per pair of frequency components against the frequency is called the coherence diagram. This diagram is estimated from the sample data (Granger and Hatanaka, 1964). The coherence is a quantitative measure used to determine the degree of linear cross-correlation along the cycles. Its range changes between zero and one. A high value of coherence (close to unity) shows that variables are strongly correlated along a specific cycle.

If two series are correlated at a frequency band, then they are either instantaneously correlated or one variable leads the other at this frequency band. It is possible that different pairs of components will be time lagged by different amounts (e.g., short-term components can have a different lag than the long-term components). The annual cycle of X may be linearly correlated with the annual cycle of Y and precede this cycle in time. This difference in time (lag at a certain frequency) is called phase. The diagram that plots the phase versus the frequency is called a phase diagram. There is no meaning to the phase if the series are not correlated at a specified frequency band.[3]

A theoretically important question is at what frequencies (periodic cycles) do we expect to see a high correlation (peaks in cross spectrum)? According to the theory of business cycles, most economic time series are dominated by certain cycles. Major business cycle has a time span of six to eight years. We expect some economic time series to show a peak at this cycle with a frequency band around 0.1w. The observation of this cycle frequently poses problems due to the noise from the strong zero-frequency component which corresponds to trend. Also

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[3] The phase diagram theoretically is a very valuable tool to analyze economic relations. The practical applications of the phase diagram however are not well documented. The estimates of the phase values are generally inconsistent and the interpretation of phase diagrams is subjective. An additional problem is the distortion of phase estimates by the commonly used stationarity inducing transformations, such as first differencing (Koopmans, 1974). Given these considerations, phase diagrams are not used in this study.

the duration of business cycles can change over time. This shifts the frequency band and causes a special type of non-stationarity. There is also a minor three-year business cycle with a range of thirty to forty months. The corresponding frequency band is a narrow band centering around 0.2w. An important cycle is the seasonal cycle with an annual (12-month) component and its typical harmonics (with peaks at six-months, four-months, three-months, and two-months). The corresponding frequency band of the harmonics are centered around 0.4w and 0.6w. The frequency bands of the harmonics are centered around 1.2 w, 1.6w, 2.1w and 2.8w. The weekly cycle (if there is one) causes a peak at 2.8 months (corresponding to a frequency band around 2.2w) if the observations are monthly. This frequency band is called Nyquist frequency.

The cross-spectrum is estimated from the sample data since the theoretical distribution is generally unknown. The estimation procedure however can lead to statistical bias if not performed properly. A number of tools are used to increase the reliability of various estimation procedures and the resolvability of the diagram. The raw estimator (periodogram) is a somewhat erratic estimator with undesirable properties. The resolvability and reliability of estimators are enhanced by certain smoothing techniques. There is not a single explicit criterion in the choice of a certain technique, and in most cases the choice depends on the nature of the problem.

The choice of bandwidth or the degree of resolution is important. Resolution is the ability of a spectrum estimate to reveal the fine structure in the spectrum and distinguish all narrow peaks. An unresolved spectrum will tend to merge the adjacent narrow peaks and form one wide peak.

This choice is subject to two conflicting criteria: (1) increasing M (the maximal lag length selected) increases the resolvability and the smoothness of the diagram, and (2) increasing M, however, also increases the variance of the estimates (Grenander uncertainty principle).

A number of trials with M = 30, 50, 100 and 200 were implemented in this study. The trials suggested the choice of M = 100 as an appropriate lag weight for all the cases considered. This value roughly corresponds to N/3 which is advocated as the maximum resolvability value with the acceptable reliability of estimates (Jenkins and Watts, 1968).

The purpose of using spectral techniques in this study can be summarized as follows. The first goal is to derive a descriptive picture of the periodic components that make up the series used in this dissertation. The periodic components of the money-interest rate and the inflation rate-interest rate relationships are described by estimating the cross-spectrum of these variables. The second goal is to test certain hypotheses statistically. The first hypothesis follows from the discussion in Chapter 3. It was argued in Chapter 3 that most of the cross-correlation between the inflation rate and the interest rate is along the trend component in the absence of short-term fluctuations. The spectrum is an appropriate tool to test this hypothesis since it explicitly distinguishes the long-term correlations from the short-term correlations. The trend component corresponds to the value of the spectral density at the zero frequency. The spectrum also gives explicit evidence about the strength of business and seasonal cycles. The hypothesis to be tested predicts weak or zero correlation along the business and seasonal cycles of the interest rate-inflation rate relationships.[4]

The second hypothesis to be tested follows from the discussion in Chapter 4. The discussion in the conclusion of this chapter suggested a periodic movement in interest rates as a result of stabilization policies and accompanying portfolio adjustment effects. If this hypothesis is valid, spectral analysis is expected to give evidence of a short-run cycle in interest rates which cannot be

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[4] This prediction follows from the decomposition of a given relation into four basic components of (a) correlation along trend, (b) correlation along business cycles, (c) correlation along seasonal cycles, and (d) short-term correlations. The correlations in b and c must be weak if the movement along trend is a good predictor of future movements of a variable in the absence of short-run fluctuations.

explained by other known periodic movements such as seasonal cycles. In addition, movements in interest rates and the money supply (M1) must be significantly correlated along this cycle.

Empirical Results

The empirical relationships between the interest rate-inflation rate and the interest rate-money supply have been examined by the spectral techniques in 1953-79 period. Monthly observations are used. The total number of observations (292) comfortably exceeded the minimum number (100) necessary for a reliable estimation. The three series--nominal M1, nominal interest rates, and actual inflation rates--are the observable variables. All the observable series are in the form of first differences of the natural logarithm. This transformation was necessary to achieve stationarity.[5] A Bartlett-type triangular window is used throughout the study.

The auto-spectra of nominal interest rates, inflation rate and nominal M1 are presented in Diagrams 11, 12, and 13 respectively. The auto-spectrum of interest rates

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[5] Another method to eliminate trend and prevent bias in the estimates is a technique called prewhitening suggested by some writers (Fishman, 1969). This method however has been criticized on technical grounds (Amos and Koopmans, 1974) and will not be used in this dissertation. The time-domain techniques used in the previous chapters indicated that first-differencing is sufficient to eliminate the trend in the variables used here.

Diagram 11. The Auto-Spectrum of Nominal Interest Rates

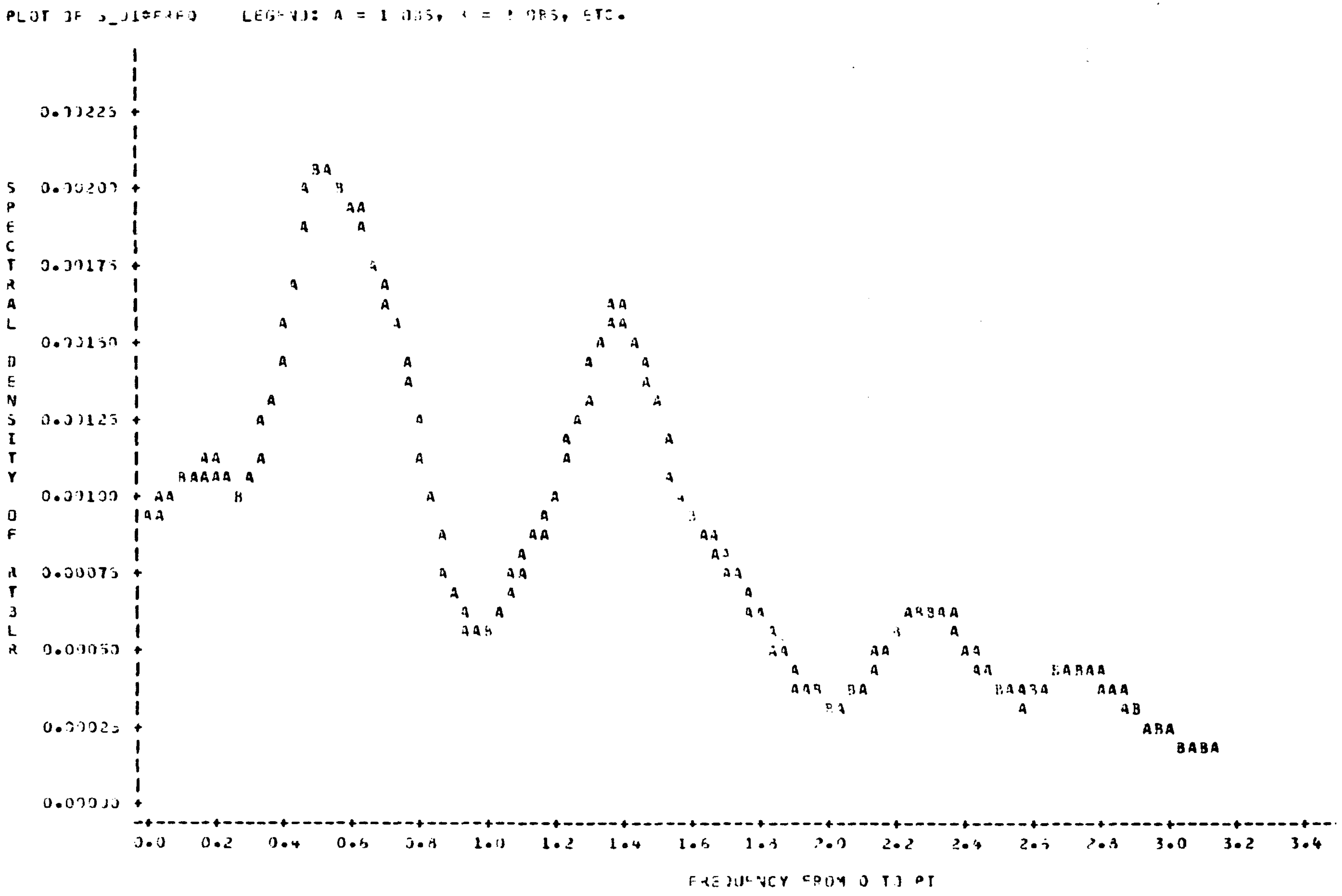


Diagram 12. The Auto-Spectrum of Inflation Rate

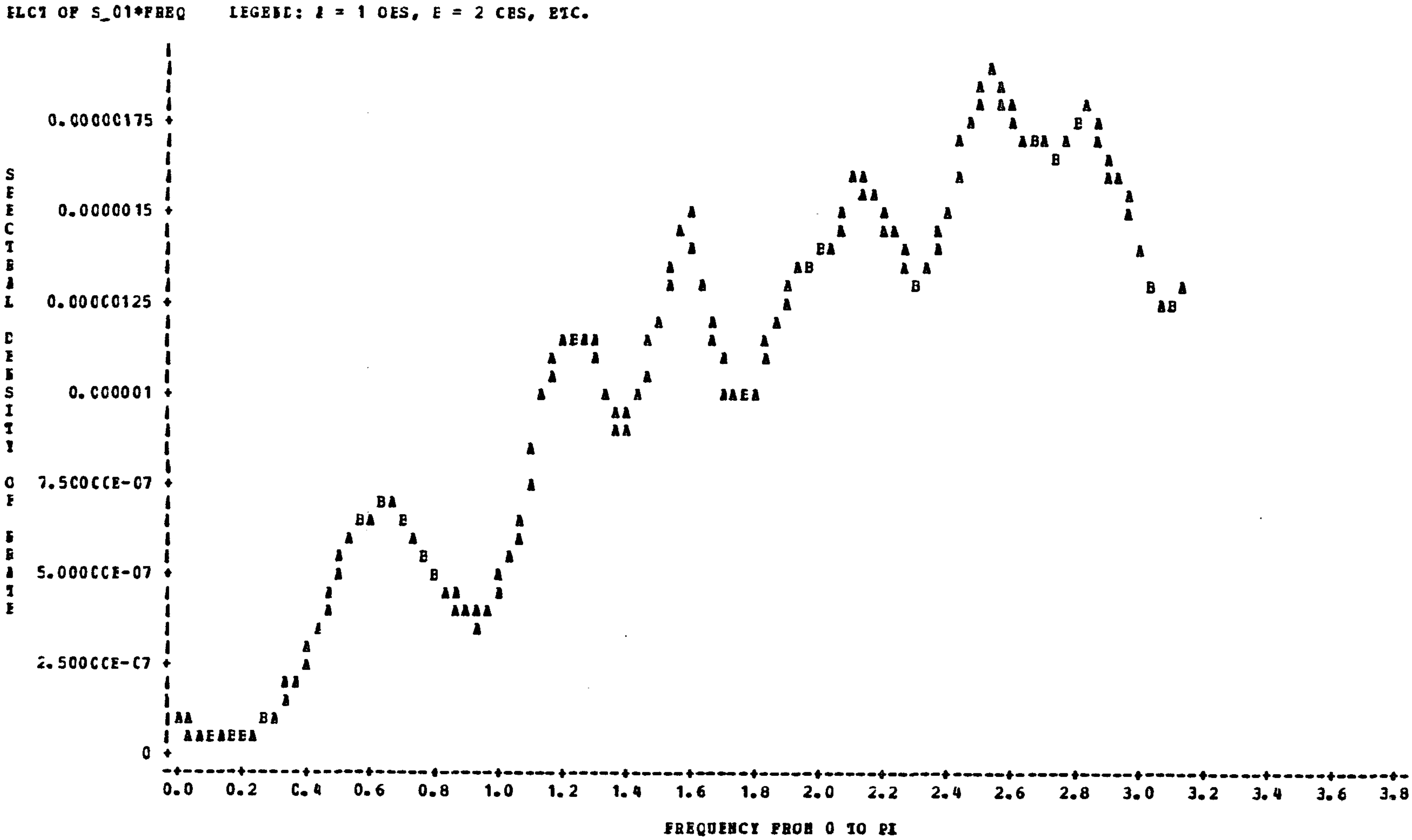
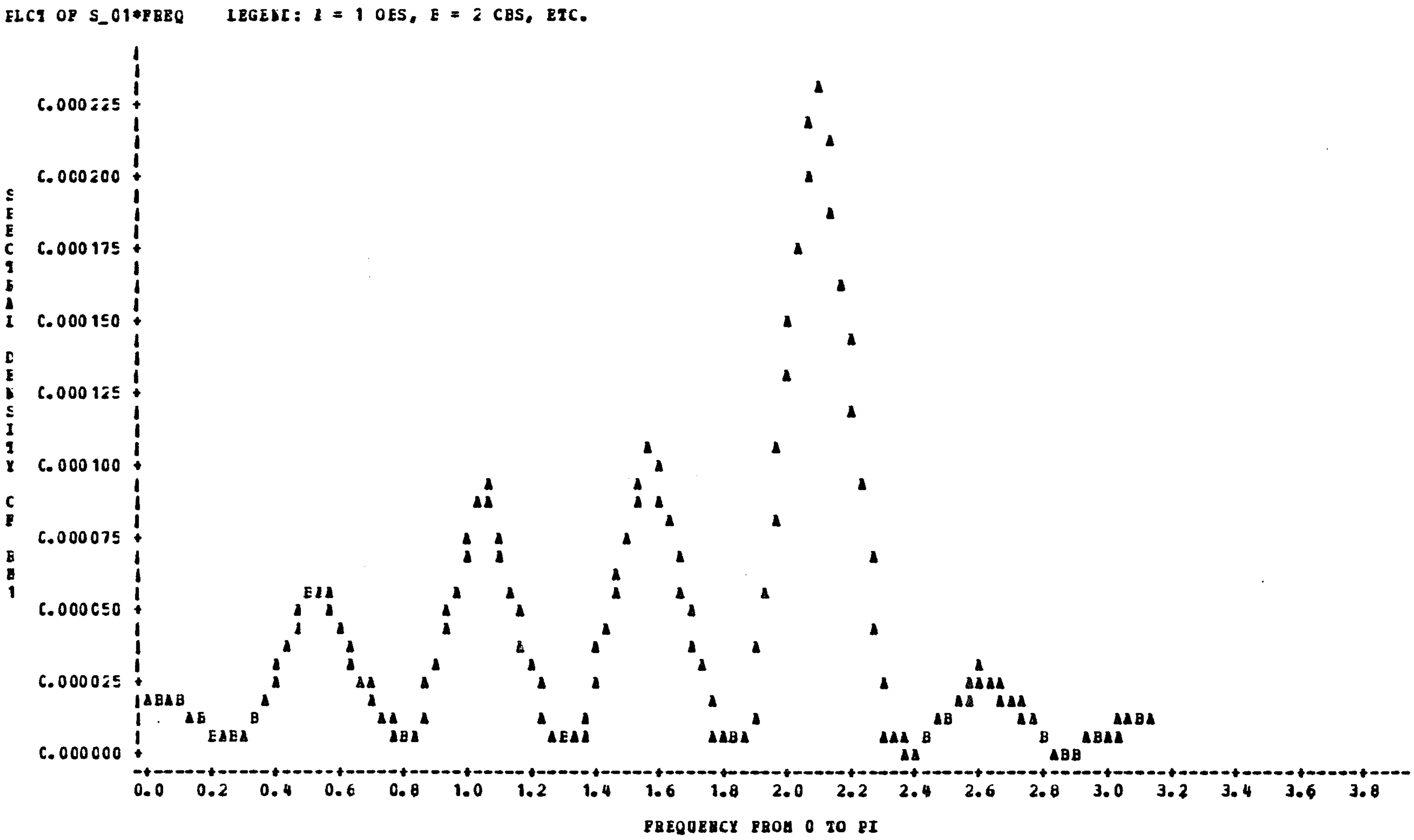


Diagram 13. The Auto-Spectrum of Nominal M1



(Diagram 11) describes the frequency-domain characteristics of this variable.

The significant peak at frequency 2.2w corresponds to the Nyquist frequency and indicates a hidden weekly cycle of interest rates. An interesting outcome is the absence of peaks at the frequencies corresponding to the business cycle and seasonal annual cycle.[6]

The periodic behavior of interest rates at lower frequencies is dominated by a peak centered at frequency 0.7w. This frequency corresponds to a periodic cycle of nine months. The spectral value (0.0009) implies a relatively weak periodic movement. The following peaks centered at frequencies 1.4w and 2.8w are the first and second harmonics of the fundamental frequency 0.7w.[7]

According to the hypothesis, this short-run cycle which cannot be explained as a seasonal movement, is related to a periodic movement in interest rates generated by the stabilization policies of the Federal Reserve. The absence of a seasonal cycle is not surprising if consideration is given to the fact that the coefficients of the seasonal component in time-domain analysis (see Chapter 3,

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[6] The use of other techniques such as prewhitening or a Granger filter did not change this conclusion.

[7] If a series has a genuine peak at a fundamental frequency w, the spectral function also shows peaks at frequencies 2w, 3w, 4w, nw. These frequencies are called the harmonics of the fundamental frequency. This is a mathematical property that follows from the properties of trigonometric functions.

Model 1) were found to have a low significance level. The frequency bands corresponding to a seasonal cycle and nine-month cycle are very close, and a weak seasonal cycle can be hidden by the relatively stronger nine-month cycle.

The auto-spectrum of inflation rate (Diagram 12) suggests a typical annual cycle with a fundamental frequency at approximately 0.6w and its harmonics 1.2w and 1.6w at the expected locations. The cycle with the frequency 2.8w implies a weekly cycle. The inflation rate spectrum does not suggest any movement along the business cycles.

The cross-spectrum between the inflation rate and the nominal interest rate is presented in Diagram 14. The shape of the cross-spectrum implies a dominant peak corresponding to the annual cycle.[8] The observation of the first, second, third and fourth harmonics at the expected frequencies of 1.0w, 1.2w, 2.1w and 2.8w further supports the evidence of a correlation along the annual seasonal cycle. The coherence value (0.35) however implies a significant but weak correlation along this cycle. The approximate confidence intervals at 80% level are between 0.2 and 0.5 (Amos and Koopmans tables, 1963). The weak

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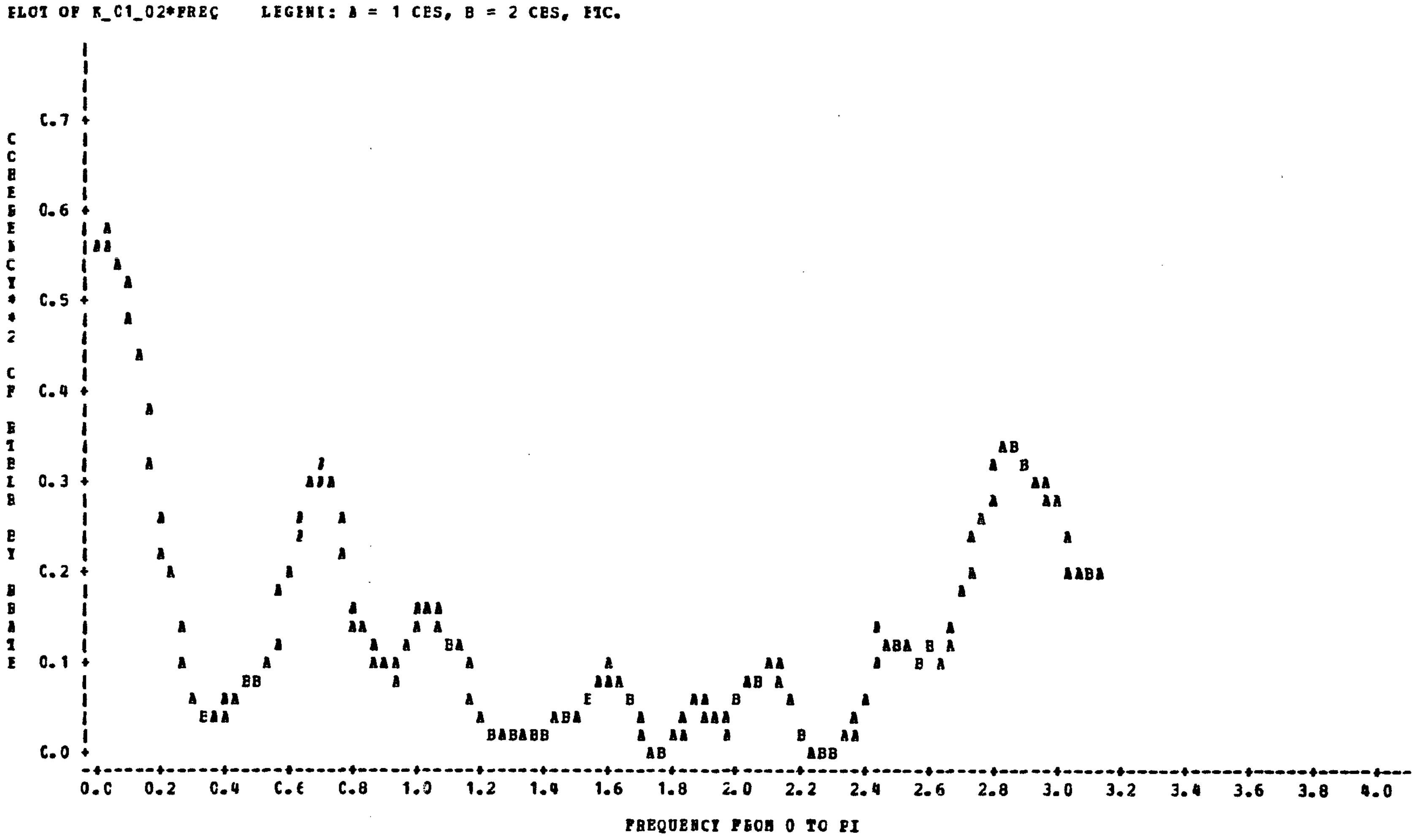
[8] The fundamental frequency is located at almost 0.6w which exactly corresponds to a 10.5 month period. This slight deviation from the expected period (12-month) of an annual cycle can be due to a slight shift in the frequency band and may indicate the effect of first differencing on the estimated cross-spectrum.

Diagram 14. Cross-Spectrum Between Inflation Rate and Interest Rate after De-trending the Series with First Differencing

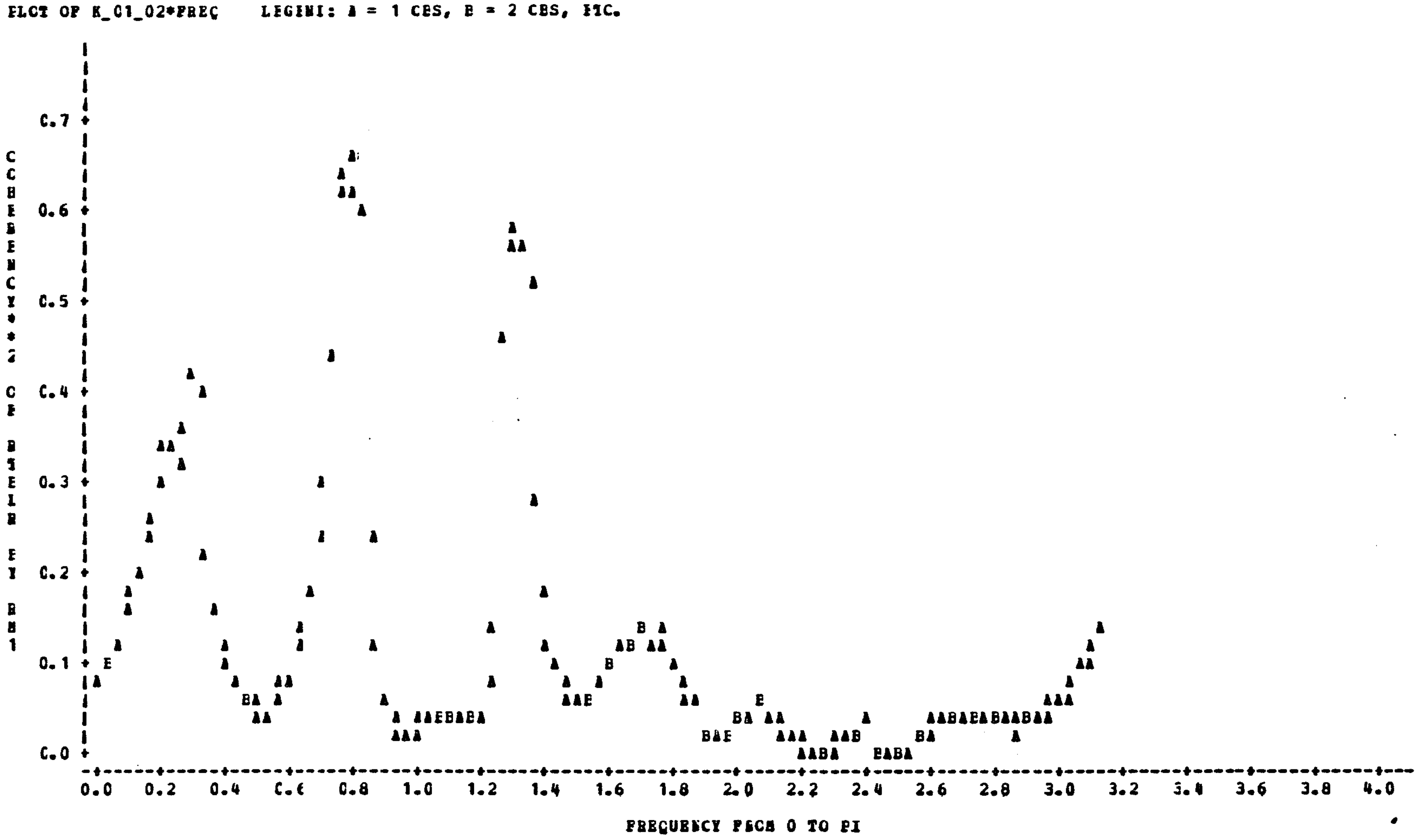


seasonal correlation and no evidence of correlation along the business cycles is a result that is consistent with the expectations hypothesis.

A more direct test of this hypothesis which predicts that most of the cross-correlation between the series is along the trend component is the behavior of zero-frequency component that corresponds to trend. The cross-spectrum between the inflation rate and interest rates is re-estimated without eliminating the trend from the individual series. The diagram indicates a strong correlation along the trend component with a high coherence of 0.6 and suggests a significant correlation along the trend component as expected.

The second hypothesis tested is the empirical evidence concerning a possible short-run cycle created as a result of stabilization policies. So far, indirect tests give some clues in that direction. The auto-spectrum of interest rates has a short nine-month cycle. The M1 prewhitening model suggested a significant B^9 term when the strong seasonality in this series is partially filtered by seasonal differencing. A direct test of the hypothesis is the cross-spectrum between M1 and nominal interest rates presented in Diagram 16. The cross-spectrum is dominated by a major and significant cycle at the frequency band centered around at 0.77 which approximately corresponds to an eight to nine month cycle as

Diagram 15. Cross-Spectrum between M1 and Nominal Interest Rates



expected. The coherence value of 0.6 indicates a significant correlation along this cycle (the confidence intervals are 0.4 to 0.78 at 80% levels; Amos and Koopmans tables). The second significant peak corresponding to a frequency band centered around 1.3w is possibly a slightly shifted first-frequency of the fundamental frequency. A third peak at a frequency band centered around at 0.2w corresponds to a thirty to thirty-five month cycle. This cycle suggests some correlation between M1 and nominal interest rates at the minor business cycles (the coherence value is 0.4).

Conclusion

Spectral techniques give supporting evidence for two statements that were put forward in the previous chapters. They indicate a significant cross-correlation at the zero-frequency and indicate a short-run cycle of nine months. Given the evidence and the arguments of Chapter 4, this cycle suggests typical behavior in M1 and nominal interest rates as a result of stabilization policies.

The correlation among the variables along the business cycles is not significant expect for the relatively significant correlation between M1 and nominal interest rates along the minor business cycles. The inflation rate and M1 series show seasonal movements. The autospectrum of nominal interest rates did not show such a seasonal movement. However, a weak but significant cross-correlation between the seasonal movements of nominal interest rates and the inflation rate suggests that there can be a weak seasonal cycle which is underestimated in the estimation of the spectrum.

CHAPTER 6

SUMMARY AND CONCLUSIONS

The empirical relation of nominal interest rates with the inflation rate and the money supply (M1) for 1953-1983 period has been analyzed in the previous chapters. The conclusions of this study can be grouped under two different headings: (1) technical results and (2) empirical results. Technical results refer to the performance of different causality detection techniques. The Gibson test, the Granger test, the Box-Jenkins filter and the Haugh filter are used to determine (1) the causal order between the variables and (2) the empirical lag distribution between the series.

All of these techniques indicate a significant causality from the inflation rate to nominal interest rates and from the money supply (M1) to nominal interest rates. All techniques used, with the exception of the Gibson test, also show a causal feedback from the inflation rate and the money supply to nominal interest rates. There is strong statistical evidence that the underestimation of causal feedback by the Gibson test is related to the statistical biases and problems associated with this method. The empirical lag distributions estimated by different techniques do not lead to completely identical results. This is expected given the fact that the estimations are inferences about the population using the sample data. There are two crucial problems. The first is the problem of sample fluctuations which cannot be completely avoided. The second problem is the degree of statistical accuracy in the estimates of standard errors which are the basis of significance tests. A complete solution of either of these problems does not seem possible. The overall results however are encouraging given these limitations when these results are compared with the results of other studies using similar tools and especially with the widely disparate results reported in the area of money-income relation.

The cross-correlation functions based on the Haugh and Box-Jenkins filters give significantly similar empirical lag patterns. On the other hand, the considerably different lag pattern suggested by the Gibson test (concerning both the location of significant lags and the signs of significant correlations) is shown to be largely related to severe multicollinearity associated with this method. The Granger test which uses first-differenced and stationary data resulted in a significant reduction of multicollinearity. This is demonstrated by the tables of correlation coefficients between the explanatory variables in Chapters 3 and 4. This is a theoretically anticipated result since first-differencing is a method recommended for the reduction of severe multicollinearity (Kmenta, 1971).

The other important effect of transforming a non-stationary series into stationary form by the use of linear operations such as first differencing is the radical change in the empirical lag distributions following this transformation. The use of stationary series however do not completely justify the use of regression-based techniques such as the Granger test or Sims´ test. Even though the Granger test gives results more compatible with the results of filter-based techniques relative to Gibson test, there is still an uneasy amount of disparity between the empirical lag distributions suggested by these respective techniques. This fact is especially evident in the important lag distribution from the inflation rate to nominal interest rates. The lags suggested by the Granger test are much longer (up to 10 quarters) than the very short lags (up to 2 months) suggested by the filtering techniques. This creates a problem of correctly interpreting the way the expectations are formed and lead to different conclusions about the Fisher hypothesis. No Monte-Carlo experiments comparing these methods have been reported in the statistical literature. There are however a number of reasons to put more faith in the results of filtering techniques. Filtering techniques are specifically designed to eliminate the spurious correlations that may arise from the serial autocorrelations between the error terms. The Granger test is subject to such spurious correlations. There are both empirical and theoretical reasons to support this statement. Empirically, all the series used in this analysis suggested at least significant first-order autocorrelation between the error terms.[1] Theoretically, operations such as first differencing are expected to generate first-order autocorrelation of error terms if such operations are not accompanied by the use of filters (Kmenta, 1971).[2] A second important reason to explain the long lags observed in regression-based methods is related to the fact that regression is a vector autoregressive form. The evidence in Chapters 3 and 4 indicated that the data in this study are represented much more adequately and parsimoniously (using less parameters) by a moving average form. If the true population structure is characterized by a moving average type relation between the variables, the long lags observed in regression may be the result of trying to fit the data

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[1] See the univariate models of the series in Chapters 3 and 4.

[2] In an earlier part of the empirical trials, filters have been applied prior to regressing the series following a procedure advocated by Granger (Granger, 1974). The results are not reported for the sake of brevity. The empirical lag distributions estimated by filtered regressions are completely identical to the distributions found by Haugh filter if separate filters are used. These results further support the validity of arguments above by showing that the observed differernces are not because of using different techniques.

into a vector autoregressive form instead of a moving average form. There is substantial evidence for the moving average form in multivariate time series models. These arguments in my view favor the use of filtering techniques.

The economic implications of the filtering techniques are as follows. The empirical evidence suggests a very short lag of one month between the changes in the actual inflation rate and the following changes in nominal interest rates. This result shows that the market participants utilize the information contained in the past history of inflation rates in assessing the nominal rates of interest as predicted by Fisher. The evidence, however, also indicates that only the information about the very recent price movements are utilized and the information about the price movements is efficiently and quickly incorporated into the nominal rates of interest. The analysis of the empirical relation between the money supply and interest rates indicated a similar short-run response of interest rates to the innovations in money supply. The estimated lag is approximately one quarter. This suggests that the market participants utilize the information in money supply series in addition to price movements and this information is also utilized quickly and efficiently.

Furthermore, the estimated multiple time series models strongly suggest that the market uses an even broader set of signals including political and financial events and the bond, commodity and money markets simultaneously respond to these signals. The expectations are formed by using all possible information in a given time. The decision makers to not only respond to the changes in systematic variables such as inflation rate and money supply but also respond significantly to unsystematic components of information. The unexpected changes as a result of aggregate supply shocks or Federal Reserve Policy changes may also play an important role in the assessment of nominal interest rates.

This interpretation also implies the possibility of explaining the observed Fama effect in an alternative way. The Fama effect is confirmed by the statistical evidence and a positive short-run feedback from interest rates to inflation rate is observed as predicted by Fama (1975). This, however, does not necessarily imply that interest rates on bills are based on assessments of expected future inflation rates as was proposed by Fama. Inflation is only one of the signals utilized by the market participants and the observed feedback is hard to explain by referring to inflation only. The observed correlation between the current interest rates and one-period ahead inflation rate may also be explained as a common response of market participants to the same set of signals in both the commodity and bond markets. The observed lag may be the result of lagged adjustment of commodity markets (with respect to bond market) to new information. The lag in adjustment may reflect the higher premium of new information and the higher cost of not using this information in the bond market.

It is significant in that regard that the empirical results also show a negative feedback from the interest rates to money supply in two to five months with negative sign. It is difficult to judge on the basis of available evidence if this reflects a lagged adjustment of money market or some other phenomenon.

Finally, the frequency-domain characteristics of the relations among the money supply, the inflation rate and nominal interest rates is analyzed by spectral techniques. The spectral analysis suggests that nominal interest rates have a cycle of approximately nine months. The significant correlation between nominal interest rates and the money supply suggests that the money supply movements and possibly the stabilization policies followed by Federal Reserve may play an important role in the creation of this cycle. The available evidence, on the other hand, does not show any strong correlation of interest rates with either the money supply or the inflation rate along the major business cycles. There is, however, a relatively weak correlation between the money supply and nominal interest rates along the minor business cycles.

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VITA

Umit Erol was born on March 16, 1953, in Bursa, Turkey, the son of Muhibbe and Adil Erol. He was graduated from Istanbul University in 1976 with a Bachelor of Science degree in Economics. He was awarded the Master of Science degree in Economics, graduating from Bogazici University, Istanbul in 1978. He came to Louisiana State University in 1980 following two years of Ph.D. study at Istanbul University. He was awarded a Master of Science degree in Finance at Louisiana State University in 1983. His minor area in Ph.D. program of Louisiana State University was Finance. He is currently leaving the United States to return to Turkey.

DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Umit Erol

Major Field: Economics

Title of Dissertation: An Empirical Inquiry Into the Variation of Interest Rates, 1959-1983

Approved:

James A. Richardson
Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

Thomas R. Beard

Thomas R. Gulledge, Jr

Lonnie R. Vandeveer

William D. McMillin

Date of Examination:

June 18, 1985