CAUSALITY TESTS OF THE STOCK
PRICE-INFLATION
RELATION

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CHAPTER I

INTRODUCTION

Background

Common stocks have traditionally been viewed as an effective hedge against inflation. Because equities represent claims to underlying real assets, their value was thought to remain invariant to changes in the price level. But the poor inflation-adjusted performance of stocks in the late 1960's and early 1970's raised considerable doubt about the effectiveness of stocks as an inflation hedge. Works by Oudet (1973), Lintner (1975), Jaffe and Mandelker (1976), Nelson (1976), Fama (1977), and Fama and Schwert (1977) offered convincing empirical evidence that postwar U.S. stock prices moved inversely with measures of actual, expected, and unexpected inflation. Later empirical studies by Solnik (1983) and Gultekin (1983) documented the same inverse relationship internationally.

Early theories by Lintner (1975), Modigliani and Cohn (1979), Feldstein (1980), and Summers (1981) argued that financing practices, the tax system, and irrational investment behavior cause stock prices to decline in inflationary environments. These theories generated substantial early interest because they suggested the presence of a causal channel from inflation to stock prices. Fama (1981), Gordon (1983), and Geske and Roll (1983) provided comprehensive evaluations of these early theories and argued convincingly that none explains more than a small fraction of the inverse relation.

Fama (1983) and Geske-Roll (1983) offered alternative theoretical interpretations of the postwar inverse relationship that continue to receive attention. Their theories are rigorous attempts to understand the stock price-inflation relation within the context of a macroeconomic framework containing money, interest rates, and real activity, and with a prescribed role for the fiscal and monetary authorities. Indeed, a secondary objective of each is the coupling of the real and monetary sectors of the economy, a long coveted goal of the financial economics community.

While the Fama and Geske-Roll arguments are fundamentally different, the conclusions are the same - the observed negative correlation between stock prices and inflation is not causal in nature. The assertion of each that inflation does not cause changes in stock prices stands in sharp contrast to the attempt of earlier work to identify such a causal channel. The arguments instead suggest that stock prices are determined by real activity, and the price level is simply a monetary phenomenon.

The models are of added interest because they prescribe a significant role to the policy actions of the fiscal and monetary authorities. Fama's (1981) is a quantity theory argument which attributes the inverse relationship to fluctuations in money demand not being fully accommodated by money supply changes, or to the Federal Reserve employing a counter-cyclical 'lean against the wind' strategy. Geske-Roll attribute the negative stock return-inflation relation to changes in inflationary expectations induced by persistent postwar deficit financing.

The models proposed by Fama and Geske-Roll are well suited for empirical testing and offer sharply contrasting views of the postwar inverse stock price-inflation relation. Each develops a broad empirical framework and offers a substantial amount of evidence supporting its respective position. The empirical evidence presented in the original works is not fully convincing, however, leaving the ability of these theories to explain the postwar inverse relation in question. Subsequent researchers noted methodological deficiencies and continued to perform empirical tests of the theories to determine which provides the most useful explanation of the seemingly paradoxical postwar inverse relation.

This dissertation focuses on a group of these follow-up papers which extend empirical testing of the theories in three promising directions. The first extension is the use by Litterman and Weiss (1985), James, Koreisha, and Partch (1985), Lee (1992), and Balduzzi (1996) of Vector Autoregressive (VAR) models as a mechanism for testing jointly the theoretical links suggested by the theories. A major criticism of the empirical tests of both Fama and Geske-Roll is their use of single equation techniques along with strong structural assumptions to test what is essentially a system of equations with unknown structure. VAR models extend the analysis to a system of equations requiring no a priori structural assumptions. This provides a more robust framework for evaluating competing multi-equation systems such as those proposed by Fama and Geske-Roll.

The second extension is the use of Granger-type causality tests as a formal tool for detecting short-run causal relationships. Litterman and Weiss (1985), James, Koreisha, and Partch (1985), and Lee (1992) demonstrate that causality tests of this type are well suited for detecting the short-run lead/lag relationships suggested by both theories. Geske-Roll, in fact, develop their theoretical model using Granger-type causality as an expository tool. Furthermore, performing causality tests within a VAR framework prevents undue influence on the causality tests resulting from structural assumptions imposed on the model.

The final extension is Kaul's (1987, 1990) suggestion that the mechanisms outlined in both the Fama and Geske-Roll theories combine to create either a positive or negative stock price-inflation link. This contribution is important because it attempts to reconcile the two models, as well as to explain periods where stock prices move positively with inflation. He argues that the operating policy of the Federal Reserve determines the direction of the stock price-inflation relation. Countercyclical money supply changes result in an inverse stock price-inflation link, while procyclical changes result in a positive link. He further cites October 1979 to December 1986 as an example of a procyclical Federal Reserve money supply regime causing stocks to move in tandem with inflation. The post-Depression era is cited as another period of procyclical policy resulting in a positive stock price-inflation link. Graham (1996) examines Kaul's findings and provides additional evidence supporting the claim that the Fama and Geske-Roll theories are consistent with the data. Graham, however, identifies 1976Q1-1982Q1 as the relevant Federal Reserve policy change period, and also finds that the inverse relationship is absent during this period.

The Problem

While improving upon the original empirical tests, subsequent work fails to resolve the uncertainty surrounding the Fama and Geske-Roll stock price-inflation models. Litterman and Weiss (1985) and Lee (1992) present findings which are more compatible with Fama's proxy theory than with Geske-Roll. James, Koreisha, and Partch's (1985) results strongly support the money supply-based framework of Geske-Roll. Balduzzi's (1996) findings suggest that neither model adequately describes the stock price inflation-relation. Kaul (1987, 1990) and Graham (1996), however, provide evidence that a union of the two models explains the postwar inverse relation.

It is argued in this dissertation that some of the uncertainty surrounding subsequent tests of the theories may be due to the econometric methodology used. The first, and primary, concern is that VAR-based causality tests are not valid as applied in these tests. In satisfying the stationarity assumption of Classical statistical inference, existing VAR-based tests of the Fama and Geske-Roll models difference the time series until stationary and then apply regression analysis to the differenced series. The concern with this differencing procedure is that it masks any information concerning the equilibrium relationships among the levels of the variables. In the case of the stock price-inflation question, differencing the data allows analysis of the short-run changes in the variables comprising the systems developed by Fama and Geske-Roll, but lost in the process is the ability to measure the tendency of the levels of the variables to maintain a long-run equilibrium relationship. The problem relates to the notion of cointegration as developed by Granger (1983), Granger and Engle (1985), and Engle and Granger (1987). The finding of cointegration implies that a long-run equilibrium relationship exists among the levels of the time series. Engle and Granger (1987) find that ignoring long-run cointegrating relationships is equivalent to omitting relevant variables from the analysis and leads to inefficient parameter estimates and misleading inferences. Not only does theory suggest the presence of cointegrating relations, but Gallinger (1994), Chowdhury (1993), Masih and Masih (1996), and Choudhry (1996) find cointegrating relations among many of the variables in the models.

The finding of cointegration has several implications for empirical tests of the Fama and Geske-Roll models. First, Hamilton (1994) shows that Granger-causality tests performed within differenced VAR's without cointegrating constraints are invalid. Second, it rules out the possibility of spurious relationships among the variables. Both the Fama and Geske-Roll theories suggest the observed stock price-inflation relation is spurious in nature. Third, short-run Granger-causality exists in at least one direction between cointegrated variables and valid causality tests must account for the cointegrating relations.

The second concern with the econometric frameworks used in existing tests surrounds the finding of Kaul (1987, 1990) and Graham (1996) that the theories jointly explain the stock price-inflation relation. While the evidence presented supports the validity of both theories, these works continue to use the single equation techniques of Fama and Geske-Roll when testing the postwar stability of the stock price-inflation relation. James, Koreisha, and Partch (1985) and Lee (1992) soundly criticize the use of single equation techniques to examine relationships best represented by a system of equations. Moreover, Kaul and Graham fail to account for any long-run equilibrium relationships among the variables.

Other concerns with subsequent tests of the theories include uncertainty surrounding the appropriate lag structure and the possible omission of key variables. James, Koreisha, and Partch (1985) and Lee (1992) use lag structures within their VAR models which do not clearly define the lead/lag relationships among the variables. Misspecification of the lag structure makes the results of Granger-causality tests suspect. In addition, Lee (1992) fails to include a measure of money in his analysis, an essential variable in both theoretical models. These procedural errors cast further doubt upon the conclusions reached in these works.

These deficiencies prevent existing tests from providing a rigorous econometric evaluation of the Fama and Geske-Roll models. The presence of long-run cointegrating relations is ignored in testing the short-run dynamics suggested by the theories. By examining only the short-run dynamics of the stock price-inflation relation, prior work not only fails to exploit the full range of causal tools which are now available for evaluating the models, but may be providing misleading conclusions concerning the theories. Other serious errors include using faulty lag structures and omitting pivotal variables in empirical tests. These problems raise similar concerns about tests of the stability of the relationship during the Federal Reserve policy change periods proposed by Kaul and Graham. Fortunately, these deficiencies are remediable.

Purpose of the Study

The purpose of this dissertation is to use an improved empirical framework to test the relative validity of the Fama and Geske-Roll models. A framework is proposed that corrects procedural errors in previous works and utilizes recently developed techniques for modeling cointegrated time series. The method further complements earlier works by using Granger-type causality tests to evaluate the lead/lag relationships suggested by both the Fama and Geske-Roll models.

The major contribution of the study is the introduction of a Vector Error-Correction Model (VECM) as a framework for performing valid short-run Granger-type causality tests within a cointegrated system of equations. VECMs, as popularized by Engle and Granger (1987), are essentially VAR models specified in differenced form, but also reflect any long-run equilibrium, or cointegrating, relationships among the levels of the variables. This improved framework is also used to test the stability of the inverse stock price-inflation relation during the policy change periods proposed by Kaul and Graham.

Objectives of the Study

The first objective in testing the theories is to establish the time series properties of the variables using the Augmented Dickey-Fuller (ADF) unit root test. Second, the maximum-likelihood cointegration approach of Johansen and Juselius (1990) is used to test for any long-run causal relationships among the variables. Third, any long-run causal relations are used along with the Vector-Error Correction Model frameworks of Toda and Phillips (1993, 1994) and Saikkonen and Lütkepohl (1996) to perform short-run causality tests. The results of the causality tests are then used to evaluate the validity of the stock price-inflation models of Fama and Geske-Roll. Finally, dummy variable tests of parameter stability are used to test for changes in the causal relations during the Federal Reserve policy change periods proposed by Kaul and Graham.

Outline of Work

The dissertation consists of five additional chapters. Chapter II describes the Fama and Geske-Roll models and reviews related empirical work. Chapter III develops the empirical framework for testing the theories. Chapter IV describes the data and methodology used in the study. Chapter V details the findings from the empirical tests and discusses the implications for the Fama and Geske-Roll models. Chapter VI summarizes the findings and the contributions made to the stock price-inflation literature.

CHAPTER II

REVIEW OF THE LITERATURE

Early Theory

Early thought, based on Fisher's (1896) model in which the nominal return on an asset is composed of a real return plus expected inflation, suggested a positive correlation between stock prices and inflation. This view of stocks as an inflation hedge held that the nominal value of the stream of corporate earnings varies in direct proportion to the price level, leaving the stream of real earnings unaffected. Hence, equity investors are fully compensated for erosion in purchasing power and the real returns to stocks are invariant to changes in the price level. The continued poor performance of equities in the inflationary 1960's and 1970's, however, prompted a reexamination of the commonly accepted view of stocks as an inflation hedge.

Early plausible explanations for the inverse relation between stocks and inflation were advanced by Lintner (1975), Modigliani and Cohn (1979), Feldstein (1980), and Summers (1981). They argued that financing practices, the tax system, and irrational investment behavior cause stock prices to decline in inflationary environments. In a widely cited article, Lintner (1975) argued that inflation depressed the value of outstanding equity because it forced firms to seek additional external financing. The key assumption was that a higher price level forced firms to seek additional financing in order to maintain working capital in a fixed proportion to inflation enhanced sales. This additional financing, it was argued, diluted the value of existing equity shares. Lintner suggested the argument held whether the additional financing was in the form of equity or debt, and for either expected or unexpected inflation. Geske-Roll (1983) disputed that this financing needs argument was capable of explaining the postwar stock price-inflation link. They suggested that rational managers instead used generally accepted methods of managing working capital requirements such as restricting the issuance of trade credit and lengthening the payment cycle on payables.

Modigliani and Cohn (1979) offer the highly controversial explanation that inflation induces an 'illusion' that leaves investors unable to price equity shares accurately. They argue that investors commit two common errors and consequently underestimate the true value of equities. First, they fail to adjust nominal profits to reflect the decline in real corporate liabilities which results from inflation. Second, investors incorrectly capitalize earnings using the nominal interest rate rather than the real rate. They, in fact, estimate that systematic valuation errors resulted in the S&P 500 being undervalued by 50% at the end of 1977. Gordon (1983), however, argues that the investor illusion theory offered by Modigliani and Cohn does not provide a convincing explanation for the inverse stock price-inflation link. He estimates a model based on q, the ratio of market value to replacement cost, and finds that the stock market would have been much more undervalued than suggested by Modigliani and Cohn if investors did indeed commit the suggested systematic errors. Geske-Roll further argue that the theory is counter to the established literature on rational expectations and market efficiency and is based on irrationality.

Feldstein (1980) implicates the use of historic cost depreciation and the taxation of nominal capital gains in explaining the negative correlation between stock prices and inflation. Under inflation, historic cost depreciation schedules result in a decline in the real value of depreciation and an increase in real taxable profits. Taxation of nominal capital gains results in inflation enhanced nominal earnings. In both cases, firms are penalized by a higher effective corporate tax burden. Summers (1981) provides additional empirical evidence supporting the tax system effect. Gordon

(1980) and Fama (1981), however, provide opposing empirical evidence and argue that these tax effects have a negligible effect on profits.

These early works were appealing because they identified potential causal channels from inflation to stock prices, but they have not generated a following in the literature. Financial economists continued to show a reluctance to subscribe to a stock price-inflation theory that lacks the rigor of a macroeconomic foundation and that is predicated principally upon financial statement phenomena and/or irrational investment behavior. Nonetheless, the work of Lintner and Modigliani-Cohn foreshadowed the direction Fama and Geske-Roll would take in seeking a macroeconomic explanation for the postwar inverse relation. Lintner, while not offering a full theoretical model linking real activity, stock prices, and inflation, presented regressions of stock returns on both changes in real earnings and long term interest rates. He further discussed the inverse stock price-inflation phenomenon within a macroeconomic framework. Similarly, Modigliani-Cohn, acknowledging the seeming implausibility of their theory, suggested that inflation may simply be proxying another relevant macroeconomic variable, or variables.

Fama Model

Fama's argument that inflation does not cause lower stock prices propelled the literature into a new direction. The work is, in many respects, an answer to the Modigliani-Cohn question of whether "inflation is simply proxying for some other relevant variable, or variables?" Fama's 'proxy' theory suggests that the relevant variable is real activity and that the observed postwar inverse relationship between stock prices and inflation merely reflects the fact that these variables adjust in opposite directions to changes in real activity. That is, there is no functional relationship between the two.

The argument rests on two assumptions. First, stock prices forecast future real activity, and second, expected inflation and future real activity are inversely related. Fama's formal framework linking stock prices and real activity is the capital expenditures process detailed in Jorgenson (1971). When real activity increases, added pressure on the capital stock raises the average return on the existing stock and forces increased capital expenditures. Fama further presumes that, under rational expectations, stock market returns respond to changes in the investment process, with higher investment inducing higher stock prices.

Fama then uses a simple model which combines rational expectations and the quantity theory to explain the inverse link between expected inflation and real activity. The framework is an adaptation of the inflation-real activity process developed in Fama (1982). Under the quantity theory, a decrease in real activity is associated with a decrease in the demand for real money balances. Fama further argues that in the post-1953 period, changes in real money demand were not fully accommodated through changes in the nominal money supply. Under this type of countercyclical monetary policy, a decrease in real money demand, given a relatively fixed nominal money supply, results in higher inflation. In other words, when economic activity is expected to slow, stock prices forecast the change in economic activity and adjust downward, while inadequate downward adjustments in the nominal money supply push the price level upward. Hence, the observed postwar inverse relationship between inflation and stock prices arises not out of a functional relationship between the two, but simply proxies for the forward looking behavior of stocks in anticipating future real activity.

Fama's framework for testing empirically the 'proxy' hypothesis consists of two steps. First, he documents the two fundamental links suggested by the theory - an inverse relationship between current expected inflation and future real activity and a positive relationship between current real stock returns and future real activity. Second, he suggests that, under the 'proxy' hypothesis, the observed inverse correlation between stock prices and expected inflation should disappear in a model which contains real activity if the relationship is indeed spurious in nature. The empirical tests use measures of real stock returns, real activity, base money, and expected inflation. Two measures of expected inflation are generated by regressing actual inflation, first on Treasury Bill yields, and then jointly on base money and real activity.

Fama estimates regressions of real stock returns on several measures of real activity and finds a consistent positive relationship between stock returns and future real activity. He also finds a consistent inverse relationship between expected inflation and changes in future real activity in single equation regressions of expected inflation on current base money growth and current and future changes in industrial production. These single equation regressions are offered as evidence supporting the two fundamental links underlying the theory.

He then estimates various regressions of real stock returns on future real activity, expected inflation, and the monetary base using monthly, quarterly, and annual data. The inverse link between stock prices and inflation disappears as predicted by the 'proxy' theory, but only in those regressions containing both real activity and the monetary base. In these equations, the coefficient on expected inflation is insignificant and is cited as evidence in support of the proxy hypothesis that the observed link between stock returns and inflation is indeed spurious.

Geske and Roll Model

Geske and Roll (1983) elaborate on Fama's proxy theory that the stock price-inflation relation is spurious. They agree that the money demand effects outlined by Fama may result in the observed inverse stock price-inflation relation, but further suggest that money supply effects cause a similar result. They argue that Fama's assumption of an incomplete adjustment to an excess supply of money ignores the impact of persistent postwar fiscal deficits on the money supply process and the subsequent impact on the stock price-inflation relation. Instead, they posit that stock price changes signal revisions in inflationary expectations in the postwar period, and that money supply changes induced by deficit financing are responsible for the change in expectations.

The monetization argument suggests that stock prices fall in anticipation of declining real activity and simply foretell a series of fiscal and monetary events leading to increased inflationary expectations. As real activity slows, government tax revenue declines, and, given relatively fixed expenditures, the government experiences budget deficits. To the extent the deficit is monetized, expected inflation increases while stock prices fall. In the absence of monetization, the increased supply of government debt securities increases the real interest component of nominal interest rates, a variable believed to reflect inflationary expectations. Hence, in the postwar period, changes in stock prices reflect revisions in inflationary expectations due either to monetization of the deficit or to an increase in the supply of government securities.

Geske-Roll detail a sufficient set of conditions necessary to validate empirically the 'inflationary expectations' hypothesis. Foremost among these conditions are the two key links in the Fama model - a positive relationship between stock returns and future real activity and an inverse link from inflationary expectations to real activity. Three money supply links are also suggested. The first, in sharp contrast to the Fama model, is the inverse link from monetary expansion to real activity. Fama argues that the money supply is invariant to changes in real activity. Additionally, links from both stock prices and expected inflation to money are suggested. These are also strongly counter to the Fama model. They also theorize that a strong contemporaneous negative relationship can exist between nominal interest rates and stock returns even if the negative link between expected inflation and stock prices is insignificant. This link can occur if deficit financing takes the form of new debt offerings. This too is in contrast to Fama's proxy model which suggests that the stock price-inflation relation should disappear in a model correctly specified to include real activity.

Finally, Geske-Roll estimate a series of single equation regressions for each stage of the 'inflationary expectations' hypothesis. The results provide support for each of the links suggested by Fama - a positive one from stock prices to real activity and an inverse link from expected inflation to real activity. Contrary to the Fama model, they find evidence supporting the role of deficit financing and money supply changes in determining the stock price inflation relation. Further, they find evidence of a significant link between nominal interest rates and stock prices when real activity is included in the model. This is also counter to Fama's empirical results where the observed inverse stock price-inflation relation is insignificant when real activity is included as an explanatory variable.

Review of Subsequent Empirical Tests

In an early test of Fama's theory, Litterman and Weiss (1985) examine the most controversial aspect of the proxy hypothesis, the money demand explanation of the inverse relationship between expected inflation and future real activity. They estimate a VAR model containing real interest rates, nominal interest rates, expected inflation, the monetary base, and future real activity. The empirical results show expected inflation and nominal interest rates to have a strong inverse relationship with future real activity, as predicted by the proxy hypothesis. However, contrary to most macroeconomic theory and consistent with the results of Geske-Roll, real interest rates have no predictive power for future real activity. While the results are consistent with the assertion of both theories that inflation is inversely related to future real activity, the exclusion of stock prices from the model precludes analysis of the other causal links suggested by the theories.

In an early joint test of the theories, James, Koreisha, and Partch (1985) criticize the basic empirical methodology used by both Fama and Geske-Roll in testing their respective theories. Of primary concern is the use of separate equations to estimate what is essentially a system of equations. A related concern is the imposition of structural form on the stock return-expected inflation link in the absence of sound theory. They use instead a Vector-Autoregressive Moving Average (VARMA) model requiring no a priori structure to examine jointly the relationships among stock returns, inflation, real activity, and nominal money in the 1962-81 period. Granger-causality tests are introduced as a tool used within a multi-equation model for detecting the lead/lag relationships suggested by both theories. Using a four variable VARMA model containing nominal stock returns, changes in the monetary base, changes in the Treasury Bill rate (as a measure of expected inflation), and changes in industrial production, they find evidence of consistent links from stock returns to future real activity and from inflation to future real activity. While this evidence is consistent with both the Fama and Geske-Roll models, they find an additional causal link from stock returns to the monetary base. This link is consistent with the early work on the stock price/money supply link by Rozeff (1974) and Rogalski and Vinso (1977), as well as the Geske-Roll model, but is in sharp contrast to the Fama model. These results favoring the Geske-Roll model are suspect, though, due to the lead/lag structure used in their VARMA model. They define the monetary base change variable as the percentage change from month_{t-12} to month_t, and the stock return variable as the percentage change in month_t. Because the monetary base change variable is deemed nonstationary, a second difference is used in the analysis. James, Koreisha, and Partch then cite a significant relation between stock returns in month_{t-2} and the twice differenced monetary base variable in month_t as evidence that stock prices forecast changes in the money supply. The problem with this lag structure is that it is actually relating past and future rates of change in the rate of change in the monetary base to current period stock price changes, making the model incapable for addressing this key link differentiating the theories. Another concern is the use of 12-month changes in industrial production (defined as percentage changes from month_t to month_{t+12}) in their VARMA model. When used as lagged explanatory variables in a VARMA model this variable represents both past and future changes in industrial production up to the eleventh lag. This lag structure further hinders the model's ability to detect the causal relations implied by the theories. The justification offered for using a 12-month lag structure is the potential nonstationarity of monthly changes in industrial production, not a concern motivated by either theory being tested.

Kaul (1987, 1990) provides evidence that the direction of the stock price-inflation relation is determined by the equilibrium process in the monetary sector. He agrees that the money demand effects suggested by Fama produce an inverse stock price-inflation link, but argues that the operating target of the monetary authority, and its subsequent relationship to the money supply, determines both the direction and magnitude of the stock price-inflation relation. Specifically, Federal Reserve behavior that results in countercyclical money supply growth, as in the Geske-Roll deficit financing argument, attenuates the inverse money demand effect. Procyclical money growth, however, results in a money supply effect capable of offsetting, or even reversing, the opposing inverse money demand effect on the stock price-inflation relation. Using official Federal Reserve documents, he cites the 1926-40 Depression-era period and the 1979-1986 Federal Reserve money supply regime as periods of procyclical money growth capable of generating a positive relationship between stock prices and inflation. The remainder of the postwar period is cited as an example of countercyclical money supply growth consistent with Fama. Kaul first performs empirical tests of the money demand/supply effects suggested by both Fama and Geske-Roll and then tests the sensitivity of the effects to the operating target of the Federal Reserve. He estimates a series of single equation regressions using monthly data in the 1953-83 period. Findings consistent with both theories include an inverse link between expected inflation and future real activity and a positive link between stock prices and future real activity. The absence of a significant relation between stock returns and expected inflation when real activity is included as an explanatory variable is offered as additional evidence supporting Fama's model. The money supply influence suggested by Geske-Roll is supported by the finding of a significant positive relation between deficits and money growth. Additional empirical support for the procyclical money supply effect is provided by documenting a positive stock price-inflation link in the post-Depression era.

Nonetheless, Kaul's empirical tests for the joint money demand/money supply effects suffer from the same empirical problems as the original Fama and Geske-Roll works. Kaul follows Fama’s framework and estimates single equation regressions for the two key links in the proxy hypothesis, and subsequently demonstrates an insignificant link between stock prices and inflation when real activity is included in the equation. This use of single equations to demonstrate causal relations among several variables is criticized by James, Koreisha, and Partch (1985). Another concern is their citing of a positive Depression-era correlation between stock prices and expected inflation as supporting evidence of a causal role for the money supply, in lieu of performing an econometric test for a causal link in this period.

In another joint test of the theories, Lee (1992) criticizes the single equation techniques used by Fama, Geske-Roll, and Kaul. Using a VAR model and Innovation Accounting techniques as popularized by Sims (1980), Lee examines the relationships among real stock returns, real interest rates, changes in industrial production, and the inflation rate in the 1947-87 period. He finds a significant causal link from stock returns to real activity, as well as nonsignificant links from stock returns to inflation and from real interest rates to real activity. These results are more nearly compatible with Fama's proxy hypothesis than with Geske-Roll.

Of more interest is the failure to find a significant link from inflation to real activity, a key linkage in both theories. These tests, however, are suspect because of Lee's failure to include a money supply variable in the analysis and perform a direct test of the pivotal links from stock prices to the money supply and from the money supply to real activity. He cites the undocumented concern that money supply changes simply mirror changes in nominal interest rates (the proxy used for expected inflation) as the reason for excluding a money supply variable from the model. Lee then reestimates the model of James, Koreisha, and Partch using monthly data in the 1947-87 period and Innovation Accounting techniques. The findings suggest a Granger-causal link from stock returns to real activity and from inflation to real activity, but do not support the existence of a Granger-causal link from stock returns to the monetary base as found in the original work by James, Koreisha, and Partch (and as suggested by Geske-Roll). These replicated results reach the opposite conclusion concerning the role of money while using the same variable definitions and lag structure.

Balduzzi (1995) examines the Fama and Geske-Roll theories using quarterly observations on real stock returns, inflation, monetary base growth, Treasury Bill yields, and Industrial Production growth using covariance decomposition techniques within a VARMA model. In contrast to Fama's (1981) findings, the results suggest that the covariance between inflation and stock returns is mostly due to innovations in inflation, not innovations in real activity. The study, however, reports covariances between stock returns and inflation only and fails to include analysis of the other causal links suggested by the theories.

Graham (1996) extends Kaul's tests of the sensitivity of the inverse stock price-inflation relation to the operating policy of the Federal Reserve. He first questions Kaul's method of using official statements of the Federal Reserve to identify the 1979-1986 period as a shift to a procyclical money supply target. Graham instead takes an econometric approach which uses a linear regression of real stock returns on actual inflation and Quandt structural break tests to identify 1976Q1-1982Q1 as a period where stock prices and inflation are positively related. He notes that the 1975-82 period covers the years from the first OPEC oil crisis to the trough of the 1981-82 recession and provides anecdotal evidence of Federal Reserve neutrality in this period. Graham also finds evidence supporting Fama's proxy hypothesis that money growth does not cause inflation in the non-policy change periods. However, he continues to use the single equation framework of Fama and Kaul to evaluate the models.

CHAPTER III

EMPIRICAL FRAMEWORK

Overview

The empirical framework used to test the Fama and Geske-Roll stock price-inflation models is discussed in this chapter. The estimators and tests considered here improve upon previously used procedures in that they account for the presence of long-run cointegrating, or equilibrium, relationships in the system. Vector error-correction models (VECM) are also used to perform valid short-run Granger-causality tests within a cointegrated system of equations. Cointegrated VECMs differ from the traditional differenced VAR's used in earlier works in that they account for equilibrium relationships among the levels of the variables.

Nonetheless, the use of VAR's has been criticized by Cooley and LeRoy (1985), Runkle (1987), and others. They argue that the method of identification used in structural simultaneous equation models is superior to the identification procedure used in VAR's. The critics, however, agree that there are important uses for the VAR model. For example, McMillin (1988) notes that VAR models are particularly useful in generating statistical evidence for evaluating the relevance of existing theories. This is the context in which VAR's are used. McMillin (1988) further notes that VAR's are useful when testing theories which imply Granger-causal linkages between the variables in the system.

The cointegration tests and vector error-correction model (VECM) procedures require knowledge of the time series properties of the data. The formal Augmented Dickey Fuller (ADF) unit root test is used to examine the stationarity properties of the data. The maximum likelihood procedure of Johansen and Juselius (1990) is then used to establish any cointegrating relations among the data series. Short-run causality is tested using Wald tests within the cointegrated VECM frameworks of Toda and Phillips (1993, 1994) and Saikkonen and Lütkepohl (1996). These show that under fairly general and verifiable conditions, short-run Granger-causality tests in VECMs are asymptotically valid. Each of these procedures is discussed in the following sections.

Unit Root Tests

The body of literature commonly known as tests for "unit roots" provides a formal method of testing for stationarity in a time series. A stationary time series has a constant mean and time independent variance and covariances. One method of testing for stationarity involves computing and plotting the sample autocovariances and then performing a visual inspection of the series. A stationary series should exhibit a rapid dampening of the autocorrelations over time. Existing tests of the Fama and Geske-Roll theories use similar informal methods to establish the stationarity of the time series. The shortcoming of this technique is the inherent difficulty in establishing the proper time frame for a "rapid" decline in autocorrelations.

Dickey and Fuller (1979) suggest a number of alternative tests for unit roots. These formal tests are used to determine the order of integration of a time series, or the number of times a series must be differenced before becoming stationary. A time series, X_t, is integrated of order d, or $X_t \sim I(d)$, if X_t must be differenced d times to achieve stationarity. In this study, the augmented Dickey-Fuller (ADF) unit root test is used to establish the stationarity of the time series. The ADF test of stationarity for any time series X_t requires running the following regression:

$$\Delta X_t = \alpha + \beta X_{t-1} + \sum_{j=1}^{k} \phi_j \Delta X_{t-j} + \upsilon_t \ , \tag{3.1}$$

where α, β, and ϕ_j, j=1,...,k, are unknown parameters. The procedure consists of regressing the first difference of X_t on a constant, the lagged level of X_t, and lagged first differences of X_t, where the number of lagged differences, k, is chosen to be large enough to eliminate serial correlation in the residuals. The time series is nonstationary if $\beta=0$. Following Dickey and Pantula (1987), each time series is tested first for the presence of two unit roots. If two unit roots are rejected for a time series, it then is tested for the presence of a single unit root. The ADF test statistic (i.e., the t-ratio associated with β) does not have a standard t-distribution and its critical values are tabulated in Fuller (1976). If the t-ratio for β is larger than the relevant critical value (which is negative) a unit root null hypothesis cannot be rejected. The cointegration technique of Johansen and Juselius (1990) and the VECM techniques of Toda and Phillips (1993, 1994) and Saikkonen and Lütkepohl (1996) require the series to be stationary, I(0), or first difference stationary, I(1).

Johansen Estimation of Cointegrating Vectors

Cointegration techniques satisfy the basic stationarity requirement of classical statistical inference while retaining information about the long-run equilibrium relationships among the levels of the variables. They further permit the investigator to abstract from the short-run dynamics of the stock price-inflation relation and isolate the long-run dynamics driving the system. The proposed tests of the Fama and Geske-Roll models use the maximum-likelihood cointegration technique of Johansen and Juselius (1990). The procedure provides consistent maximum-likelihood estimates of the vector of cointegrating relations for any nonstationary I(1) Vector-Autoregressive process with Gaussian errors. It further allows likelihood ratio tests of both hypotheses about the dimension of the cointegrating space and linear hypotheses about the elements of the cointegrating vectors.

Several other approaches to testing for cointegration have been suggested in the literature. Among these are ordinary least squares by Engle and Granger (1987), nonlinear least squares by Stock and Watson (1987), principal components by Stock and Watson (1988), canonical correlations by Bossaerts (1988), instrumental variables by Hansen and Phillips (1990), spectral regression by Phillips (1991), and maximum likelihood by Saikkonen (1991). In a Monte Carlo study of cointegration tests, Gonzalo (1994) finds that the Johansen and Juselius maximum likelihood approach in a fully specified Vector Error-Correction model has more satisfactory properties than the other estimators. It produces coefficient estimates which are median unbiased and allows hypothesis tests using standard asymptotic chi-squared tests. These conclusions are valid in finite samples as well. The Johansen-Juselius maximum-likelihood approach is used because of these desirable properties.

For convenience in testing for cointegration, Johansen-Juselius assume the I(1) n-vector time series, Y_t, follows the unrestricted Vector Error-Correction Model (VECM) format

$$\Delta Y_t = \mu + \sum_{j=1}^{k-1} \Gamma_j \Delta Y_{t-j} + \Pi Y_{t-k} + e_t \ , \tag{3.2}$$

where μ, Γ_j, Π are unknown parameter matrices. The parameter vector μ contains intercepts, Γ_j, j=1,...,k-1, are matrices of coefficients on the lagged differences of Y_t, and Π is known as the cointegration matrix. Note that the formulation used in (3.2) is algebraically equivalent to a k-order VAR estimated in levels. The order of the estimated VECM may be determined using a statistical model selection criteria such as Akaike's AIC or Schwarz's SC (Judge, et. al. p.848).

The rank, r, of the (n x n) cointegration matrix, Π, equals the number of significant long-run cointegrating relations spanning the n time series in Y_t. The matrix Π may also be decomposed as $\Pi=\alpha\beta'$ where α is an (n x r) matrix of weights and β is an (n x r) matrix of individual cointegrating vectors. Likelihood ratio tests of linear restrictions on α and β may also be performed. For example, tests of zero restrictions on the coefficients within β are used to determine whether each variable enters the r cointegrating vectors significantly.

The rank of the cointegration matrix, Π, determines the type of Vector-Autoregressive framework required for performing valid short-run Granger-type causality tests. If the cointegrating matrix has zero rank, or $r = \text{rank}(\Pi) = 0$, the time series are not cointegrated and the system can be estimated by a VAR specified in differences. Standard Granger-type causality tests are valid within this type of traditional non-cointegrated VAR framework with differenced time series. If the cointegrating matrix has full rank, or $r = \text{rank}(\Pi) = n$, the time series are stationary and the system can be estimated by a VAR in levels and standard causality tests are again valid. If instead the rank of the cointegrating matrix is non-zero and less than full rank, or $0 < r = \text{rank}(\Pi) < n$, the system is cointegrated with the number of significant cointegrating vectors equal to r. Hamilton (1994) demonstrates that under these conditions, hypothesis tests performed within a non-cointegrated VAR specified in differences are invalid. Valid inference in the presence of cointegration instead requires the estimation of a VECM with the estimated long-run cointegrating constraints imposed. Toda and Phillips (1993, 1994), however, demonstrate that, even if performed within a VECM, standard Granger-type causality tests can result in test statistics involving nonstandard distributions and nuisance parameters. Recent works, however, provide frameworks for performing valid Granger-type causality tests within a cointegrated VECM and are discussed in the following sections.

Cointegration and Short-Run Granger-Causality Testing

Engle and Granger (1987) show that a set of cointegrated variables has a corresponding Vector Error-Correction Model (VECM) representation. The VECM implies that changes in the dependent variable are a function of lagged differences and the lagged level of each explanatory variable. The VECM further allows us to distinguish between the long-run and short-run dynamics driving the system. The cointegrating relationships represent the long-run equilibrium relationships between the levels of the variables, while the short-run effects are measured by the lagged differenced explanatory variables in the VECM. The estimated short-run coefficients on the lagged differences in the VECM can be used to conduct short-run Granger-causality tests.

Several methods for performing short-run Granger-type causality tests within a cointegrated system of equations are discussed in the literature. Lütkepohl and Reimers (1992), Toda and Yamamoto (1995), and Dolado and Lütkepohl (1996) suggest overfitting a VAR estimated in levels. If the true data generation process is a VAR(k), these methods propose fitting a VAR(k+1) and performing causality tests on the first k lags only. Though suffering from the inefficiency of estimating surplus lags, this approach is easily understood and produces test statistics with asymptotic chi-square distributions.

Other methods include fully modified least squares (FM-OLS) by Phillips (1995) and the Vector Error-Correction Model-based maximum-likelihood approaches of Mosconi and Giannini (1992), Toda and Phillips (1993, 1994) and Saikkonen and Lütkepohl (1996). These methods offer obvious efficiency gains over the overfitting methods. Phillips (1995) advocates the FM-OLS approach because it does not require either knowledge of the number of unit roots in the system or pretesting for the dimension of the cointegrating space. Nonetheless, the approach is difficult to implement and does not guarantee efficiency gains over the maximum-likelihood methods. Both the Mosconi and Giannini (1992) and Toda and Phillips (1993, 1994) maximum-likelihood methods are direct extensions of the Johansen-Juselius cointegration approach. These methods impose the estimated cointegrating vectors from the Johansen-Juselius method as restrictions on the VECM when performing causality tests. The Saikkonen and Lütkepohl approach produces maximum-likelihood estimates of the cointegrating vectors as an interim step in performing causality tests and further differs in that it is developed for a more general infinite order VAR process.

Zapata and Rambaldi (1997) perform a Monte Carlo study of the overfit VAR approaches of Lütkepohl and Reimers (1992), Toda and Yamamoto (1995), and Dolado and Lütkepohl (1996), as well as the maximum likelihood approach of Mosconi and Giannini (1992). They conclude that the maximum likelihood approach offers superior performance in large and small samples and is less sensitive to misspecification of the order of the VAR. The VAR overfitting techniques are more sensitive to underfitting the true order of the model and have low power in small samples.

The procedures used in this study are the maximum-likelihood vector error-correction model approaches of both Toda and Phillips (1993, 1994) and Saikkonen and Lütkepohl (1996). These frameworks are used to perform short-run Granger-causality tests of the key causal relationships in the

Fama and Geske-Roll models. The maximum likelihood approach of Toda and Phillips is selected because it is a direct extension of the Johansen-Juselius cointegration technique and is more tractable than the iterative approach used by Mosconi and Giannini. The Saikkonen and Lütkepohl method is selected due to its more general infinite order process and because it avoids any bias resulting from pretesting for the cointegrating vectors. Each method provides an easily understood method of testing the short-run Granger causal effects of one variable on another variable or group of variables and generate test statistics with standard chi-square distributions. Using both techniques provides the added advantage of testing the sensitivity of the causality tests to the modeling method used. The two VECM techniques are discussed in detail in the following sections.

Toda and Phillips Short-Run Causality Tests

The Toda and Phillips (1993, 1994) Vector-Error Correction Model framework imposes the maximum-likelihood estimates of the cointegrating vectors from the Johansen-Juselius procedure as restrictions on the VECM. Short-run Granger-type causality tests are conducted on the estimated parameters from the restricted model. While traditional

Granger causality tests are generally not valid within a cointegrated VECM, Toda and Phillips show that, under fairly general and verifiable conditions, Granger causal inferences are valid using their technique.

To apply the procedure to any I(1) n-vector time series Y_t, fit the following k-order VECM by multivariate least squares

$$\Delta Y_t = \mu + \sum_{j=1}^{k} \Pi_j \Delta Y_{t-j} + \Gamma \hat{A}' Y_{t-1} + e_t \ , \qquad (3.3)$$

where μ, Π_j, and Γ are unknown parameter matrices. The vector μ is an intercept and Π_j, j=1,...,k, are matrices of coefficients on the lagged first differences of Y_t. Γ is known as the cointegration matrix, ΔY_t is the first difference of Y_t, and Y_{t-1} is Y_t lagged one period. The matrix $\hat{A}$ denotes the Johansen-Juselius (1990) maximum likelihood estimate of the r significant cointegrating eigenvectors of Y_t. Each of the eigenvectors in $\hat{A}$ is normalized using the method suggested by Johansen (1988, p.235). If the estimated matrix of eigenvectors, $\tilde{A}$, is calculated using a standard econometric software package that normalizes $\tilde{A}_i' \tilde{A}_i = 1, \ i = 1, \ldots, n$, then Johansen's normalized estimate is $\hat{A}_i = \tilde{A}_i \div \sqrt{\tilde{A}_i' \tilde{\Sigma}_{VV} \tilde{A}_i}$, where $\tilde{\Sigma}_{VV}$ is the variance-covariance matrix of the least-squares residuals from the second auxiliary regression in the Johansen-Juselius method. The matrix $\hat{A}'Y_{t-1}$ represents the r error-correction terms, or the short-run adjustments to long-run equilibrium trends. The error correction terms differentiate the VECM from a differenced VAR and open up the additional channel of long-run causality ignored by traditional causality tests. In addition, Engle and Granger (1987) demonstrate that any cointegrated time series vector can be fully represented by the error-correction mechanism in (3.3). This implies that changes in the dependent variable are solely a function of the error-correction terms and lagged changes in the explanatory variables. Again, the order of the estimated VECM may be determined using a model selection criteria such as Akaike's AIC or Schwarz's SC.

The maximum likelihood estimator of the unknown parameters (μ, Π_j, Γ) is given by

$$(\hat{\mu}, \hat{\Pi}_1, \ldots, \hat{\Pi}_k, \hat{\Gamma}) = \Delta Y'\hat{Z}_1(\hat{Z}_1'\hat{Z}_1)^{-1} \tag{3.4}$$

where $\hat{Z}_1 = (1, \Delta Y_{t-1}, \ldots, \Delta Y_{t-k}, \hat{A}'Y_{t-1})$. The estimated covariance matrix of e_t is

$$\hat{\Sigma}_e = T^{-1}\left[\Delta Y'\Delta Y - \Delta Y'\hat{Z}_1(\hat{Z}_1'\hat{Z}_1)^{-1}\hat{Z}_1'\Delta Y\right] \tag{3.5}$$

where T is the sample size. Wald tests for short-run causality using the parameter matrices $\hat{\Pi}_j$, j=1,…k, are now possible.

For discussion of causality tests in this section, suppose the objective is to test whether there are causal effects from the n_3 elements of Y_3 to the n_1 elements of Y_1. Partition the n-vector time series Y_t accordingly into three sub-vectors $Y_t = (Y_{1t}, Y_{2t}, Y_{3t})$ where $n_1+n_2+n_3=n$. The null hypothesis of short-run Granger noncausality from Y_3 to Y_1 based on the model (3.1) is formulated as

$$H_\pi(Y_3 \to Y_1) : \Pi_{1,13} = \ldots = \Pi_{k,13} = 0 . \qquad (3.6)$$

The $\Pi_{i,13}$'s in (3.6) are the k estimated coefficients corresponding to sub-vector Y_3 in the first equation of the VECM with Y_1 as the dependent variable and → denotes the hypothesized direction of causality. The alternative hypothesis is that the estimated coefficients are not jointly equal to zero and a short-run Granger-causal relationship exists from Y_3 to Y_1. Under the null hypothesis H_π,

$$F_\pi = \mathrm{vec}(\hat{\Phi}_\pi)' \left[S_1' \hat{\Sigma}_e S_1' \otimes (I_k \otimes S_3') \hat{\Sigma}_\pi (I_k \otimes S_3) \right]^{-1} \mathrm{vec}(\hat{\Phi}_\pi) \xrightarrow{d} \chi^2_{n_1 n_3 k} , \qquad (3.7)$$

where $S_1 = (I_{n1}, 0)$ and $S_3 = (0, I_{n3})$ are selector matrices, I_{n1}, I_{n3}, and I_k are identity matrices, $\hat{\Phi}_\pi = (\hat{\Pi}_{1,13}, \ldots, \hat{\Pi}_{k,13})$, and $\hat{\Sigma}_\pi$ is the corresponding (nk+1) x (nk+1) upper-left block of $(\hat{Z}_1' \hat{Z}_1)^{-1}$. The test statistic F_π has a limiting χ^2 distribution with $n_1 n_3 k$ degrees of freedom under the null hypothesis of noncausality.

Saikkonen and Lütkepohl Short-Run Causality Tests

The Saikkonen and Lütkepohl (1996) VECM method similarly enables valid short-run Granger-causality tests within a cointegrated system of equations. It differs from the Toda and Phillips method, however, in that it does not require knowledge of the estimated cointegrating vectors prior to fitting the VECM. The cointegrating vectors are estimated instead by maximum likelihood as an interim step in performing the causality tests. The Saikkonen and Lütkepohl method further allows the data to be fitted by a more general infinite-order VAR process. This method is of interest in testing Granger-type causality because, in a VECM framework, the hypothesis of Granger noncausality is characterized by a set of zero restrictions which grows with the sample size. The general infinite-order process is approximated by fitting a finite-order model to the data, where the number of restrictions is fixed for any given sample size. The limiting χ^2 distribution of the test statistic is similarly derived under the assumption that the number of restrictions goes to infinity with the sample size.

For any I(1) n-vector time series Y_t, Saikkonen and Lütkepohl fit the following unrestricted k-order VECM by multivariate least squares

$$\Delta Y_t = \mu + \sum_{j=1}^{k} \Pi_j \Delta Y_{t-j} + \Psi Y_{t-1} + e_t \ , \qquad (3.8)$$

where μ, Π_j, j=1,...,k, Y_t, Y_{t-1}, and ΔY_t are defined as before. Ψ is known as the cointegration matrix. The finite order of the model, k, is chosen where k increases with the sample size in such a way that the assumption $k \sim o(T^{1/3})$ is satisfied. This assumption suggests an upper bound of $T^{1/3}$ for the order of the VECM where T is the sample size. In practice, a model selection criteria such as Akaike's AIC or Schwarz's SC may be used to determine the order of the VECM subject to the upper bound.

The estimator of the unknown parameters (μ, Π_j, Ψ) is given by

$$(\hat{\mu}, \hat{\Pi}_1, \ldots, \hat{\Pi}_k, \hat{\Psi}) = \Delta Y' \hat{Z}_2 (\hat{Z}_2' \hat{Z}_2)^{-1} \qquad (3.9)$$

where $\hat{Z}_2 = (1, \Delta Y_{t-1}, \ldots, \Delta Y_{t-k}, Y_{t-1})$. The estimated covariance matrix of e_t is

$$\hat{\Sigma}_e = N^{-1}\left[\Delta Y' \Delta Y - \Delta Y' \hat{Z}_2 (\hat{Z}_2' \hat{Z}_2)^{-1} \hat{Z}_2' \Delta Y\right] \qquad (3.10)$$

where N=T-k-1. Wald tests for Granger-type causality using the estimated parameter matrices $\hat{\Pi}_j$ and $\hat{\Psi}$ are now possible. For discussion of causality tests in this section, suppose the objective is to test whether there are causal effects from the

n_3 elements of Y_3 to the n_1 elements of Y_1. Partition the n-vector time series Y_t accordingly into three sub-vectors $Y_t = (Y_{1t}, Y_{2t}, Y_{3t})$ where $n_1+n_2+n_3=n$. Now define $\hat{\Psi}_1$ as the first n_1 columns of $\hat{\Psi}$, $\hat{\Psi}_2$ as the n_3 right-hand columns of $\hat{\Psi}$, and

$$\tilde{C} = -(\hat{\Psi}_1' \hat{\Sigma}_e^{-1} \hat{\Psi}_1)^{-1} \hat{\Psi}_1 \hat{\Sigma}_e^{-1} \hat{\Psi}_2 , \qquad (3.11)$$

where $\tilde{C}$ represents the maximum likelihood estimate of the matrix of cointegrating vectors. The null hypothesis of short-run noncausality from Y_3 to Y_1 based on the model (3.6) is formulated as

$$H_\lambda \left(Y_3 \to Y_1\right): R'\mathrm{vec}(\Psi_1, \Pi_1, \ldots, \Pi_k) = r \qquad (3.12)$$

where R is a known $((n + nn_1 + n^2k) \times J)$ selector matrix of full column rank and r is a known (J x 1) vector of constants. r is a (J x 1) vector of zeros when testing for short-run noncausality where → denotes the hypothesized direction of causality. The alternative hypothesis is that the estimated coefficients are not jointly equal to zero and a short-run Granger-causal relationship exists from Y_3 to Y_1. Under the null hypothesis H_λ,

$$F_\lambda = N\mathrm{vec}(\hat{\Phi}_\pi - \Phi_\pi)' R (R'(\hat{\Gamma}_{ECM}^{-1} \otimes \hat{\Sigma}_e) R)^{-1} R' \mathrm{vec}(\hat{\Phi}_\pi - \Phi_\pi) \xrightarrow{d} \chi_J^2 , \qquad (3.13)$$

where $\hat{\Phi}_\pi = \mathrm{vec}(\hat{\Psi}_1, \hat{\Pi}_1, \ldots, \hat{\Pi}_k)$, $\Phi_\pi = \mathrm{vec}(\Psi_1, \Pi_1, \ldots, \Pi_k)$,

$$\hat{\Gamma}_{ECM} = \frac{1}{N}\sum_{t=k+2}^{T}\begin{bmatrix}1\\ \hat{u}_{1,t-1}\\ \Delta Y_{t-1}\\ \vdots\\ \Delta Y_{t-k}\end{bmatrix}\left[1, \hat{u}_{1,t-1}, \Delta Y_{t-1}, \ldots, \Delta Y_{t-k}\right], \tag{3.14}$$

and

$$\hat{u}_{1,t-1} = Y_{1,t-1} - \tilde{C}Y_{3,t-1}\,. \tag{3.15}$$

The test statistic F_λ has a limiting χ^2 distribution with J degrees of freedom under the null hypothesis of noncausality. In the next chapter, the methodology for employing cointegration analysis and VECMs in tests of the Fama and Geske-Roll models is discussed.

CHAPTER IV

METHODOLOGY

Overview

The approach to developing an improved empirical test of the Fama (1981) and Geske and Roll (1983) theories is to resolve prior methodological problems and use recently developed techniques for modeling cointegrated time series. The application of the approach in testing the models is detailed in the following sections in the sequence in which the empirical procedures are performed. First, a variable set is proposed which remedies the methodological problems of variable selection and lag structure found in earlier works. Second, the role of the Augmented Dickey Fuller (ADF) unit root test in establishing the stationarity of the time series is discussed. The third section considers the process of testing for cointegration among the variables using the maximum-likelihood approach of Johansen and Juselius (1990). Fourth, the complementary nature of the two models is leveraged to develop a set of hypothesis tests for the presence of the short-run causal links suggested by the models. The approach to performing these hypothesis tests within the cointegrated vector error-correction model (VECM) frameworks of Toda and

Phillips (1993, 1994) and Saikkonen and Lütkepohl (1996) is then discussed. In the final section, a dummy variable is added to the VECMs in order to test the stability of the stock price-inflation relation in the policy change periods proposed by Kaul and Graham.

Variable Selection and Data

The tests use measures of stock prices, real activity, nominal money supply, and expected inflation. The inclusion of stock prices and real activity is not a point of contention in the literature. A money supply variable, however, is not used in all subsequent tests. Lee (1992) excludes a measure of the money supply from the system and cites the undocumented concern that it is correlated with inflation to such a degree that using both would result in one being redundant in the estimated model. A money supply variable is included in this study in order to test the pivotal role of the money supply in the models. Fama argues that the money supply is invariant to real activity, while Geske-Roll propose causal chains from money to real activity and from both stock prices and expected inflation to money.

Most of the uncertainty surrounding variable selection in existing tests concerns the choice of an expected inflation variable. In testing the 'proxy' hypothesis, Fama uses two measures of expected inflation - short-term nominal interest rates and multivariate forecasts of actual inflation using money and real activity. Geske-Roll, James, Koreisha, and Partch (1985), and Kaul (1987, 1990) use short-term nominal interest rates. Litterman and Weiss (1985) follow Fama and examine both nominal rates and expected inflation. Lee (1992) and Graham (1996) use actual inflation as a proxy for expected inflation, while Balduzzi (1996) uses both measures simultaneously in the estimated VAR. The present tests use both short-term nominal interest rates and multivariate forecasts of actual inflation as measures of expected inflation.[1] Estimating the models using both measures accomplishes two things. First, it allows a test of the Geske-Roll assertion that nominal interest rates may be causal for stock returns even if the expected inflation component of nominal rates is not. Using both measures further allows a test of the sensitivity of the results to the measure of expected inflation.

Several issues must be resolved when choosing observable time series for the empirical tests. In the original works, Fama uses real stock prices while Geske-Roll use nominal

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[1] The results from using a third measure of expected inflation, long-term nominal interest rates, are presented in Appendix I.

prices. The concern when choosing a stock price measure is that much of the inflationary 1960s and 1970s is characterized by positive nominal, but negative inflation-adjusted, stock returns. Fama firmly establishes his concern with real variables as he develops the theoretical link between real stock prices and real activity using a simplified version of Jorgenson's Accelerator model. Fama's stock return measure is the continuously compounded nominal return (excluding dividends) on the value-weighted portfolio of all New York Stock Exchange stocks less the annual continuously compounded Consumer Price Index inflation rate. Geske-Roll, on the other hand, measure stock price changes with the nominal return on the S&P 500 Composite stock index. While Geske-Roll do not address Fama's use of real stock prices, they assert that all asset prices should decline with increased expected inflation. And since the bulk of the literature is concerned with the Fisherian notion of real stock returns not offsetting inflation in the postwar period, the tests remain consistent with the literature and use real stock prices. The real stock price series used is the value-weighted S&P 500 Composite stock index divided by the Consumer Price Index.

Fama measures real economic output using Industrial Production, real Gross National Product, and the capital expenditures of nonfinancial corporations. He further notes a preference for Industrial Production because it represents the earliest available information on real activity. Geske-Roll instead use corporate earnings and the unemployment rate to measure real activity. They argue that these measures are more closely related to changes in tax receipts and are more consistent with their theoretical model. The bulk of the stock price-inflation literature, however, uses Industrial Production. To remain consistent with the literature the empirical tests use Industrial Production as a measure of real economic activity.

Both Fama and Geske-Roll use base money to measure the nominal money supply, arguing that it is the monetary measure most under the control of the Federal Reserve. The bulk of the stock price-inflation literature also uses the Monetary Base. Again, to remain consistent with the literature, the nominal money stock is measured with the Monetary Base adjusted for changes in reserve requirements using the method of the St. Louis Federal Reserve Bank.

Again, two measures of expected inflation are used - short term nominal interest rates and a multivariate estimate of next-period actual CPI inflation. The 3-month Treasury Bill yield (bid price on a discount basis) is used as a measure of short term nominal interest rates. The estimated expected inflation series is a multivariate estimate of the next period inflation rate formed from a 4-variable Vector-Autoregressive (VAR) model with six lags of actual CPI inflation, the Monetary Base, Industrial Production, and the real S&P 500 stock price index. The order of the VAR is determined using Akaike's AIC. Table 1 of Appendix A details the estimated coefficients of the VAR, while plots for actual and estimated next period CPI inflation are shown in Figure 1 of Appendix G.

The dataset contains quarterly observations for the S&P 500 Composite (SP) stock price index, real S&P 500 Composite (SPR) stock price index, Industrial Production (IP), the Monetary Base (MB), the 3-month Treasury Bill yield (ST), the estimated Expected Inflation series (EI), and the Consumer Price Index (CPI) in the 1950.1-1996.4 period. The S&P 500 Composite stock price index and the 3-month Treasury Bill yield (ST) are measured on the last trading day of each quarter. Summary statistics for the first difference of each time series are in Table 2 of Appendix A, while plots for each of the series are in Figures 2-4 of Appendix G. None of the variables is seasonally adjusted. The complete dataset appears in Appendix H.

Unit Root Tests

Many of the economic time series under investigation are known to possess a unit root, or are nonstationary in levels but stationary in differences. None of the existing tests of the theories discussed in chapter 2, however, uses recognized techniques for establishing the presence of a unit root in a time series. In this study, the formal Augmented Dickey-Fuller (ADF) stationarity test is applied to each of the five time series used in the models. Specifically, (3.1) is estimated using quarterly data in the 1950.1-1996.4 period for the real S&P 500 stock price index (SPR), the Monetary Base (MB), Industrial Production (IP), the 3-month Treasury bill yield (ST), and the estimated expected inflation series (EI). All variables except EI are in natural logarithms.

Existing work reaches a consensus on the I(1) status of real stock prices (SPR), Treasury bill yields (ST), and expected inflation (EI). Some uncertainty, however, surrounds the stationarity of the Industrial Production (IP) and Monetary Base (MB) series. As noted in chapter 2, James, Koreisha, and Partch (1985) find them to be I(2) in monthly data in the 1962-81 period. They estimate their VARMA model using second differences of the Monetary Base and 12-month changes in Industrial Production. The unit root tests are used to confirm that each of the quarterly time series is either I(0) or I(1). The Johansen and Juselius (1990) procedure requires either I(0) or I(1) time series. Both the Toda and Phillips (1993, 1994) and Saikkonen and Lütkepohl (1996) VECM techniques similarly require I(0) or I(1) time series.

Cointegration Tests

Cointegration tests serve to determine whether a long-run linear equilibrium relationship exists among the variables in the models. The maximum-likelihood approach of Johansen-Juselius is used to test for the presence of cointegration in the 1950.1-1996.4 period. Any significant cointegrating relations are later used in the VECM framework of Toda-Phillips to perform short-run causality tests. Failure to include these equilibrium relations in traditional short-run Granger causality tests results in invalid inferences. Because two measures of expected inflation are used, (3.2) is estimated using each measure. The first variable set contains real stock prices (SPR), the Monetary Base (MB), Industrial Production (IP), and the 3-month Treasury bill yield (ST), or $Y_t = [SPR_t \ \ IP_t \ \ MB_t \ \ ST_t]'$ in equation (3.2). The second set substitutes the estimated expected inflation (EI) series for nominal rates (M3), or $Y_t = [SPR_t \;\; IP_t \;\; MB_t \;\; EI_t]'$ in equation (3.2). The same two variable sets are used when performing short-run causality tests within the VECM frameworks of Toda-Phillips and Saikkonen-Lütkepohl.

Selecting the order of the estimated VECM in (3.2) requires special care. In general, underestimating the true order of the VECM can result in estimation bias and inconsistent parameter estimates. Two statistical model selection criteria are considered - Akaike's AIC and Schwarz's SC (Judge, et. al. p.848). In the case of AIC, the criterion for a model of order k is

$$AIC_k = \ln\left|\hat{\Sigma}_k\right| + 2k/T , \tag{4.1}$$

where T is the sample size and $\hat{\Sigma}_k$ is the variance-covariance matrix of Y. In the case of SC, the criterion for a model of order k is

$$SC_k = \ln\left|\hat{\Sigma}_k\right| + \ln(T)k/T , \tag{4.2}$$

where T and $\hat{\Sigma}_k$ are similarly defined. The Schwarz criterion tends to choose smaller models, on average, than the Akaike. DeSerres and Guay (1995) further demonstrate that the SC systematically underperforms the AIC and leads to a lag structure that is too parsimonious. The order of each estimated VECM is therefore selected using Akaike's AIC.

After deriving estimates of the cointegrating vectors, both the maximum eigenvalue and trace tests of Johansen-Juselius are used to determine the rank of the cointegrating matrix, Π. Among the four variables in Y_t there is the possibility of zero, one, two, or three cointegrating vectors. The null hypothesis is that there are r or fewer cointegrating vectors. The alternative hypothesis is that at least r+1 cointegrating vectors are present. A likelihood ratio test of whether each variable enters the cointegrating vectors significantly is then applied to each element of the significant cointegrating vectors of β. If each enters significantly, there is a cointegrating relationship governing the long-run movements among real stock prices, real activity, the nominal money supply, and expected inflation in the 1950.1-1996.4 period.

Vector Error-Correction Models

Vector Error-Correction models (VECMs) are used as a platform for performing valid short-run Granger causality tests within a cointegrated system of equations. Causality tests of this type are ideally suited for detecting the lead/lag relationships suggested by both models. Two versions of a 4-variable VECM are estimated using both the Toda-Phillips and

Saikkonen-Lütkepohl methods. The first version uses nominal interest rates (M3) as a measure of expected inflation, while the second version replaces nominal rates (M3) with the estimated expected inflation series (EI).

For the Toda-Phillips method, the 4-variable k-order VECMs in (4.3) and (4.4) are estimated using quarterly data in the 1950.1-1996.4 period. The order of the estimated VECMs is determined using Akaike's AIC. Equation (4.3) uses short-term nominal interest rates (ST) for expected inflation, while Equation (4.4) uses the estimated expected inflation series (EI) detailed in Table 1.

$$\begin{bmatrix} \Delta SPR_t \\ \Delta IP_t \\ \Delta MB_t \\ \Delta ST_t \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \end{bmatrix} + \Pi_1 \begin{bmatrix} \Delta SPR_{t-1} \\ \Delta IP_{t-1} \\ \Delta MB_{t-1} \\ \Delta ST_{t-1} \end{bmatrix} + \Pi_2 \begin{bmatrix} \Delta SPR_{t-2} \\ \Delta IP_{t-2} \\ \Delta MB_{t-2} \\ \Delta ST_{t-2} \end{bmatrix} + \ldots + \Pi_k \begin{bmatrix} \Delta SPR_{t-k} \\ \Delta IP_{t-k} \\ \Delta MB_{t-k} \\ \Delta ST_{t-k} \end{bmatrix} + \Gamma \hat{A}' \begin{bmatrix} SPR_{t-1} \\ IP_{t-1} \\ MB_{t-1} \\ ST_{t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \\ e_{4t} \end{bmatrix} \quad (4.3)$$

$$\begin{bmatrix} \Delta SPR_t \\ \Delta IP_t \\ \Delta MB_t \\ \Delta EI_t \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \end{bmatrix} + \Pi_1 \begin{bmatrix} \Delta SPR_{t-1} \\ \Delta IP_{t-1} \\ \Delta MB_{t-1} \\ \Delta EI_{t-1} \end{bmatrix} + \Pi_2 \begin{bmatrix} \Delta SPR_{t-2} \\ \Delta IP_{t-2} \\ \Delta MB_{t-2} \\ \Delta EI_{t-2} \end{bmatrix} + \ldots + \Pi_k \begin{bmatrix} \Delta SPR_{t-k} \\ \Delta IP_{t-k} \\ \Delta MB_{t-k} \\ \Delta EI_{t-k} \end{bmatrix} + \Gamma \hat{A}' \begin{bmatrix} SPR_{t-1} \\ IP_{t-1} \\ MB_{t-1} \\ EI_{t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \\ e_{4t} \end{bmatrix} \quad (4.4)$$

In each equation, the first difference of each dependent variable is regressed on k lagged differences and the lagged level of all four variables. $\hat{A}$ denotes the Johansen-Juselius maximum likelihood estimate of the r significant cointegrating eigenvectors of Y_t. These cointegrating constraints are directly imposed on the VECM as shown in (4.3) and (4.4) and estimates of the unknown parameters μ_i, Π_j, and Γ are obtained. The estimated Π_j, j=1,…,k, are used in the next section to construct short-run causality tests of the Fama and Geske-Roll models.

For the Saikkonen-Lütkepohl method, the 4-variable k-order VECMs in (4.5) and (4.6) are estimated using quarterly data in the 1950.1-1996.4 period.

$$\begin{bmatrix} \Delta SPR_t \\ \Delta IP_t \\ \Delta MB_t \\ \Delta ST_t \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \end{bmatrix} + \Pi_1 \begin{bmatrix} \Delta SPR_{t-1} \\ \Delta IP_{t-1} \\ \Delta MB_{t-1} \\ \Delta ST_{t-1} \end{bmatrix} + \Pi_2 \begin{bmatrix} \Delta SPR_{t-2} \\ \Delta IP_{t-2} \\ \Delta MB_{t-2} \\ \Delta ST_{t-2} \end{bmatrix} + \ldots + \Pi_k \begin{bmatrix} \Delta SPR_{t-k} \\ \Delta IP_{t-k} \\ \Delta MB_{t-k} \\ \Delta ST_{t-k} \end{bmatrix} + \Psi \begin{bmatrix} SPR_{t-1} \\ IP_{t-1} \\ MB_{t-1} \\ ST_{t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \\ e_{4t} \end{bmatrix} \quad (4.5)$$

$$\begin{bmatrix} \Delta SPR_t \\ \Delta IP_t \\ \Delta MB_t \\ \Delta EI_t \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \end{bmatrix} + \Pi_1 \begin{bmatrix} \Delta SPR_{t-1} \\ \Delta IP_{t-1} \\ \Delta MB_{t-1} \\ \Delta EI_{t-1} \end{bmatrix} + \Pi_2 \begin{bmatrix} \Delta SPR_{t-2} \\ \Delta IP_{t-2} \\ \Delta MB_{t-2} \\ \Delta EI_{t-2} \end{bmatrix} + \ldots + \Pi_k \begin{bmatrix} \Delta SPR_{t-k} \\ \Delta IP_{t-k} \\ \Delta MB_{t-k} \\ \Delta EI_{t-k} \end{bmatrix} + \Psi \begin{bmatrix} SPR_{t-1} \\ IP_{t-1} \\ MB_{t-1} \\ EI_{t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \\ e_{4t} \end{bmatrix} \quad (4.6)$$

As in the Toda-Phillips method, the first difference of each dependent variable is regressed on k lagged differences and the lagged level of all four variables. The procedure differs though in that the cointegrating vectors from the Johansen-Juselius method are not imposed on the VECM prior to obtaining estimates for the unknown parameters μ_i, Π_j, and Ψ. Instead, the lagged level of each variable is directly included as an explanatory variable in the VECM. The estimated Π_j, j=1,…,k, and Ψ are used to construct short-run causality tests of the Fama and Geske-Roll models. The order of the estimated

VECMs is determined using Akaike's AIC. In the next section, the procedure for using the estimated parameters from the VECMs in (4.3)-(4.6) to conduct short-run Granger-causality tests is discussed.

Short-Run Causality Tests

The VECM frameworks of Toda-Phillips and Saikkonen-Lütkepohl are used to test seven key short-run Granger-casual relations among real stock prices (SPR), real activity (IP), the money supply (MB), and expected inflation (ST and EI). In practice, the null hypothesis of Granger-noncausality from vector Y_1 to vector Y_2 is tested by using a set of zero restrictions on the coefficients of the lagged differences of Y_1 in the equation of the VECM with Y_2 as the dependent variable. The alternative hypothesis is that the coefficients are not jointly equal to zero and that a Granger-causal relation exists from Y_1 to Y_2. In notation, the null hypothesis is $H_0(Y_1 \rightarrow Y_2): \Pi_{1,Y_1} = \ldots = \Pi_{k,Y_1} = 0$ and the alternative hypothesis is $H_A(Y_1 \rightarrow Y_2): \Pi_{1,Y_1} \neq \ldots \neq \Pi_{k,Y_1} \neq 0$.

The hypothesis tests reflect the fact that the Geske-Roll theory is a direct extension of the Fama theory. The first set of tests evaluates the causal links common to both theories, while the remainder of the tests concern those aspects of the

Geske-Roll model which are extensions of the Fama model. The two causal links common to both theories are:

1. Do changes in real stock prices Granger-cause changes in real activity? Both theories suggest that real activity is the primary force driving stock price movements. The ability of stock prices to forecast future real activity is consistently found in the literature. The null hypothesis of Granger-noncausality from real stock prices (SPR) to real activity (IP) is $H_1(\mathrm{SPR} \rightarrow \mathrm{IP}): \Pi_{1,\mathrm{SPR}} = \ldots = \Pi_{k,\mathrm{SPR}} = 0$, where the $\Pi_{i,\mathrm{SPR}}$'s are the k estimated coefficients corresponding to the lagged differences of SPR in the estimated equation of each VECM with IP as the dependent variable. The alternative hypothesis is Granger-causality from real stock prices (SPR) to real activity (IP).

2. Do changes in inflationary expectations Granger-cause changes in real activity? This is a pivotal causal link in both the Fama and Geske-Roll models. Fama suggests that a rational expectations version of the quantity theory explains the link while Geske-Roll detail a mechanism driven by postwar deficit financing. The null hypothesis of Granger-noncausality from expected inflation (ST/EI) to real activity (IP) is $H_2(\mathrm{ST/EI} \rightarrow \mathrm{IP}): \Pi_{1,\mathrm{ST/EI}} = \ldots = \Pi_{k,\mathrm{ST/EI}} = 0$, where the $\Pi_{i,\mathrm{ST/EI}}$'s are the k estimated coefficients corresponding to the lagged differences of either ST or EI in the estimated equation of each VECM with

IP as the dependent variable. The alternative hypothesis is Granger-causality from expected inflation (ST/EI) to real activity (IP).

Three money supply-related causal links suggested by Geske-Roll are tested next.

3. <u>Do changes in the money supply Granger-cause changes in real activity?</u> This is the most sharply contrasting element of the proposed theories. Fama suggests that the money supply is invariant to changes in real activity, while Geske-Roll argue that variation in the money supply, in response to changes in real activity, is the primary causal factor generating the postwar inverse stock price-inflation relation. The null hypothesis of Granger-noncausality from the money supply (MB) to real activity (IP) is $H_3(MB \rightarrow IP): \Pi_{1,MB} = \ldots = \Pi_{k,MB} = 0$, where the $\Pi_{i,MB}$'s are the k estimated coefficients corresponding to the lagged differences of MB in the estimated equation of each VECM with IP as the dependent variable. The alternative hypothesis is Granger-causality from the money supply (MB) to real activity (IP).

4. <u>Do changes in real stock prices Granger-cause changes in the money supply?</u> If the money supply-based argument of Geske-Roll is accurate, stock prices should forecast changes in both the money supply and real activity. Fama argues against a link

from stock prices to money. The null hypothesis of Granger-noncausality from real stock prices (SPR) to the monetary base (MB) is $H_4(\mathrm{SPR} \rightarrow \mathrm{MB})\colon \Pi_{1,\mathrm{SPR}} = \ldots = \Pi_{k,\mathrm{SPR}} = 0$, where the $\Pi_{i,\mathrm{SPR}}$'s are the k estimated coefficients corresponding to the lagged differences of SPR in the estimated equation of each VECM with MB as the dependent variable. The alternative hypothesis is Granger-causality from real stock prices (SPR) to the monetary base (MB).

5. <u>Do changes in inflationary expectations Granger-cause changes in the money supply?</u> Geske-Roll propose two possible causal chains from money supply expansion to inflationary expectations - monetization and debt expansion. Fama suggests that this link should not be significant. The null hypothesis of Granger noncausality from expected inflation (ST/EI) to the money supply (MB) is $H_5(\mathrm{ST/EI} \rightarrow \mathrm{MB})\colon \Pi_{1,\mathrm{ST/EI}} = \ldots = \Pi_{k,\mathrm{ST/EI}} = 0$, where the $\Pi_{i,\mathrm{ST/EI}}$'s are the k estimated coefficients corresponding to the lagged differences of either ST or EI in the estimated equation of each VECM with MB as the dependent variable. The alternative hypothesis is Granger-causality from expected inflation (ST/EI) to the money supply (MB).

The final tests examine the link between stock prices and the two expected inflation measures:

6. Is a statistically significant relationship between inflationary expectations and stock returns present in a model containing real output and money? Fama suggests that the relationship should disappear in the presence of real output and money, while Geske-Roll contend that theory allows an observed inverse comovement between inflation and stock prices. The two measures of expected inflation used will also allow us to test Geske-Roll's suggested link between nominal rates and stock prices even if no link is found between the expected inflation component of interest rates and stock prices. The null hypothesis of Granger noncausality from expected inflation (ST/EI) to real stock prices (SPR) is $H_6(ST/EI \rightarrow SPR): \Pi_{1,ST/EI} = \ldots = \Pi_{k,ST/EI} = 0$, where the $\Pi_{i,ST/EI}$'s are the k estimated coefficients corresponding to the lagged differences of either ST or EI in the estimated equation of each VECM with SPR as the dependent variable. The alternative hypothesis is Granger-causality from expected inflation (ST/EI) to real stock prices (SPR).

7. Is a causal relationship from stock prices to expected inflation, or a feedback effect, present? The Geske-Roll theory allows for reversed causality, or a feedback effect from inflation to stock prices. The null hypothesis of Granger-noncausality from real stock prices (SPR) to expected inflation

(ST/EI) is $H_7(\mathrm{SPR} \rightarrow \mathrm{ST/EI}): \Pi_{1,\mathrm{SPR}} = \ldots = \Pi_{k,\mathrm{SPR}} = 0$, where the $\Pi_{i,\mathrm{SPR}}$'s are the k estimated coefficients corresponding to the lagged differences of SPR in the estimated equation of each VECM with either ST or EI as the dependent variable. The alternative hypothesis is Granger-causality from real stock prices (SPR) to expected inflation (ST/EI).

Policy Change Period

Tests of the sensitivity of the stock price-inflation relation to the operating policy of the Federal Reserve are performed using dummy variable tests of parameter stability. A multiplicative dummy variable is created using the two expected inflation variables, ST and EI, and D , where D equals one during the policy change periods, and zero otherwise. The policy change periods suggested by Graham and Kaul are 1976Q1-1982Q1 and 1979Q1-1986Q4, respectively. Equations (4.7)-(4.10) are estimated using the Toda-Phillips VECM framework as shown in (4.7)-(4.8), and the Saikkonen-Lütkepohl method as in (4.9)-(4.10).

$$\begin{bmatrix}\Delta \mathrm{SPR}_t\\ \Delta \mathrm{IP}_t\\ \Delta \mathrm{MB}_t\\ \Delta \mathrm{ST}_t\end{bmatrix} = \begin{bmatrix}\mu_1\\ \mu_2\\ \mu_3\\ \mu_4\end{bmatrix} + \Pi_1 \begin{bmatrix}\Delta \mathrm{SPR}_{t-1}\\ \Delta \mathrm{IP}_{t-1}\\ \Delta \mathrm{MB}_{t-1}\\ \Delta \mathrm{ST}_{t-1}\end{bmatrix} + \ldots + \Pi_k \begin{bmatrix}\Delta \mathrm{SPR}_{t-k}\\ \Delta \mathrm{IP}_{t-k}\\ \Delta \mathrm{MB}_{t-k}\\ \Delta \mathrm{ST}_{t-k}\end{bmatrix} + \sum_{j=1}^{k} B_j D \Delta \mathrm{ST}_{t-j} + \Gamma \hat{A}' \begin{bmatrix}\mathrm{SPR}_{t-1}\\ \mathrm{IP}_{t-1}\\ \mathrm{MB}_{t-1}\\ \mathrm{ST}_{t-1}\end{bmatrix} + \begin{bmatrix}e_{1t}\\ e_{2t}\\ e_{3t}\\ e_{4t}\end{bmatrix} \quad (4.7)$$

$$\begin{bmatrix} \Delta SPR_t \\ \Delta IP_t \\ \Delta MB_t \\ \Delta EI_t \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \end{bmatrix} + \Pi_1 \begin{bmatrix} \Delta SPR_{t-1} \\ \Delta IP_{t-1} \\ \Delta MB_{t-1} \\ \Delta EI_{t-1} \end{bmatrix} + \ldots + \Pi_k \begin{bmatrix} \Delta SPR_{t-k} \\ \Delta IP_{t-k} \\ \Delta MB_{t-k} \\ \Delta EI_{t-k} \end{bmatrix} + \sum_{j=1}^{k} B_j D \Delta EI_{t-j} + \Gamma \hat{A}' \begin{bmatrix} SPR_{t-1} \\ IP_{t-1} \\ MB_{t-1} \\ EI_{t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \\ e_{4t} \end{bmatrix} \quad (4.8)$$

$$\begin{bmatrix} \Delta SPR_t \\ \Delta IP_t \\ \Delta MB_t \\ \Delta ST_t \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \end{bmatrix} + \Pi_1 \begin{bmatrix} \Delta SPR_{t-1} \\ \Delta IP_{t-1} \\ \Delta MB_{t-1} \\ \Delta ST_{t-1} \end{bmatrix} + \ldots + \Pi_k \begin{bmatrix} \Delta SPR_{t-k} \\ \Delta IP_{t-k} \\ \Delta MB_{t-k} \\ \Delta ST_{t-k} \end{bmatrix} + \sum_{j=1}^{k} B_j D \Delta ST_{t-j} + \Psi \begin{bmatrix} SPR_{t-1} \\ IP_{t-1} \\ MB_{t-1} \\ ST_{t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \\ e_{4t} \end{bmatrix} \quad (4.9)$$

$$\begin{bmatrix} \Delta SPR_t \\ \Delta IP_t \\ \Delta MB_t \\ \Delta EI_t \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \mu_4 \end{bmatrix} + \Pi_1 \begin{bmatrix} \Delta SPR_{t-1} \\ \Delta IP_{t-1} \\ \Delta MB_{t-1} \\ \Delta EI_{t-1} \end{bmatrix} + \ldots + \Pi_k \begin{bmatrix} \Delta SPR_{t-k} \\ \Delta IP_{t-k} \\ \Delta MB_{t-k} \\ \Delta EI_{t-k} \end{bmatrix} + \sum_{j=1}^{k} B_j D \Delta EI_{t-j} + \Psi \begin{bmatrix} SPR_{t-1} \\ IP_{t-1} \\ MB_{t-1} \\ EI_{t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \\ e_{4t} \end{bmatrix} \quad (4.10)$$

Tests for changes in the stock price-inflation relation in the two periods are performed by testing the significance of the dummy variable coefficients in the equation of each VECM with real stock prices (SPR) as the dependent variable. The final step is to check for changes in the causal relations found in the original VECM-based causality tests.

The results of the empirical tests are detailed in the next chapter. First, findings from the unit root tests of stationarity are discussed. Second, the cointegrating relations identified using the Johansen-Juselius method are compared to the behavior predicted by Fama and Geske-Roll. Third, the findings from the estimated VECMs and causal conclusions from the short-run Granger causality tests are used to evaluate the Fama and Geske-Roll stock price-inflation models. The chapter concludes with a discussion of the dummy variable tests of the sensitivity of the estimated expected inflation parameters during the policy regime periods proposed by Kaul and Graham.

CHAPTER V

FINDINGS

Overview

The results of the empirical tests of the two stock price-inflation models are reported in this chapter. Augmented Dickey-Fuller (ADF) unit root tests indicate that each of the time series is difference stationary, or has a unit root. Tests for cointegration suggest the presence of a significant long-run equilibrium relationship among real stock prices, real activity, nominal money, and expected inflation in the 1950.1-1996.4 period. The long-run tendency of stock prices is to increase with real activity and decline in response to higher expected inflation and nominal money expansion.

Short-run causality tests suggest that neither model provides a complete explanation of the postwar inverse stock price-inflation relation. Strong evidence of a causal link from stock prices to real activity is found, but the tests provide only limited support for a significant inverse causal link from expected inflation to future real activity. Limited support is similarly found for the short-run money supply linkages proposed by Geske-Roll. Dummy variable tests also fail to validate the presence of a significantly different stock price-inflation relation in the policy change periods proposed by Kaul and Graham. Each finding is discussed in the following sections.

Unit Root Tests

The results of the Augmented Dickey-Fuller (ADF) unit root tests are presented in Table 3 of Appendix B. The data span the 1950.1-1996.4 period and all variables except the estimated expected inflation series (EI) are in natural logarithms. Following Schwert (1987, 1989), up to twelve lags are used in the ADF tests and the number of significant lags is noted in parentheses. All insignificant lags are dropped from the regression unless their elimination produces serial correlation. Following Dickey and Pantula (1987), each time series is tested first for two unit roots. If the null hypothesis of two unit roots is rejected, the series is tested for the presence of a single unit root.

As Table 3 shows, the null hypothesis of two unit roots is rejected at the 5 percent level of significance for all five series. Subsequent tests for a single unit root fail to reject the null hypothesis for all five series. This suggests that the variables are nonstationary in levels and stationary in differences, i.e. are I(1). In other words, the ADF tests indicate that each variable contains a single unit root. These results are consistent with the bulk of the stock price inflation literature, as well as unit root tests in Chowdhury (1993), Masih and Masih (1996), and Choudhry (1996). They differ, however, from the finding of James, Koreisha, and Partch (1985) of I(2) Monetary Base and Industrial Production. Furthermore, the I(1) nature of the variables makes them suitable for use in the cointegration and short-run causality tests in the following sections.

Cointegration Tests

The results from the Johansen and Juselius cointegration tests are presented in Table 4 of Appendix B. The first test examines cointegration between the real S&P 500 stock price index (SPR), Industrial Production (IP), the Monetary Base (MB), and the 3-month Treasury Bill yield (ST). The second test replaces the 3-month Treasury Bill yield (ST) with the estimated expected inflation series (EI).

Implementation of the Johansen and Juselius (1990) procedure requires choosing a lag length for the estimated VECM. The results using Akaike's AIC indicate that the optimum lag length is eight for both measures of expected inflation. Both versions of (3.2) are estimated with eight lagged differences and the lagged level of each variable. Hypothesis tests for the presence of r cointegrating relations among the four variables are conducted using both the maximum eigenvalue and trace test statistics from Johansen-Juselius. Among four variables there is the possibility of zero, one, two, or three cointegrating vectors. The associated null and alternative hypotheses are shown at the top of each column in Table 4.

As indicated there, the cointegration tests using the Treasury Bill yield (ST) as a measure of expected inflation reject the null hypotheses $r=0$ and $r\leq1$ using both the maximum eigenvalue and trace test statistics at the 5% significance level. These tests, however, fail to reject the null hypotheses $r\leq2$ and $r\leq3$ using both the maximum eigenvalue and trace test statistics. This implies that there are two significant cointegrating vectors, or stationary linear relationships, among the four variables. The results are the same using the estimated expected inflation series (EI). The null hypotheses $r\leq2$ and $r\leq3$ cannot be rejected using either the maximum eigenvalue or trace test statistics, but the hypotheses $r=0$ and $r\leq1$ are rejected by both tests at the 5% significance level. Therefore, the tests suggest the presence of two linear long-run equilibrium, or cointegrating, relationships among real stock prices, real activity, nominal money, and expected inflation.

Although the evidence indicates that a long-run linear relationship exists among the variables, of further interest is whether each variable enters the cointegrating vectors significantly. If all four enter significantly, the long-run movement of each variable is jointly constrained by the estimated relations. Table 5 of Appendix B details likelihood ratio tests of the null hypothesis that the coefficients within the cointegrating vectors for an individual variable are zero. Since two significant cointegrating vectors are found with each measure of expected inflation, the tests consist of zero restriction across both vectors.

The first null hypothesis in Table 5, $H_o:B_{SPR1}=B_{SPR2}=0$, tests whether the coefficients on real stock prices (SPR) in the first and second cointegrating vectors are jointly equal to zero. Similar hypothesis tests are performed on each coefficient of the significant estimated cointegrating vectors using both measures of expected inflation. The test statistics have a $\chi^2(2)$ distribution under the null hypothesis that the coefficients jointly equal zero. The alternative hypothesis is that the coefficients are not jointly equal to zero. The findings in Table 5 suggest that all four variables enter the cointegrating vectors significantly at the 1% level. The results are consistent using either measure of expected inflation and indicate that long-run movements among real stock prices, real activity, nominal money supply, and expected inflation are jointly governed by a cointegrating relationship.

The empirical estimates of the cointegrating vectors provide additional insight into the postwar stock price-inflation relation. To give the estimated long-run relations economic meaning, the vectors are normalized on real stock prices (SPR) by setting the estimated coefficient on SPR equal to -1 and dividing the other elements of the cointegrating vector by the negative of the estimated SPR coefficient. This normalization yields estimates of the long-run elasticities between the time series.

The normalized cointegrating vectors are shown in Table 5. The signs on the coefficients suggest that the long-run tendency of stock prices is to increase with real activity, but decline in response to nominal money expansion and higher expected inflation. The signs are consistent using either measure of expected inflation. Although neither Fama nor Geske-Roll distinguish between the short and long-run relations among the variables, the positive relationship between Industrial Production and real stock prices is consistent with the behavior suggested by both theories, as well as conventional wisdom that stock prices increase with real economic activity in the long-run.

The inverse long-run linkages between stock prices and both nominal money and expected inflation, however, are more consistent with Geske-Roll than with Fama. Fama argues that the observed inverse relationship between stock prices and expected inflation becomes insignificant when real activity and money are present in the estimated model. Geske and Roll suggest that the relationship is not only observable, but that it also can present itself through either of the expected inflation measures used, nominal interest rates or expected inflation. The finding of a long-run inverse linkage between base money and real stock prices is also consistent with Geske-Roll, and strongly counter to the Fama model.

The finding of cointegration has several implications for the models. First, it rules out the possibility of a spurious relationship between the variables in the competing frameworks. Each model suggests that the observed correlation between stock prices and inflation is spurious in nature. Second, the VAR-based tests of Litterman and Weiss (1985), James, Koreisha, and Partch (1985), Lee (1992), and Balduzzi (1996) ignore valuable long-run information concerning the interaction between the levels of the variables. Further, conclusions from the VAR-based causality tests concerning the Fama and Geske-Roll models are suspect. Third, a short-run Granger-causal relationship exists in at least one direction between the variables in models, and the direction of the causal relationships can be detected within a VECM framework incorporating the long-run cointegrating constraints. In the next section, the cointegrating relations are used to estimate a VECM representation of the proposed systems.

Vector Error-Correction Model Estimates

The VECMs in (4.3)-(4.6) are estimated using the frameworks of Toda and Phillips (1993, 1994) and Saikkonen and Lütkepohl (1996), hereafter referred to as the TP and SL methods, respectively. As in the cointegration tests, the first set of VECMs use the real S&P 500 stock price index (SPR), Industrial Production (IP), the Monetary Base (MB), and the 3-month Treasury Bill yield (ST). The 3-month Treasury Bill yield (ST) is replaced with the estimated expected inflation series (EI) in the second set of VECMs. All data are quarterly in the 1950.1-1996.4 period and all variables except EI are in natural logarithms.

Using Akaike's AIC, a lag length of six is selected for both the TP and SL methods. Because TP find that Granger-causality tests in VECMs are sensitive to underfitting the true lag length, results are reported for lag lengths of six and eight quarters, noted as VECM(6) and VECM(8), respectively. Tables 6-9 of Appendix C contain the results for the VECM(6) and VECM(8) models estimated with the TP method using, first, ST, and then, EI, for expected inflation. Tables 10-13 of Appendix C contain the results for the same set of VECMs estimated with the SL method. For each equation of the estimated models the adjusted R^2 and test statistics for the Durbin-Watson test of first-order serial correlation, the Jarque-Bera test for normality of the residuals, a test for ARCH residuals, and the Ramsey RESET specification test (see SHAZAM 7.0 User's Manual) are reported.

Note that the difference between the output for the two methods in Tables 6-13 is the independent variables representing the long-run effect of the level of the variables. The TP method (Tables 6-9) incorporates the information from the two significant cointegrating vectors as lagged error correction terms, $ECT1_{t-1}$ and $ECT2_{t-1}$, while the SL method (Tables 10-13) directly includes the lagged level of all four variables in the estimated VECM. Because the set of lagged differenced explanatory variables is identical in the two methods, the short-run parameter estimates are generally similar in sign and magnitude. In the next section, the estimated coefficients from the VECMs are used to perform short-run causality tests of the key linkages proposed by Fama and Geske-Roll.

Short-Run Causality Tests

Tables 14-17 of Appendix D contain the results of short-run Granger-causality tests among real stock prices, real activity, nominal money, and expected inflation. The hypothesis tests are labeled H_1-H_7 and consist of zero restrictions on the coefficients in the estimated VECMs detailed in Tables 6-13. Tables 14-15 summarize the results using the TP method, while Tables 16-17 contain the results using the SL method. The test statistics have a $\chi^2(k)$ distribution under the null hypothesis of noncausality in the TP method, where k is the order of the estimated VECM, and a $\chi^2(1)$ distribution under the null hypothesis of noncausality in the SL method. Table 18 provides a convenient summary of the significant causal findings using each VECM modeling technique.

The first short-run causal relation of interest is the proposed positive link between stock prices (SPR) and future real activity (IP), or H_1 in Table 18. The VECM parameter estimates in Tables 6-13 indicate that stock prices have a consistent positive relationship with future real activity using both the TP and SL methods at both lag lengths and with either measure of expected inflation in the model. The short-run causality test H_1 in Table 18 indicates a Granger-causal relationship from stock prices to real activity using both VECM techniques and with both measures of expected inflation. This finding is consistent with both Fama and Geske-Roll, as well as all prior tests of the theories. It is also consistent with the positive long-run link found between stock prices and real activity in the cointegration analysis.

The second causality test examines the pivotal inverse link between expected inflation (ST/EI) and future real activity (IP), or H_2 in Table 18. This link is suggested in both theoretical frameworks. The results, however, provide only weak support for the inverse relationship reported by Fama and Geske-Roll. The coefficients on the estimated expected inflation series (EI) are mostly negative using both the TP and SL methods, but are consistently positive using short term nominal interest rates (ST) as a measure of expected inflation. With the TP method, a causal relationship is significant from expected inflation (EI) to real activity (IP) using six lags.

A significant causal link from nominal rates (ST) to real activity (IP) is similarly found using both six and eight lags. However, neither of the expected inflation measures is Granger-causal for real activity using the SL method. Lee (1992) similarly finds a negative but insignificant link in the short-run using nominal interest rates.

The next three relationships of interest concern the pivotal role of the nominal money supply in the Geske-Roll model. These hypothesis tests are labeled H_3, H_4, and H_5 in Table 18. H_3 is a test of their suggestion that deficit driven money supply changes are inversely related to future changes in real activity. The results in Tables 6-13, however, show that monetary expansion leads to higher real activity in the short run. The coefficients from money supply (MB) to real activity (IP) using both the SL and TP methods and either measure of expected inflation are consistently positive. The causality tests in Table 18 further suggest a significant short-run Granger-causal link from nominal money to real activity. This finding is in sharp contrast to both the Fama and Geske-Roll models.

Geske-Roll further suggest that if a causal link from money to real activity exists, both stock prices and expected inflation should forecast future changes in the money supply.

These two links are tested with hypotheses H_4 and H_5. The Geske-Roll theory predicts that expected inflation is positively, and real stock prices inversely, related to future changes in the money supply. Tables 6-13 show that the coefficients from both expected inflation and stock prices to money are mostly negative using both VECM methods. The Granger-causality tests indicate that the link from stock prices to nominal money is insignificant using both the TP and SL methods. There is some support, however, for a causal link from expected inflation to money. As Table 18 shows, a consistent causal link is found from nominal rates (ST) to the nominal money supply (MB) using both techniques, but is insignificant for the estimated expected inflation series (EI) using the SL method. On balance, the evidence does not support the presence of the three short-run money supply linkages suggested by Geske-Roll.

Finally, the causal relationship between expected inflation and stock prices is examined. The earlier finding of cointegration indicates that a short-run Granger-causal relationship exists between the variables in at least one direction. These hypothesis tests are labeled H_6 and H_7 in Table 18. The two theoretical models differ greatly in that Fama suggests the stock price-inflation relationship should be insignificant in the presence of money and real activity, while Geske-Roll posit that an inverse relationship may present itself through either nominal interest rates or the expected inflation component of nominal rates.

Using both the TP and SL methods, the results in Tables 6-13 show consistently negative coefficients from nominal interest rates (ST) to stock prices (SPR), but small positive coefficients from expected inflation (EI) to stock prices (SPR). The causality tests in Table 18 suggest a Granger-causal link from nominal interest rates (ST) to stock prices (SPR) using both the TP and SL methods, but only in the models with eight lags. A significant causal link from expected inflation (EI) to stock prices (SPR) is similarly found using both methods. The large negative coefficients on nominal rates (ST) are consistent with Geske-Roll's assertion that a significant inverse relationship may exist between stock prices and nominal interest rates even if the expected inflation component is not inversely related. The positive coefficients from expected inflation (EI) to stock prices (SPR) suggest that some of the uncertainty concerning this link in existing works is due to the measure of expected inflation. In order to assess the impact of the measure used, Appendix I contains the results of causality tests using a third measure of expected inflation, long-term interest rates.

The final hypothesis test examines the reverse link from stock prices to expected inflation, or H_7 in Table 18. If a causal relation exists in both directions a feedback effect is present. Geske-Roll suggest that reversed causality, or a feedback effect, between expected inflation and stock prices is possible. The estimated coefficients in Tables 6-13 are consistently positive using either measure of expected inflation and with both the TP and SL methods. The causality tests in Table 18 provide strong evidence of a causal link from stock prices (SPR) to nominal rates (ST), but less conclusive evidence of a causal link from stock prices (SPR) to expected inflation (EI). Titman and Warga (1989) similarly find a positive link from stock prices to both expected inflation and nominal interest rates. They suggest that a rational expectations approach implies that if stock prices react to changes in expected inflation, then stock prices must be a reliable predictor of future inflation and nominal interest rates. They explain the anomalous positive sign of the relationship as evidence of a positive link between future real activity and future inflation, the opposite of the relationship suggested by Fama and Geske-Roll.

In the presence of the cointegrating constraints, the short-run causality tests provide a different view of the stock price-inflation relation than found in the original Fama and Geske-Roll works. The evidence supports the presence of a Granger-causal link from stock prices to real activity, but the critical link suggested by both works of a link from expected inflation to real activity is less certain. The remainder of the short-run causality tests are not entirely consistent with either model. Geske-Roll suggest three roles for the nominal money supply but none are supported by the data. Fama argues that the link between expected inflation and stock prices is spurious but the evidence supports the existence of a causal channel. Additional findings include a positive Granger-causal link from nominal money to real activity and a feedback effect from stock prices to inflation.

Policy Change Period

The final objective is to examine the stability of the estimated causal relations during the policy change periods proposed by Kaul and Graham. The VECMs in (4.7)-(4.10) are estimated using a multiplicative dummy variable for expected inflation in the policy change periods. Dummy variable D_1 corresponds to the 1976.1-1982.1 period suggested by Graham, while D_2 covers the 1979.1-1986.4 period suggested by Kaul. If either model accurately describes the behavior of stock prices and expected inflation in the respective policy change period, the estimated coefficients on the dummy variables are expected to be positive. Stock prices should further exhibit an insignificant or positive relationship with nominal interest rates (ST) as well as a stronger positive relationship with expected inflation (EI) when the dummy variable is included in the VECM.

The results for each equation of the estimated VECMs with stock prices (SPR) as the dependent variable are shown in Tables 19-26 of Appendix E. The results are reported for lag lengths of six and eight, again, noted as VECM(6) and VECM(8), respectively. The estimated coefficients in the VECMs show a consistent positive sign for both dummy variables in the policy change periods as predicted by Kaul and Graham. Though positive in sign, hypothesis tests that the estimated coefficients on the multiplicative dummy variables are jointly equal to zero are performed. Table 27 contains the results from these tests. The test statistics have a $\chi^2(k)$ distribution under the null hypothesis in the TP method, where k is the order of the estimated VECM, and a $\chi^2(1)$ distribution under the null hypothesis in the SL method.

Though consistently positive in sign, the results show that the dummy variables are not significantly different from zero at the 5% level in either proposed policy change period. The only significant hypothesis test contains ST in the 1976.1-1982.1 period using the SL method with eight lags. The coefficients on the lagged differences of nominal interest rates (ST), however, continue to have a negative sign and are greater in magnitude than the positive dummy variable coefficients. The coefficients on the lagged differences of expected inflation (EI) similarly maintain a positive sign and are similar in magnitude to the original estimates. Neither set of coefficients on the original lagged differenced variables suggests a significant change in the relationship during the policy change period.

Although the dummy variables are deemed insignificant, for completeness, the short-run causality tests from the prior section are examined for changes in the causal conclusions in the presence of the dummy variables. Any changes in the causal conclusions suggests that the models are misspecified. The causality tests are repeated using the estimated coefficients from the VECMs in (4.5)-(4.8). The results of these tests are shown in Tables 28-31 of Appendix F and are similar to the original causal findings. Consistent evidence of causal links from both nominal interest rates (ST) and expected inflation (EI) to stock prices (SPR) is found in the presence of the dummy variables. Strong support of a causal link from stock prices (SPR) to nominal rates (ST) is present, but less consistent support for a causal link from stock prices (SPR) to the expected inflation (EI) series is found.

The results from the dummy variable tests do not support the finding of Kaul and Graham of a significantly different stock price-inflation relation in the proposed policy change periods. The data fail to confirm the presence of a significant change in the original coefficients of the estimated VECMs during either policy change period. The link between nominal interest rates (M3) and stock prices (SPR) remains inverse and Granger-causal in the proposed periods. The link between expected inflation (EI) and stock prices (SPR) likewise remains positive and significant. Evidence of causal feedback between stock prices and expected inflation is similarly found in the presence of the dummy variables.

CHAPTER VI

CONCLUSION

This dissertation addresses the stock price-inflation models of Fama (1981) and Geske and Roll (1983) by employing recently developed econometric tools. The approach differs from existing tests in that it accounts for cointegrating relationships among the variables. Vector error-correction models (VECMs) incorporating these cointegrating constraints are also used to perform short-run causality tests of the Fama and Geske-Roll models.

Tests for cointegration using the maximum-likelihood approach of Johansen and Juselius (1990) indicate in the postwar period a linear long-run equilibrium relationship among real stock prices, real economic activity, nominal money, and expected inflation. The results further show that each variable enters the cointegrating vectors significantly and suggest that a long-run equilibrium relationship governs the movements among the variables. The normalized cointegrating vectors provide further evidence that stock prices increase along with real activity, but move inversely with changes in both nominal money and expected inflation. These long-run causal findings are more consistent with Geske-Roll than with

Fama. The finding that stock prices have an inverse long-run relation with the nominal money supply is consistent with Geske-Roll. The existence of a long-run causal stock price-inflation link is similarly consistent with Geske-Roll, but strongly counter to the Fama. The positive long-run causal link from stock prices to real activity, however, is consistent with both theories.

The finding of cointegration further suggests that the results in existing works using differenced VAR's without cointegration constraints must be viewed with suspicion. Valid short-run causality tests must be performed within a VECM which incorporates these cointegrating relations. Cointegration further implies that a short-run causal relationship exists in at least one direction between the variables in the models and can be detected using a VECM.

The use of the cointegrated VECM frameworks of Toda-Phillips and Saikkonen-Lütkepohl provide a much different perspective of the short-run stock price-inflation relation than found in the original Fama and Geske-Roll works. Short-run causality tests suggest that neither theory provides a comprehensive explanation of the inverse postwar relation. Strong support is found for a Granger-causal link from stock prices to real activity, but the critical link in both models from expected inflation to real activity has less support.

The remainder of the short-run causality tests are not entirely consistent with either model. Geske-Roll suggest three roles for the nominal money supply but none is strongly supported by the data. Fama argues that the link between expected inflation and stock prices is spurious but the evidence supports the existence of a causal channel. Additional findings include a positive Granger-causal link from nominal money to real activity and a feedback effect from stock prices to inflation.

The results from dummy variable tests do not indicate a significantly different stock price-inflation relation in the policy regime change periods of Kaul (1987, 1990) and Graham (1996). The data does not confirm the presence of a significant change in the original coefficients of the estimated VECM's using either policy change period, and the original causal conclusions are unchanged.

The results, however, do confirm the critical role of real activity in determining stock prices. Both long-run and short-run causality tests confirm that stock prices reliably forecast future real activity. The evidence remains mixed concerning the exact structure of the relationship between stock prices and both nominal interest rates and expected inflation. The data show a reliable inverse relationship in the long-run, but the short-run relationship differs with the measure of expected inflation. While a significant inverse long-run causal link between stock prices and money is found, the results do not establish a short-run role for money in the stock price-inflation link.

These findings have several implications for future research on the link between stock prices and inflation. First, the finding of cointegration suggests that the relationship between stock prices and inflation is not spurious in nature as suggested by Fama and Geske-Roll. Their work is widely cited as evidence that the stock price-inflation link is not casual in nature. It further suggests that the modeling techniques used to evaluate the link must account for the presence of these cointegrating relations. Second, it reinforces the role of real activity in determining stock prices. An econometric framework which simultaneously incorporates this structure and accounts for the cointegrating relations, however, remains unavailable. Third, though the short-run role of the money supply in the stock pricing process is not firmly established, support for a long-run inverse cointegrating relationship between stock prices and the money supply is found. This evidence supplements an already extensive literature documenting a link between stock prices and the money supply. Lastly, the mixed results concerning several of the short-run causal links reinforces the fragility of causality testing. Future tests should continue to use multiple econometric frameworks to validate the existence of any proposed causal links.

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APPENDIX A

DATA SERIES

Table 1. Estimated Expected Inflation (EI) Series

Variable	Estimated Coefficient	Standard Error	T-Ratio	P-Value
CONSTANT	-16.4440	4.6550	-3.5320	0.0010
$INFL_{t-1}$	0.3170	0.0769	4.1240	0.0000
$INFL_{t-2}$	0.0642	0.0796	0.8066	0.4210
$INFL_{t-3}$	0.2413	0.0780	3.0960	0.0020
$INFL_{t-4}$	0.0816	0.0739	1.1060	0.2710
$INFL_{t-5}$	-0.1449	0.0733	-1.9780	0.0500
$INFL_{t-6}$	-0.0539	0.0723	-0.7447	0.4570
SPR_{t-1}	-3.7055	2.5820	-1.4350	0.1530
SPR_{t-2}	3.8652	3.7240	1.0380	0.3010
SPR_{t-3}	-2.4348	3.7310	-0.6526	0.5150
SPR_{t-4}	1.5011	3.7610	0.3992	0.6900
SPR_{t-5}	-2.8070	3.7570	-0.7471	0.4560
SPR_{t-6}	1.2278	2.7620	0.4445	0.6570
IP_{t-1}	18.7520	7.8570	2.3870	0.0180
IP_{t-2}	-8.7342	11.0600	-0.7898	0.4310
IP_{t-3}	4.3902	10.6900	0.4107	0.6820
IP_{t-4}	-1.8879	10.3100	-0.1831	0.8550
IP_{t-5}	-15.0140	10.2400	-1.4660	0.1440
IP_{t-6}	10.8190	6.7910	1.5930	0.1130
MB_{t-1}	-19.9810	19.9000	-1.0040	0.3170
MB_{t-2}	12.6820	22.5800	0.5617	0.5750
MB_{t-3}	24.4930	16.4300	1.4910	0.1380
MB_{t-4}	-43.1050	16.5200	-2.6100	0.0100
MB_{t-5}	11.0030	23.9300	0.4598	0.6460
MB_{t-6}	11.8920	20.5400	0.5789	0.5630

Adjusted $R^2 = 0.55$, DW = 2.0076, Normality $\chi^2[2] = 17.97$
ARCH $\chi^2[1] = 7.701$, RESET $F[1,169] = 5.54$

Data are quarterly for the 1948.1-1996.4 period. See Figure 3 for a plot of the series.
Estimated Using a 4-Variable VAR With 6 Lags of CPI Inflation (INFL), Real S&P 500 Stock Index (SPR), Industrial Production (IP), and the Monetary Base (MB). Order of the VAR selected using Akaike's AIC.
DW is the Durbin-Watson test of first-order residual autocorrelation.
Normality $\chi^2[2]$ is the Jarque-Bera test for skewness and excess kurtosis.
ARCH $\chi^2[1]$ is the test for autoregressive conditional heteroskedasticity.
RESET F[q,T-k-Q] is the qth order Ramsey-Reset Statistic.

Table 2. Data Summary Statistics

Variable Name	Mean	Standard Deviation	Maximum	Minimum
ΔSP	2.02	7.38	19.55	-30.27
ΔCPI	1.01	0.88	4.34	-0.76
ΔSPR	1.00	7.61	18.02	-33.48
ΔIP	0.90	3.70	9.77	-14.80
ΔMB	1.41	2.15	5.48	-4.13
ΔST	0.80	18.47	107.83	-84.95
ΔEI	0.02	1.62	3.63	-5.30

Note: Summary Statistics are for the first difference (Δ) of each series X 100%.
Data are quarterly for the 1950.1-1996.4 period for Nominal S&P 500 Stock Index (SP), Consumer Price Index (CPI), Real S&P 500 Composite Stock Index (SPR), Industrial Production (IP), Monetary Base (MB), 3-Month Treasury Bill Yield (ST), and Estimated Expected Inflation (EI) Series.

APPENDIX B

UNIT ROOT AND COINTEGRATION TESTS

Table 3. ADF Unit Root Tests

Variables	**Two Unit Roots**		**Single Unit Root**	
SPR	-4.8683^{a}	(8)	-1.8357	(9)
IP	-4.9384^{a}	(9)	-2.0222	(9)
MB	-4.3466^{a}	(12)	-1.5791	(12)
ST	-4.8446^{a}	(12)	-2.0471	(12)
EI	-4.0986^{a}	(6)	-2.1747	(12)

Notes: Significant lags in parenthesis.
a denotes rejection of the null at the 5% level.
Data are quarterly in the 1950.1-1996.4 period.
SPR = real S&P 500 stock index, IP = Industrial Production, MB = Monetary Base, ST = 3-month Treasury Bill yield, EI = Estimated Expected Inflation series.

Table 4. Johansen-Juselius Cointegration Tests

	Maximum Eigenvalue Test			
Variables	$H_0: r=0$ $H_1: r>0$	$H_0: r\leq1$ $H_1: r>1$	$H_0: r\leq2$ $H_1: r>2$	$H_0: r\leq3$ $H_1: r>3$
SPR IP MB ST	38.9339^{a}	23.7317^{a}	10.7157	0.2711
SPR IP MB EI	49.8542^{a}	22.7249^{a}	7.2175	0.3594
CV(95%)	27.0670	20.9670	14.0690	3.7620
CV(90%)	24.7340	18.5980	12.0710	2.6870

	Trace Test			
Variables	$H_0: r=0$ $H_1: r>0$	$H_0: r\leq1$ $H_1: r>1$	$H_0: r\leq2$ $H_1: r>2$	$H_0: r\leq3$ $H_1: r>3$
SPR IP MB ST	73.6524^{a}	34.7185^{a}	10.9868	0.2711
SPR IP MB EI	80.1559^{a}	30.3017^{a}	7.5768	0.3594
CV(95%)	47.2100	29.6800	15.4100	3.7620
CV(90%)	43.9490	26.7850	13.3250	2.6870

Notes: VECM with 8 lags selected with Akaike's AIC.
r denotes the number of significant cointegrating vectors.
^{a} denotes rejection of the null at the 5% level.
CV(90%) and CV(95%) are critical values at the 90% and 95% confidence levels.
Data are quarterly in the 1950.1-1996.4 period.
SPR = real S&P 500 stock index, IP = Industrial Production, MB = Monetary Base, ST = 3-month Treasury Bill yield, EI = Estimated Expected Inflation series.

Table 5. Cointegrating Vectors and Likelihood Ratio Tests

		Normalized Cointegrating Vectors			
Variables		SPR	IP	MB	ST
SPR IP MB ST	(1)	-1.0000	4.3710	-0.8922	-0.2310
	(2)	-1.0000	6.4296	-2.1939	-1.9190

or

(1) $SPR_t = 4.3710IP_t - 0.8922MB_t - 0.2310ST_t$

(2) $SPR_t = 6.4296IP_t - 2.1939MB_t - 1.9190ST_t$

Variables		SPR	IP	MB	EI
SPR IP MB EI	(1)	-1.0000	2.8403	-0.8146	-0.1791
	(2)	-1.0000	0.3610	-0.8646	-0.5231

or

(1) $SPR_t = 2.8403IP_t - 0.8146MB_t - 0.1791Ei_t$

(2) $SPR_t = 0.3610IP_t - 0.8646MB_t - 0.5231Ei_t$

	Likelihood Ratio Tests			
Variables	$H_o: B_{SPR1}=B_{SPR2}=0$	$H_o: B_{IP1}=B_{IP2}=0$	$H_o: B_{MB1}=B_{MB2}=0$	$H_o: B_{ST1}=B_{ST2}=0$
SPR IP MB ST	15.1900 [a]	12.3849 [a]	16.1008 [a]	12.7807 [a]
	$H_o: B_{SPR1}=B_{SPR2}=0$	$H_o: B_{IP1}=B_{IP2}=0$	$H_o: B_{MB1}=B_{MB2}=0$	$H_o: B_{EI1}=B_{EI2}=0$
SPR IP MB EI	31.9325 [a]	31.3445 [a]	27.6366 [a]	17.7188 [a]

Notes: The test statistics have a $\chi^2(2)$ distribution under the null hypothesis.
a denotes rejection of the null at the 1% level.
Data are quarterly in the 1950.1-1996.4 period.
SPR = real S&P 500 stock index, IP = Industrial Production, MB = Monetary Base, ST = 3-month Treasury Bill yield, EI = Estimated Expected Inflation series.

APPENDIX C

TP AND SL VECM ESTIMATES

Table 6. VECM(6) Toda-Phillips Method (ST)

Dependent Variable = ΔIP			Dependent Variable = ΔST		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.020	-0.31	Constant	-1.942	-3.95
ΔIP_{t-1}	0.092	1.06	ΔIP_{t-1}	1.165	1.81
ΔIP_{t-2}	-0.202	-2.46	ΔIP_{t-2}	-0.137	-0.22
ΔIP_{t-3}	-0.134	-1.71	ΔIP_{t-3}	0.389	0.67
ΔIP_{t-4}	0.219	2.89	ΔIP_{t-4}	-0.719	-1.29
ΔIP_{t-5}	-0.290	-3.94	ΔIP_{t-5}	-1.312	-2.41
ΔIP_{t-6}	-0.050	-0.66	ΔIP_{t-6}	-0.441	-0.78
	Σ = -0.365			Σ = -1.055	
ΔMB_{t-1}	-0.035	-0.17	ΔMB_{t-1}	0.230	0.15
ΔMB_{t-2}	-0.173	-0.87	ΔMB_{t-2}	1.646	1.11
ΔMB_{t-3}	0.832	5.71	ΔMB_{t-3}	0.816	0.76
ΔMB_{t-4}	-0.172	-1.07	ΔMB_{t-4}	-0.283	-0.24
ΔMB_{t-5}	0.069	0.35	ΔMB_{t-5}	-0.303	-0.21
ΔMB_{t-6}	0.503	2.50	ΔMB_{t-6}	-3.640	-2.44
	Σ = 1.024			Σ = -1.534	
ΔSPR_{t-1}	0.088	3.85	ΔSPR_{t-1}	0.469	2.78
ΔSPR_{t-2}	0.081	3.37	ΔSPR_{t-2}	0.416	2.34
ΔSPR_{t-3}	0.015	0.61	ΔSPR_{t-3}	0.007	0.04
ΔSPR_{t-4}	0.069	2.84	ΔSPR_{t-4}	0.076	0.42
ΔSPR_{t-5}	0.019	0.79	ΔSPR_{t-5}	0.126	0.69
ΔSPR_{t-6}	0.001	0.06	ΔSPR_{t-6}	0.047	0.26
	Σ = 0.273			Σ = 1.141	
ΔST_{t-1}	0.020	1.68	ΔST_{t-1}	0.105	1.20
ΔST_{t-2}	-0.001	-0.08	ΔST_{t-2}	-0.093	-1.06
ΔST_{t-3}	0.013	1.06	ΔST_{t-3}	0.231	2.57
ΔST_{t-4}	-0.030	-2.45	ΔST_{t-4}	0.156	1.74
ΔST_{t-5}	0.035	2.96	ΔST_{t-5}	0.273	3.15
ΔST_{t-6}	-0.006	-0.52	ΔST_{t-6}	0.021	0.24
	Σ = 0.031			Σ = 0.693	
$ECT1_{t-1}$	-0.048	-3.10	$ECT1_{t-1}$	0.047	0.41
$ECT2_{t-1}$	0.059	2.49	$ECT2_{t-1}$	0.765	4.36
Adjusted R^2 = 0.66, DW = 2.0358 Normality $\chi^2[2]$ = 16.91, ARCH $\chi^2[1]$ = 4.975 RESET F[1,160] = 8.79			Adjusted R^2 = 0.25, DW = 2.0139 Normality $\chi^2[2]$ = 149.6, ARCH $\chi^2[1]$ = 0.001 RESET F[1,160] = 2.03		

Continued

Table 6. (Cont.) VECM(6) Toda-Phillips Method (ST)

Dependent Variable = ΔMB			Dependent Variable = ΔSPR		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.054	-2.34	Constant	-0.104	-0.46
ΔIP_{t-1}	0.022	0.71	ΔIP_{t-1}	-0.218	-0.74
ΔIP_{t-2}	0.021	0.72	ΔIP_{t-2}	-0.346	-1.25
ΔIP_{t-3}	0.054	1.96	ΔIP_{t-3}	0.012	0.04
ΔIP_{t-4}	-0.065	-2.47	ΔIP_{t-4}	-0.288	-1.13
ΔIP_{t-5}	0.063	2.46	ΔIP_{t-5}	-0.132	-0.53
ΔIP_{t-6}	0.015	0.58	ΔIP_{t-6}	0.151	0.58
	Σ = 0.110			Σ = -0.821	
ΔMB_{t-1}	-0.030	-0.41	ΔMB_{t-1}	-1.217	-1.72
ΔMB_{t-2}	0.153	2.19	ΔMB_{t-2}	0.917	1.35
ΔMB_{t-3}	-0.108	-2.11	ΔMB_{t-3}	-0.820	-1.66
ΔMB_{t-4}	0.564	10.09	ΔMB_{t-4}	-0.765	-1.41
ΔMB_{t-5}	-0.158	-2.28	ΔMB_{t-5}	0.545	0.81
ΔMB_{t-6}	-0.233	-3.31	ΔMB_{t-6}	-1.668	-2.45
	Σ = 0.188			Σ = -3.008	
ΔSPR_{t-1}	-0.004	-0.45	ΔSPR_{t-1}	0.072	0.94
ΔSPR_{t-2}	-0.009	-1.10	ΔSPR_{t-2}	-0.128	-1.58
ΔSPR_{t-3}	0.002	0.24	ΔSPR_{t-3}	0.035	0.42
ΔSPR_{t-4}	0.006	0.67	ΔSPR_{t-4}	-0.011	-0.14
ΔSPR_{t-5}	-0.006	-0.76	ΔSPR_{t-5}	0.044	0.52
ΔSPR_{t-6}	0.003	0.31	ΔSPR_{t-6}	-0.020	-0.25
	Σ = -0.008			Σ = -0.008	
ΔST_{t-1}	-0.005	-1.22	ΔST_{t-1}	-0.022	-0.55
ΔST_{t-2}	-0.014	-3.37	ΔST_{t-2}	-0.048	-1.20
ΔST_{t-3}	-0.004	-0.96	ΔST_{t-3}	-0.021	-0.51
ΔST_{t-4}	-0.001	-0.28	ΔST_{t-4}	-0.066	-1.62
ΔST_{t-5}	-0.002	-0.55	ΔST_{t-5}	-0.005	-0.12
ΔST_{t-6}	-0.009	-2.06	ΔST_{t-6}	-0.103	-2.56
	Σ = -0.035			Σ = -0.265	
$ECT1_{t-1}$	0.022	4.12	$ECT1_{t-1}$	0.045	0.86
$ECT2_{t-1}$	0.003	0.33	$ECT2_{t-1}$	0.019	0.24
Adjusted R^2 = 0.88, DW = 2.0247 Normality $\chi^2[2]$ = 6.78, ARCH $\chi^2[1]$ = 3.365 RESET F[1,160] = 2.56			Adjusted R^2 = 0.08, DW = 2.0030 Normality $\chi^2[2]$ = 102.9, ARCH $\chi^2[1]$ = 0.001 RESET F[1,160] = 0.01		

Notes: VECM(6) using Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), and 3-Month Treasury Bill (ST). Quarterly data in the 1950.1-1996.4 period. DW is the Durbin-Watson test of first-order residual autocorrelation.

Normality $\chi^2[2]$ is the Jarque-Bera test for skewness and excess kurtosis.

ARCH $\chi^2[1]$ is the test for autoregressive conditional heteroskedasticity.

RESET F[q,T-k-Q] is the qth order Ramsey-Reset Statistic.

Table 7. VECM(6) Toda-Phillips Method (EI)

Dependent Variable = ΔEI			Dependent Variable = ΔIP		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-2.070	-0.69	Constant	0.147	2.47
ΔEI_{t-1}	-0.238	-2.06	ΔEI_{t-1}	0.002	1.01
ΔEI_{t-2}	0.030	0.27	ΔEI_{t-2}	0.003	1.36
ΔEI_{t-3}	0.127	1.19	ΔEI_{t-3}	-0.001	-0.33
ΔEI_{t-4}	-0.129	-1.20	ΔEI_{t-4}	-0.004	-2.01
ΔEI_{t-5}	-0.168	-1.68	ΔEI_{t-5}	-0.004	-1.84
ΔEI_{t-6}	-0.097	-1.19	ΔEI_{t-6}	-0.002	-1.44
	Σ = -0.475			Σ = -0.006	
ΔIP_{t-1}	8.421	1.96	ΔIP_{t-1}	0.030	0.36
ΔIP_{t-2}	6.842	1.60	ΔIP_{t-2}	-0.173	-2.06
ΔIP_{t-3}	2.404	0.58	ΔIP_{t-3}	-0.103	-1.25
ΔIP_{t-4}	-1.764	-0.43	ΔIP_{t-4}	0.265	3.28
ΔIP_{t-5}	1.850	0.44	ΔIP_{t-5}	-0.089	-1.08
ΔIP_{t-6}	9.645	2.41	ΔIP_{t-6}	0.057	0.72
	Σ = 27.398			Σ = -0.013	
ΔMB_{t-1}	-4.836	-0.45	ΔMB_{t-1}	0.224	1.06
ΔMB_{t-2}	29.913	2.86	ΔMB_{t-2}	0.098	0.47
ΔMB_{t-3}	-19.722	-2.30	ΔMB_{t-3}	0.626	3.72
ΔMB_{t-4}	-41.024	-4.42	ΔMB_{t-4}	-0.196	-1.07
ΔMB_{t-5}	21.911	1.94	ΔMB_{t-5}	0.126	0.57
ΔMB_{t-6}	27.954	2.44	ΔMB_{t-6}	0.533	2.37
	Σ = 14.196			Σ = 1.411	
ΔSPR_{t-1}	4.186	3.13	ΔSPR_{t-1}	0.097	3.70
ΔSPR_{t-2}	1.448	1.04	ΔSPR_{t-2}	0.098	3.58
ΔSPR_{t-3}	-0.176	-0.13	ΔSPR_{t-3}	0.004	0.16
ΔSPR_{t-4}	-1.415	-1.03	ΔSPR_{t-4}	0.050	1.83
ΔSPR_{t-5}	0.570	0.41	ΔSPR_{t-5}	0.008	0.30
ΔSPR_{t-6}	-2.164	-1.59	ΔSPR_{t-6}	-0.013	-0.50
	Σ = 2.449			Σ = 0.244	
$ECT1_{t-1}$	0.914	0.69	$ECT1_{t-1}$	-0.056	-2.14
$ECT2_{t-1}$	0.192	1.17	$ECT2_{t-1}$	0.008	2.56
Adjusted R^2 = 0.50, DW = 2.0182 Normality $\chi^2[2]$ = 0.66, ARCH $\chi^2[1]$ = 14.435 RESET F[1,160] = 1.17			Adjusted R^2 = 0.63, DW = 2.0188 Normality $\chi^2[2]$ = 22.27, ARCH $\chi^2[1]$ = 7.111 RESET F[1,160] = 3.79		

Continued

Table 7. (Cont.) VECM(6) Toda-Phillips Method (EI)

Dependent Variable = ΔMB			Dependent Variable = ΔSPR		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.038	-1.85	Constant	-0.550	-2.90
ΔEI_{t-1}	-0.001	-1.21	ΔEI_{t-1}	0.013	1.76
ΔEI_{t-2}	-0.000	-0.49	ΔEI_{t-2}	0.016	2.38
ΔEI_{t-3}	0.001	0.95	ΔEI_{t-3}	0.007	1.00
ΔEI_{t-4}	0.001	0.96	ΔEI_{t-4}	0.009	1.34
ΔEI_{t-5}	-0.002	-2.28	ΔEI_{t-5}	0.009	1.41
ΔEI_{t-6}	-0.001	-1.27	ΔEI_{t-6}	0.001	0.12
	Σ = -0.002			Σ = 0.055	
ΔIP_{t-1}	0.014	0.47	ΔIP_{t-1}	-0.537	-1.99
ΔIP_{t-2}	-0.020	-0.68	ΔIP_{t-2}	-0.441	-1.65
ΔIP_{t-3}	0.021	0.75	ΔIP_{t-3}	-0.231	-0.89
ΔIP_{t-4}	-0.073	-2.63	ΔIP_{t-4}	-0.561	-2.18
ΔIP_{t-5}	0.045	1.57	ΔIP_{t-5}	-0.286	-1.09
ΔIP_{t-6}	-0.000	-0.00	ΔIP_{t-6}	-0.185	-0.74
	Σ = -0.013			Σ = -2.241	
ΔMB_{t-1}	0.019	0.27	ΔMB_{t-1}	-0.659	-0.98
ΔMB_{t-2}	0.157	2.21	ΔMB_{t-2}	0.997	1.52
ΔMB_{t-3}	-0.007	-0.13	ΔMB_{t-3}	-0.470	-0.87
ΔMB_{t-4}	0.562	8.91	ΔMB_{t-4}	-0.268	-0.46
ΔMB_{t-5}	-0.259	-3.37	ΔMB_{t-5}	0.044	0.06
ΔMB_{t-6}	-0.209	-2.69	ΔMB_{t-6}	-2.105	-2.93
	Σ = 0.263			Σ = -2.461	
ΔSPR_{t-1}	-0.009	-1.00	ΔSPR_{t-1}	0.074	0.88
ΔSPR_{t-2}	-0.005	-0.56	ΔSPR_{t-2}	-0.047	-0.53
ΔSPR_{t-3}	0.009	0.95	ΔSPR_{t-3}	-0.022	-0.25
ΔSPR_{t-4}	0.005	0.54	ΔSPR_{t-4}	0.039	0.45
ΔSPR_{t-5}	-0.013	-1.36	ΔSPR_{t-5}	0.059	0.68
ΔSPR_{t-6}	0.013	1.46	ΔSPR_{t-6}	-0.049	-0.57
	Σ = 0.000			Σ = 0.054	
$ECT1_{t-1}$	0.016	1.79	$ECT1_{t-1}$	0.272	3.29
$ECT2_{t-1}$	-0.003	-2.87	$ECT2_{t-1}$	0.015	1.49
Adjusted R^2 = 0.87, DW = 1.9200 Normality $\chi^2[2]$ = 0.64, ARCH $\chi^2[1]$ = 0.004 RESET F[1,160] = 2.28			Adjusted R^2 = 0.11, DW = 2.0418 Normality $\chi^2[2]$ = 142.9, ARCH $\chi^2[1]$ = 0.069 RESET F[1,160] = 0.01		

Notes: VECM(6) using Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), and Estimated Expected Inflation (EI). Quarterly data in the 1950.1-1996.4 period.

DW is the Durbin-Watson test of first-order residual autocorrelation.

Normality $\chi^2[2]$ is the Jarque-Bera test for skewness and excess kurtosis.

ARCH $\chi^2[1]$ is the test for autoregressive conditional heteroskedasticity.

RESET F[q,T-k-Q] is the qth order Ramsey-Reset Statistic.

Table 8. VECM(8) Toda-Phillips Method (ST)

Dependent Variable = ΔIP			Dependent Variable = ΔST		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.082	-1.08	Constant	-2.098	-3.67
ΔIP_{t-1}	0.073	0.83	ΔIP_{t-1}	1.319	2.00
ΔIP_{t-2}	-0.185	-2.11	ΔIP_{t-2}	-0.169	-0.26
ΔIP_{t-3}	-0.134	-1.54	ΔIP_{t-3}	0.630	0.96
ΔIP_{t-4}	0.175	2.08	ΔIP_{t-4}	-1.172	-1.86
ΔIP_{t-5}	-0.280	-3.39	ΔIP_{t-5}	-1.567	-2.52
ΔIP_{t-6}	-0.073	-0.88	ΔIP_{t-6}	-0.494	-0.78
ΔIP_{t-7}	-0.126	-1.61	ΔIP_{t-7}	-0.373	-0.64
ΔIP_{t-8}	0.049	0.65	ΔIP_{t-8}	1.327	2.36
	$\Sigma = -0.501$			$\Sigma = -0.499$	
ΔMB_{t-1}	-0.051	-0.24	ΔMB_{t-1}	0.166	0.10
ΔMB_{t-2}	-0.131	-0.61	ΔMB_{t-2}	1.686	1.04
ΔMB_{t-3}	0.555	2.69	ΔMB_{t-3}	-0.004	-0.00
ΔMB_{t-4}	0.148	0.71	ΔMB_{t-4}	0.026	0.02
ΔMB_{t-5}	0.034	0.17	ΔMB_{t-5}	-0.302	-0.20
ΔMB_{t-6}	0.539	2.64	ΔMB_{t-6}	-4.239	-2.76
ΔMB_{t-7}	0.122	0.57	ΔMB_{t-7}	-0.413	-0.26
ΔMB_{t-8}	-0.497	-2.31	ΔMB_{t-8}	-0.068	-0.04
	$\Sigma = 0.719$			$\Sigma = -3.148$	
ΔSPR_{t-1}	0.092	3.91	ΔSPR_{t-1}	0.469	2.65
ΔSPR_{t-2}	0.079	3.21	ΔSPR_{t-2}	0.401	2.17
ΔSPR_{t-3}	0.016	0.67	ΔSPR_{t-3}	0.025	0.14
ΔSPR_{t-4}	0.071	2.88	ΔSPR_{t-4}	0.070	0.38
ΔSPR_{t-5}	0.024	0.97	ΔSPR_{t-5}	0.155	0.84
ΔSPR_{t-6}	0.006	0.25	ΔSPR_{t-6}	0.096	0.52
ΔSPR_{t-7}	0.008	0.35	ΔSPR_{t-7}	0.298	1.64
ΔSPR_{t-8}	0.036	1.46	ΔSPR_{t-8}	0.115	0.63
	$\Sigma = 0.332$			$\Sigma = 1.629$	
ΔST_{t-1}	0.024	1.93	ΔST_{t-1}	0.086	0.93
ΔST_{t-2}	-0.002	-0.19	ΔST_{t-2}	-0.102	-1.10
ΔST_{t-3}	0.015	1.20	ΔST_{t-3}	0.240	2.58
ΔST_{t-4}	-0.026	-2.10	ΔST_{t-4}	0.176	1.87
ΔST_{t-5}	0.035	2.73	ΔST_{t-5}	0.263	2.75
ΔST_{t-6}	0.002	0.13	ΔST_{t-6}	-0.006	-0.06
ΔST_{t-7}	-0.003	-0.25	ΔST_{t-7}	-0.014	-0.15
ΔST_{t-8}	0.014	1.18	ΔST_{t-8}	-0.060	-0.67
	$\Sigma = 0.059$			$\Sigma = 0.583$	
$ECT1_{t-1}$	-0.029	-1.85	$ECT1_{t-1}$	0.098	0.82
$ECT2_{t-1}$	0.061	2.77	$ECT2_{t-1}$	0.635	3.83
Adjusted $R^2 = 0.67$, DW = 1.9551			Adjusted $R^2 = 0.25$, DW = 1.9941		
Normality $\chi^2[2] = 14.90$, ARCH $\chi^2[1] = 5.737$			Normality $\chi^2[2] = 204.7$, ARCH $\chi^2[1] = 13.42$		
RESET F[1,152] = 4.85			RESET F[1,152] = 0.28		

Continued

Table 8. (Cont.) VECM(8) Toda-Phillips Method (ST)

Dependent Variable = ΔMB			Dependent Variable = ΔSPR		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.051	-1.89	Constant	0.101	0.39
ΔIP_{t-1}	0.030	0.95	ΔIP_{t-1}	-0.120	-0.40
ΔIP_{t-2}	0.016	0.50	ΔIP_{t-2}	-0.259	-0.86
ΔIP_{t-3}	0.063	2.04	ΔIP_{t-3}	0.244	0.82
ΔIP_{t-4}	-0.056	-1.87	ΔIP_{t-4}	-0.322	-1.12
ΔIP_{t-5}	0.057	1.94	ΔIP_{t-5}	0.045	0.16
ΔIP_{t-6}	0.027	0.91	ΔIP_{t-6}	0.311	1.08
ΔIP_{t-7}	0.000	0.00	ΔIP_{t-7}	0.314	1.17
ΔIP_{t-8}	0.015	0.54	ΔIP_{t-8}	0.373	1.45
	Σ = 0.152			Σ = 0.586	
ΔMB_{t-1}	-0.060	-0.77	ΔMB_{t-1}	-1.316	-1.79
ΔMB_{t-2}	0.132	1.72	ΔMB_{t-2}	0.567	0.77
ΔMB_{t-3}	-0.030	-0.41	ΔMB_{t-3}	-0.687	-0.97
ΔMB_{t-4}	0.510	6.86	ΔMB_{t-4}	-1.051	-1.47
ΔMB_{t-5}	-0.154	-2.14	ΔMB_{t-5}	0.425	0.61
ΔMB_{t-6}	-0.263	-3.60	ΔMB_{t-6}	-2.033	-2.90
ΔMB_{t-7}	-0.115	-1.49	ΔMB_{t-7}	-0.100	-0.13
ΔMB_{t-8}	0.064	0.82	ΔMB_{t-8}	0.596	0.80
	Σ = 0.084			Σ = -3.599	
ΔSPR_{t-1}	-0.007	-0.88	ΔSPR_{t-1}	0.050	0.62
ΔSPR_{t-2}	-0.010	-1.10	ΔSPR_{t-2}	-0.157	-1.85
ΔSPR_{t-3}	0.000	0.04	ΔSPR_{t-3}	0.023	0.27
ΔSPR_{t-4}	0.004	0.49	ΔSPR_{t-4}	-0.055	-0.65
ΔSPR_{t-5}	-0.009	-1.02	ΔSPR_{t-5}	0.019	0.22
ΔSPR_{t-6}	0.000	0.05	ΔSPR_{t-6}	-0.048	-0.56
ΔSPR_{t-7}	-0.005	-0.62	ΔSPR_{t-7}	-0.106	-1.27
ΔSPR_{t-8}	-0.006	-0.69	ΔSPR_{t-8}	-0.079	-0.95
	Σ = -0.033			Σ = -0.353	
ΔST_{t-1}	-0.007	-1.66	ΔST_{t-1}	-0.049	-1.17
ΔST_{t-2}	-0.014	-3.29	ΔST_{t-2}	-0.069	-1.64
ΔST_{t-3}	-0.006	-1.26	ΔST_{t-3}	-0.040	-0.94
ΔST_{t-4}	-0.002	-0.36	ΔST_{t-4}	-0.092	-2.14
ΔST_{t-5}	-0.002	-0.53	ΔST_{t-5}	-0.022	-0.50
ΔST_{t-6}	-0.010	-2.14	ΔST_{t-6}	-0.146	-3.30
ΔST_{t-7}	-0.002	-0.50	ΔST_{t-7}	-0.025	-0.57
ΔST_{t-8}	-0.005	-1.24	ΔST_{t-8}	-0.101	-2.43
	Σ = -0.048			Σ = -0.544	
$ECT1_{t-1}$	0.020	3.59	$ECT1_{t-1}$	0.046	0.84
$ECT2_{t-1}$	-0.001	-0.06	$ECT2_{t-1}$	-0.064	-0.84
Adjusted R^2 = 0.87, DW = 1.9474			Adjusted R^2 = 0.08, DW = 1.9862		
Normality $\chi^2[2]$ = 7.19, ARCH $\chi^2[1]$ = 4.428 RESET F[1,152] = 3.61			Normality $\chi^2[2]$ = 62.2, ARCH $\chi^2[1]$ = 0.001 RESET F[1,152] = 3.17		

Notes: VECM(8) using Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), and 3-Month Treasury Bill (ST). Quarterly data in the 1950.1-1996.4 period. DW is the Durbin-Watson test of first-order residual autocorrelation.

Normality $\chi^2[2]$ is the Jarque-Bera test for skewness and excess kurtosis.

ARCH $\chi^2[1]$ is the test for autoregressive conditional heteroskedasticity.

RESET F[q,T-k-Q] is the qth order Ramsey-Reset Statistic.

Table 9. VECM(8) Toda-Phillips Method (EI)

Dependent Variable = ΔEI			Dependent Variable = ΔIP		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-4.041	-1.08	Constant	0.127	1.75
ΔEI_{t-1}	-0.169	-1.32	ΔEI_{t-1}	0.003	1.34
ΔEI_{t-2}	0.112	0.88	ΔEI_{t-2}	0.003	1.28
ΔEI_{t-3}	0.217	1.71	ΔEI_{t-3}	-0.001	-0.32
ΔEI_{t-4}	-0.121	-1.04	ΔEI_{t-4}	-0.003	-1.53
ΔEI_{t-5}	-0.145	-1.28	ΔEI_{t-5}	-0.003	-1.29
ΔEI_{t-6}	0.010	0.08	ΔEI_{t-6}	-0.001	-0.51
ΔEI_{t-7}	0.144	1.41	ΔEI_{t-7}	0.001	0.52
ΔEI_{t-8}	0.043	0.51	ΔEI_{t-8}	0.001	0.49
	Σ = 0.091			Σ = 0.000	
ΔIP_{t-1}	7.411	1.67	ΔIP_{t-1}	0.024	0.28
ΔIP_{t-2}	6.772	1.52	ΔIP_{t-2}	-0.180	-2.08
ΔIP_{t-3}	1.315	0.29	ΔIP_{t-3}	-0.051	-0.58
ΔIP_{t-4}	-1.947	-0.43	ΔIP_{t-4}	0.201	2.32
ΔIP_{t-5}	1.091	0.23	ΔIP_{t-5}	-0.094	-1.02
ΔIP_{t-6}	6.750	1.45	ΔIP_{t-6}	0.033	0.37
ΔIP_{t-7}	-1.971	-0.45	ΔIP_{t-7}	-0.184	-2.17
ΔIP_{t-8}	-4.372	-1.05	ΔIP_{t-8}	0.072	0.89
	Σ = 15.049			Σ = -0.179	
ΔMB_{t-1}	-1.620	-0.14	ΔMB_{t-1}	0.227	1.04
ΔMB_{t-2}	30.162	2.68	ΔMB_{t-2}	0.173	0.79
ΔMB_{t-3}	-27.091	-2.31	ΔMB_{t-3}	0.286	1.26
ΔMB_{t-4}	-35.925	-2.96	ΔMB_{t-4}	0.061	0.26
ΔMB_{t-5}	18.853	1.53	ΔMB_{t-5}	0.146	0.61
ΔMB_{t-6}	36.269	2.90	ΔMB_{t-6}	0.498	2.06
ΔMB_{t-7}	5.332	0.43	ΔMB_{t-7}	0.224	0.94
ΔMB_{t-8}	-17.706	-1.47	ΔMB_{t-8}	-0.300	-1.28
	Σ = 8.274			Σ = 1.315	
ΔSPR_{t-1}	4.371	3.16	ΔSPR_{t-1}	0.105	3.92
ΔSPR_{t-2}	1.339	0.91	ΔSPR_{t-2}	0.084	2.94
ΔSPR_{t-3}	0.121	0.08	ΔSPR_{t-3}	0.005	0.16
ΔSPR_{t-4}	-2.199	-1.51	ΔSPR_{t-4}	0.046	1.65
ΔSPR_{t-5}	0.539	0.38	ΔSPR_{t-5}	0.006	0.23
ΔSPR_{t-6}	-1.768	-1.24	ΔSPR_{t-6}	-0.010	-0.37
ΔSPR_{t-7}	0.457	0.32	ΔSPR_{t-7}	0.010	0.36
ΔSPR_{t-8}	-0.105	-0.08	ΔSPR_{t-8}	0.021	0.78
	Σ = 2.755			Σ = 0.267	
$ECT1_{t-1}$	1.560	1.13	$ECT1_{t-1}$	-0.039	-1.46
$ECT2_{t-1}$	0.182	1.16	$ECT2_{t-1}$	0.007	2.19
Adjusted R^2 = 0.49, DW = 2.0074			Adjusted R^2 = 0.63, DW = 1.9930		
Normality $\chi^2[2]$ = 0.79, ARCH $\chi^2[1]$ = 17.361			Normality $\chi^2[2]$ = 28.23, ARCH $\chi^2[1]$ = 6.208		
RESET F[1,152] = 0.72			RESET F[1,152] = 3.39		

Continued

Table 9. (Cont.) VECM(8) Toda-Phillips Method (EI)

Dependent Variable = ΔMB			Dependent Variable = ΔSPR		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.051	-2.02	Constant	-0.731	-3.17
ΔEI_{t-1}	-0.001	-0.59	ΔEI_{t-1}	0.019	2.40
ΔEI_{t-2}	0.000	0.32	ΔEI_{t-2}	0.023	2.97
ΔEI_{t-3}	0.001	1.58	ΔEI_{t-3}	0.009	1.22
ΔEI_{t-4}	0.001	1.12	ΔEI_{t-4}	0.010	1.40
ΔEI_{t-5}	-0.001	-1.64	ΔEI_{t-5}	0.015	2.15
ΔEI_{t-6}	-0.000	-0.02	ΔEI_{t-6}	0.009	1.23
ΔEI_{t-7}	0.001	1.54	ΔEI_{t-7}	0.010	1.61
ΔEI_{t-8}	0.000	0.82	ΔEI_{t-8}	0.001	0.12
	$\Sigma = 0.001$			$\Sigma = 0.096$	
ΔIP_{t-1}	0.011	0.37	ΔIP_{t-1}	-0.517	-1.90
ΔIP_{t-2}	-0.022	-0.72	ΔIP_{t-2}	-0.526	-1.92
ΔIP_{t-3}	0.022	0.71	ΔIP_{t-3}	-0.060	-0.21
ΔIP_{t-4}	-0.058	-1.90	ΔIP_{t-4}	-0.435	-1.58
ΔIP_{t-5}	0.036	1.12	ΔIP_{t-5}	-0.412	-1.42
ΔIP_{t-6}	-0.002	-0.06	ΔIP_{t-6}	-0.080	-0.28
ΔIP_{t-7}	0.011	0.38	ΔIP_{t-7}	-0.149	-0.56
ΔIP_{t-8}	-0.025	-0.89	ΔIP_{t-8}	0.037	0.14
	$\Sigma = -0.027$			$\Sigma = -2.142$	
ΔMB_{t-1}	0.038	0.50	ΔMB_{t-1}	-0.513	-0.74
ΔMB_{t-2}	0.171	2.25	ΔMB_{t-2}	1.081	1.56
ΔMB_{t-3}	0.025	0.31	ΔMB_{t-3}	-0.146	-0.20
ΔMB_{t-4}	0.491	6.00	ΔMB_{t-4}	-0.957	-1.28
ΔMB_{t-5}	-0.281	-3.38	ΔMB_{t-5}	0.159	0.21
ΔMB_{t-6}	-0.172	-2.03	ΔMB_{t-6}	-1.993	-2.60
ΔMB_{t-7}	0.004	0.04	ΔMB_{t-7}	-0.762	-1.01
ΔMB_{t-8}	0.039	0.48	ΔMB_{t-8}	0.644	0.87
	$\Sigma = 0.315$			$\Sigma = -2.487$	
ΔSPR_{t-1}	-0.011	-1.20	ΔSPR_{t-1}	0.057	0.67
ΔSPR_{t-2}	-0.001	-0.09	ΔSPR_{t-2}	-0.005	-0.06
ΔSPR_{t-3}	0.010	1.04	ΔSPR_{t-3}	-0.042	-0.47
ΔSPR_{t-4}	0.003	0.26	ΔSPR_{t-4}	0.029	0.32
ΔSPR_{t-5}	-0.016	-1.60	ΔSPR_{t-5}	0.034	0.38
ΔSPR_{t-6}	0.015	1.52	ΔSPR_{t-6}	-0.035	-0.40
ΔSPR_{t-7}	-0.006	-0.67	ΔSPR_{t-7}	-0.113	-1.30
ΔSPR_{t-8}	-0.013	-1.35	ΔSPR_{t-8}	-0.141	-1.64
	$\Sigma = -0.019$			$\Sigma = -0.216$	
$ECT1_{t-1}$	0.019	2.05	$ECT1_{t-1}$	0.303	3.56
$ECT2_{t-1}$	-0.002	-1.65	$ECT2_{t-1}$	0.019	1.96
Adjusted $R^2 = 0.87$, DW = 1.9165			Adjusted $R^2 = 0.12$, DW = 1.9906		
Normality $\chi^2[2] = 0.78$, ARCH $\chi^2[1] = 0.169$			Normality $\chi^2[2] = 110.5$, ARCH $\chi^2[1] = 0.012$		
RESET F[1,152] = 1.96			RESET F[1,152] = 2.86		

Notes: VECM(8) using Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), and Estimated Expected Inflation (EI). Quarterly data in the 1950.1-1996.4 period.

DW is the Durbin-Watson test of first-order residual autocorrelation.

Normality $\chi^2[2]$ is the Jarque-Bera test for skewness and excess kurtosis.

ARCH $\chi^2[1]$ is the test for autoregressive conditional heteroskedasticity.

RESET F[q,T-k-Q] is the qth order Ramsey-Reset Statistic.

Table 10. VECM(6) Saikkonen-Lütkepohl Method (ST)

Dependent Variable = ΔIP			Dependent Variable = ΔST		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.023	-0.35	Constant	-1.925	-3.85
ΔIP_{t-1}	0.088	1.00	ΔIP_{t-1}	1.177	1.81
ΔIP_{t-2}	-0.206	-2.48	ΔIP_{t-2}	-0.123	-0.20
ΔIP_{t-3}	-0.135	-1.71	ΔIP_{t-3}	0.397	0.68
ΔIP_{t-4}	0.219	2.88	ΔIP_{t-4}	-0.717	-1.27
ΔIP_{t-5}	-0.288	-3.89	ΔIP_{t-5}	-1.316	-2.40
ΔIP_{t-6}	-0.047	-0.60	ΔIP_{t-6}	-0.448	-0.79
	Σ = -0.369			Σ = -1.030	
ΔMB_{t-1}	-0.049	-0.23	ΔMB_{t-1}	0.236	0.15
ΔMB_{t-2}	-0.184	-0.91	ΔMB_{t-2}	1.660	1.11
ΔMB_{t-3}	0.831	5.66	ΔMB_{t-3}	0.805	0.74
ΔMB_{t-4}	-0.171	-1.06	ΔMB_{t-4}	-0.300	-0.25
ΔMB_{t-5}	0.084	0.42	ΔMB_{t-5}	-0.331	-0.22
ΔMB_{t-6}	0.514	2.52	ΔMB_{t-6}	-3.672	-2.43
	Σ = 1.025			Σ = -1.602	
ΔSPR_{t-1}	0.091	3.84	ΔSPR_{t-1}	0.462	2.65
ΔSPR_{t-2}	0.084	3.38	ΔSPR_{t-2}	0.408	2.22
ΔSPR_{t-3}	0.018	0.70	ΔSPR_{t-3}	-0.001	-0.00
ΔSPR_{t-4}	0.072	2.87	ΔSPR_{t-4}	0.068	0.37
ΔSPR_{t-5}	0.022	0.88	ΔSPR_{t-5}	0.119	0.64
ΔSPR_{t-6}	0.004	0.15	ΔSPR_{t-6}	0.041	0.22
	Σ = 0.291			Σ = 1.097	
ΔST_{t-1}	0.019	1.57	ΔST_{t-1}	0.104	1.17
ΔST_{t-2}	-0.002	-0.15	ΔST_{t-2}	-0.094	-1.04
ΔST_{t-3}	0.012	0.94	ΔST_{t-3}	0.232	2.52
ΔST_{t-4}	-0.031	-2.50	ΔST_{t-4}	0.156	1.72
ΔST_{t-5}	0.034	2.85	ΔST_{t-5}	0.274	3.11
ΔST_{t-6}	-0.007	-0.56	ΔST_{t-6}	0.022	0.24
	Σ = 0.025			Σ = 0.694	
IP_{t-1}	0.031	0.95	IP_{t-1}	0.953	3.93
ST_{t-1}	-0.018	-2.01	ST_{t-1}	-0.277	-4.21
MB_{t-1}	-0.018	-1.61	MB_{t-1}	-0.319	-3.86
SPR_{t-1}	-0.002	-0.24	SPR_{t-1}	-0.143	-2.48
Adjusted R^2 = 0.66, DW = 2.0380			Adjusted R^2 = 0.24, DW = 2.0140		
Normality $\chi^2[2]$ = 16.64, ARCH $\chi^2[1]$ = 5.107			Normality $\chi^2[2]$ = 146.0, ARCH $\chi^2[1]$ = 14.55		
RESET F[1,158] = 9.31			RESET F[1,158] = 2.14		

Continued

Table 10. (Cont.) VECM(6) Saikkonen-Lütkepohl Method (ST)

Dependent Variable = ΔMB			Dependent Variable = ΔSPR		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.057	-2.41	Constant	-0.101	-0.45
ΔIP_{t-1}	0.018	0.59	ΔIP_{t-1}	-0.179	-0.61
ΔIP_{t-2}	0.018	0.61	ΔIP_{t-2}	-0.321	-1.17
ΔIP_{t-3}	0.053	1.94	ΔIP_{t-3}	0.006	0.02
ΔIP_{t-4}	-0.065	-2.46	ΔIP_{t-4}	-0.299	-1.19
ΔIP_{t-5}	0.065	2.51	ΔIP_{t-5}	-0.153	-0.62
ΔIP_{t-6}	0.019	0.69	ΔIP_{t-6}	0.108	0.42
	Σ = 0.108			Σ = -0.838	
ΔMB_{t-1}	-0.043	-0.58	ΔMB_{t-1}	-0.992	-1.41
ΔMB_{t-2}	0.144	2.05	ΔMB_{t-2}	1.061	1.58
ΔMB_{t-3}	-0.109	-2.14	ΔMB_{t-3}	-0.767	-1.58
ΔMB_{t-4}	0.564	10.06	ΔMB_{t-4}	-0.722	-1.35
ΔMB_{t-5}	-0.146	-2.08	ΔMB_{t-5}	0.365	0.55
ΔMB_{t-6}	-0.224	-3.17	ΔMB_{t-6}	-1.764	-2.61
	Σ = 0.186			Σ = -2.819	
ΔSPR_{t-1}	-0.001	-0.16	ΔSPR_{t-1}	0.046	0.59
ΔSPR_{t-2}	-0.007	-0.80	ΔSPR_{t-2}	-0.155	-1.89
ΔSPR_{t-3}	0.004	0.49	ΔSPR_{t-3}	0.008	0.10
ΔSPR_{t-4}	0.008	0.92	ΔSPR_{t-4}	-0.038	-0.46
ΔSPR_{t-5}	-0.004	-0.47	ΔSPR_{t-5}	0.015	0.18
ΔSPR_{t-6}	0.005	0.53	ΔSPR_{t-6}	-0.043	-0.51
	Σ = 0.005			Σ = -0.167	
ΔST_{t-1}	-0.006	-1.40	ΔST_{t-1}	-0.005	-0.12
ΔST_{t-2}	-0.015	-3.53	ΔST_{t-2}	-0.031	-0.76
ΔST_{t-3}	-0.005	-1.18	ΔST_{t-3}	-0.002	-0.06
ΔST_{t-4}	-0.002	-0.52	ΔST_{t-4}	-0.048	-1.19
ΔST_{t-5}	-0.003	-0.72	ΔST_{t-5}	0.007	0.17
ΔST_{t-6}	-0.009	-2.16	ΔST_{t-6}	-0.094	-2.37
	Σ = -0.040			Σ = -0.173	
IP_{t-1}	0.026	2.28	IP_{t-1}	0.038	0.35
ST_{t-1}	-0.001	-0.35	ST_{t-1}	-0.029	-0.98
MB_{t-1}	-0.007	-1.89	MB_{t-1}	0.015	0.40
SPR_{t-1}	-0.005	-2.02	SPR_{t-1}	-0.029	-1.13
Adjusted R^2 = 0.88, DW = 2.0154 Normality $\chi^2[2]$ = 9.11, ARCH $\chi^2[1]$ = 2.397 RESET F[1,158] = 3.37			Adjusted R^2 = 0.10, DW = 2.0101 Normality $\chi^2[2]$ = 113.4, ARCH $\chi^2[1]$ = 0.050 RESET F[1,158] = 0.59		

Notes: VECM(6) using Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), and 3-Month Treasury Bill (ST). Quarterly data in the 1950.1-1996.4 period. DW is the Durbin-Watson test of first-order residual autocorrelation.

Normality $\chi^2[2]$ is the Jarque-Bera test for skewness and excess kurtosis.

ARCH $\chi^2[1]$ is the test for autoregressive conditional heteroskedasticity.

RESET F[q,T-k-Q] is the qth order Ramsey-Reset Statistic.

Table 11. VECM(6) Saikkonen-Lütkepohl Method (EI)

Dependent Variable = ΔEI			Dependent Variable = ΔIP		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-5.442	-1.52	Constant	0.106	1.49
ΔEI_{t-1}	-0.179	-1.49	ΔEI_{t-1}	0.003	1.27
ΔEI_{t-2}	0.078	0.70	ΔEI_{t-2}	0.004	1.58
ΔEI_{t-3}	0.168	1.55	ΔEI_{t-3}	-0.000	-0.08
ΔEI_{t-4}	-0.085	-0.77	ΔEI_{t-4}	-0.004	-1.70
ΔEI_{t-5}	-0.136	-1.34	ΔEI_{t-5}	-0.003	-1.60
ΔEI_{t-6}	-0.082	-1.00	ΔEI_{t-6}	-0.002	-1.28
	$\Sigma = -0.236$			$\Sigma = -0.002$	
ΔIP_{t-1}	6.162	1.38	ΔIP_{t-1}	0.003	0.03
ΔIP_{t-2}	5.015	1.14	ΔIP_{t-2}	-0.196	-2.25
ΔIP_{t-3}	0.736	0.17	ΔIP_{t-3}	-0.124	-1.46
ΔIP_{t-4}	-3.278	-0.79	ΔIP_{t-4}	0.246	2.97
ΔIP_{t-5}	0.836	0.20	ΔIP_{t-5}	-0.101	-1.21
ΔIP_{t-6}	9.056	2.27	ΔIP_{t-6}	0.051	0.64
	$\Sigma = 18.527$			$\Sigma = -0.121$	
ΔMB_{t-1}	-6.397	-0.60	ΔMB_{t-1}	0.209	0.98
ΔMB_{t-2}	28.524	2.74	ΔMB_{t-2}	0.082	0.39
ΔMB_{t-3}	-19.748	-2.32	ΔMB_{t-3}	0.630	3.72
ΔMB_{t-4}	-41.322	-4.47	ΔMB_{t-4}	-0.193	-1.05
ΔMB_{t-5}	22.052	1.95	ΔMB_{t-5}	0.135	0.60
ΔMB_{t-6}	27.369	2.40	ΔMB_{t-6}	0.535	2.36
	$\Sigma = 10.478$			$\Sigma = 1.398$	
ΔSPR_{t-1}	4.557	3.33	ΔSPR_{t-1}	0.103	3.79
ΔSPR_{t-2}	1.898	1.32	ΔSPR_{t-2}	0.105	3.68
ΔSPR_{t-3}	0.268	0.19	ΔSPR_{t-3}	0.011	0.39
ΔSPR_{t-4}	-0.930	-0.65	ΔSPR_{t-4}	0.057	2.00
ΔSPR_{t-5}	0.982	0.69	ΔSPR_{t-5}	0.014	0.51
ΔSPR_{t-6}	-1.842	-1.33	ΔSPR_{t-6}	-0.008	-0.31
	$\Sigma = 4.933$			$\Sigma = 0.282$	
EI_{t-1}	-0.199	-1.80	EI_{t-1}	0.000	0.10
IP_{t-1}	3.007	1.66	IP_{t-1}	-0.033	-0.90
MB_{t-1}	-1.306	-1.95	MB_{t-1}	0.001	0.11
SPR_{t-1}	-0.696	-1.12	SPR_{t-1}	0.011	0.86
Adjusted $R^2 = 0.50$, DW = 2.0212 Normality $\chi^2[2] = 3.04$, ARCH $\chi^2[1] = 11.643$ RESET F[1,158] = 1.70			Adjusted $R^2 = 0.63$, DW = 2.0181 Normality $\chi^2[2] = 21.04$, ARCH $\chi^2[1] = 7.761$ RESET F[1,158] = 4.67		

Continued

Table 11. (Cont.) VECM(6) Saikkonen-Lütkepohl Method (EI)

Dependent Variable = ΔMB			Dependent Variable = ΔSPR		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.053	-2.14	Constant	-0.409	-1.81
ΔEI_{t-1}	-0.001	-0.84	ΔEI_{t-1}	0.010	1.36
ΔEI_{t-2}	-0.000	-0.18	ΔEI_{t-2}	0.014	2.02
ΔEI_{t-3}	0.001	1.17	ΔEI_{t-3}	0.005	0.73
ΔEI_{t-4}	0.001	1.19	ΔEI_{t-4}	0.007	1.04
ΔEI_{t-5}	-0.001	-2.02	ΔEI_{t-5}	0.008	1.17
ΔEI_{t-6}	-0.001	-1.09	ΔEI_{t-6}	0.000	0.01
	Σ = -0.001			Σ = 0.044	
ΔIP_{t-1}	0.004	0.12	ΔIP_{t-1}	-0.442	-1.57
ΔIP_{t-2}	-0.028	-0.94	ΔIP_{t-2}	-0.365	-1.32
ΔIP_{t-3}	0.013	0.45	ΔIP_{t-3}	-0.163	-0.60
ΔIP_{t-4}	-0.080	-2.80	ΔIP_{t-4}	-0.498	-1.89
ΔIP_{t-5}	0.041	1.41	ΔIP_{t-5}	-0.243	-0.92
ΔIP_{t-6}	-0.002	-0.08	ΔIP_{t-6}	-0.159	-0.63
	Σ = -0.052			Σ = -1.870	
ΔMB_{t-1}	0.014	0.20	ΔMB_{t-1}	-0.590	-0.87
ΔMB_{t-2}	0.151	2.12	ΔMB_{t-2}	1.056	1.60
ΔMB_{t-3}	-0.006	-0.09	ΔMB_{t-3}	-0.464	-0.86
ΔMB_{t-4}	0.563	8.89	ΔMB_{t-4}	-0.249	-0.43
ΔMB_{t-5}	-0.255	-3.29	ΔMB_{t-5}	0.045	0.06
ΔMB_{t-6}	-0.207	-2.65	ΔMB_{t-6}	-2.071	-2.88
	Σ = 0.260			Σ = -2.273	
ΔSPR_{t-1}	-0.007	-0.73	ΔSPR_{t-1}	0.060	0.69
ΔSPR_{t-2}	-0.003	-0.28	ΔSPR_{t-2}	-0.064	-0.71
ΔSPR_{t-3}	0.011	1.17	ΔSPR_{t-3}	-0.039	-0.44
ΔSPR_{t-4}	0.008	0.79	ΔSPR_{t-4}	0.019	0.22
ΔSPR_{t-5}	-0.011	-1.07	ΔSPR_{t-5}	0.043	0.48
ΔSPR_{t-6}	0.015	1.62	ΔSPR_{t-6}	-0.061	-0.70
	Σ = 0.031			Σ = -0.042	
EI_{t-1}	-0.000	-0.56	EI_{t-1}	-0.019	-2.76
IP_{t-1}	0.025	2.02	IP_{t-1}	0.206	1.80
MB_{t-1}	-0.007	-1.57	MB_{t-1}	-0.051	-1.20
SPR_{t-1}	-0.006	-1.45	SPR_{t-1}	-0.102	-2.59
Adjusted R^2 = 0.87, DW = 1.9156			Adjusted R^2 = 0.11, DW = 2.0430		
Normality $\chi^2[2]$ = 1.63, ARCH $\chi^2[1]$ = 0.001			Normality $\chi^2[2]$ = 144.3, ARCH $\chi^2[1]$ = 0.121		
RESET F[1,158] = 3.08			RESET F[1,158] = 0.50		

Notes: VECM(6) using Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), and Estimated Expected Inflation (EI). Quarterly data in the 1950.1-1996.4 period.

DW is the Durbin-Watson test of first-order residual autocorrelation.

Normality $\chi^2[2]$ is the Jarque-Bera test for skewness and excess kurtosis.

ARCH $\chi^2[1]$ is the test for autoregressive conditional heteroskedasticity.

RESET F[q,T-k-Q] is the qth order Ramsey-Reset Statistic.

Table 12. VECM(8) Saikkonen-Lütkepohl Method (ST)

Dependent Variable = ΔIP			Dependent Variable = ΔST		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.085	-1.11	Constant	-2.105	-3.65
ΔIP_{t-1}	0.067	0.76	ΔIP_{t-1}	1.300	1.94
ΔIP_{t-2}	-0.189	-2.13	ΔIP_{t-2}	-0.181	-0.27
ΔIP_{t-3}	-0.139	-1.58	ΔIP_{t-3}	0.616	0.93
ΔIP_{t-4}	0.170	2.01	ΔIP_{t-4}	-1.186	-1.86
ΔIP_{t-5}	-0.281	-3.38	ΔIP_{t-5}	-1.570	-2.51
ΔIP_{t-6}	-0.073	-0.87	ΔIP_{t-6}	-0.493	-0.78
ΔIP_{t-7}	-0.123	-1.57	ΔIP_{t-7}	-0.364	-0.61
ΔIP_{t-8}	0.051	0.68	ΔIP_{t-8}	1.335	2.35
	$\Sigma = -0.517$			$\Sigma = -0.543$	
ΔMB_{t-1}	-0.065	-0.30	ΔMB_{t-1}	0.106	0.06
ΔMB_{t-2}	-0.143	-0.66	ΔMB_{t-2}	1.636	1.00
ΔMB_{t-3}	0.545	2.62	ΔMB_{t-3}	-0.039	-0.03
ΔMB_{t-4}	0.142	0.68	ΔMB_{t-4}	0.000	0.00
ΔMB_{t-5}	0.049	0.24	ΔMB_{t-5}	-0.251	-0.16
ΔMB_{t-6}	0.553	2.68	ΔMB_{t-6}	-4.196	-2.70
ΔMB_{t-7}	0.137	0.63	ΔMB_{t-7}	-0.369	-0.22
ΔMB_{t-8}	-0.487	-2.23	ΔMB_{t-8}	-0.039	-0.02
	$\Sigma = 0.731$			$\Sigma = -3.152$	
ΔSPR_{t-1}	0.096	3.91	ΔSPR_{t-1}	0.480	2.62
ΔSPR_{t-2}	0.082	3.24	ΔSPR_{t-2}	0.411	2.15
ΔSPR_{t-3}	0.020	0.77	ΔSPR_{t-3}	0.035	0.19
ΔSPR_{t-4}	0.074	2.93	ΔSPR_{t-4}	0.080	0.42
ΔSPR_{t-5}	0.027	1.08	ΔSPR_{t-5}	0.168	0.88
ΔSPR_{t-6}	0.009	0.37	ΔSPR_{t-6}	0.106	0.56
ΔSPR_{t-7}	0.011	0.46	ΔSPR_{t-7}	0.309	1.65
ΔSPR_{t-8}	0.038	1.55	ΔSPR_{t-8}	0.125	0.67
	$\Sigma = 0.357$			$\Sigma = 1.714$	
ΔST_{t-1}	0.023	1.81	ΔST_{t-1}	0.081	0.86
ΔST_{t-2}	-0.003	-0.27	ΔST_{t-2}	-0.106	-1.13
ΔST_{t-3}	0.014	1.09	ΔST_{t-3}	0.235	2.49
ΔST_{t-4}	-0.027	-2.16	ΔST_{t-4}	0.171	1.79
ΔST_{t-5}	0.034	2.60	ΔST_{t-5}	0.259	2.67
ΔST_{t-6}	0.001	0.04	ΔST_{t-6}	-0.010	-0.10
ΔST_{t-7}	-0.004	-0.31	ΔST_{t-7}	-0.017	-0.18
ΔST_{t-8}	0.014	1.13	ΔST_{t-8}	-0.062	-0.68
	$\Sigma = 0.052$			$\Sigma = 0.551$	
IP_{t-1}	0.060	1.62	IP_{t-1}	1.030	3.73
ST_{t-1}	-0.023	-2.37	ST_{t-1}	-0.272	-3.70
MB_{t-1}	-0.027	-2.16	MB_{t-1}	-0.344	-3.72
SPR_{t-1}	-0.007	-0.85	SPR_{t-1}	-0.166	-2.69

Adjusted $R^2 = 0.67$, DW = 1.9581
Normality $\chi^2[2] = 15.34$, ARCH $\chi^2[1] = 5.667$
RESET F[1,150] = 5.23

Adjusted $R^2 = 0.25$, DW = 1.9949
Normality $\chi^2[2] = 209.3$, ARCH $\chi^2[1] = 12.94$
RESET F[1,150] = 0.17

Continued

Table 12. (Cont.) VECM(8) Saikkonen-Lütkepohl Method (ST)

Dependent Variable = ΔMB			Dependent Variable = ΔSPR		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.053	-1.93	Constant	0.113	0.44
ΔIP_{t-1}	0.026	0.83	ΔIP_{t-1}	-0.065	-0.22
ΔIP_{t-2}	0.013	0.42	ΔIP_{t-2}	-0.232	-0.78
ΔIP_{t-3}	0.061	1.94	ΔIP_{t-3}	0.281	0.95
ΔIP_{t-4}	-0.059	-1.94	ΔIP_{t-4}	-0.283	-1.00
ΔIP_{t-5}	0.057	1.91	ΔIP_{t-5}	0.054	0.19
ΔIP_{t-6}	0.027	0.91	ΔIP_{t-6}	0.313	1.10
ΔIP_{t-7}	0.002	0.06	ΔIP_{t-7}	0.282	1.07
ΔIP_{t-8}	0.016	0.59	ΔIP_{t-8}	0.353	1.39
	Σ = 0.143			Σ = 0.703	
ΔMB_{t-1}	-0.070	-0.90	ΔMB_{t-1}	-1.081	-1.48
ΔMB_{t-2}	0.124	1.60	ΔMB_{t-2}	0.753	1.03
ΔMB_{t-3}	-0.037	-0.49	ΔMB_{t-3}	-0.574	-0.82
ΔMB_{t-4}	0.506	6.78	ΔMB_{t-4}	-0.960	-1.37
ΔMB_{t-5}	-0.145	-2.00	ΔMB_{t-5}	0.269	0.39
ΔMB_{t-6}	-0.255	-3.46	ΔMB_{t-6}	-2.147	-3.10
ΔMB_{t-7}	-0.106	-1.36	ΔMB_{t-7}	-0.204	-0.28
ΔMB_{t-8}	0.070	0.89	ΔMB_{t-8}	0.542	0.74
	Σ = 0.087			Σ = -3.402	
ΔSPR_{t-1}	-0.005	-0.60	ΔSPR_{t-1}	0.017	0.20
ΔSPR_{t-2}	-0.008	-0.85	ΔSPR_{t-2}	-0.186	-2.18
ΔSPR_{t-3}	0.002	0.25	ΔSPR_{t-3}	-0.006	-0.07
ΔSPR_{t-4}	0.006	0.70	ΔSPR_{t-4}	-0.085	-1.00
ΔSPR_{t-5}	-0.007	-0.74	ΔSPR_{t-5}	-0.017	-0.20
ΔSPR_{t-6}	0.002	0.26	ΔSPR_{t-6}	-0.077	-0.91
ΔSPR_{t-7}	-0.003	-0.39	ΔSPR_{t-7}	-0.137	-1.65
ΔSPR_{t-8}	-0.004	-0.47	ΔSPR_{t-8}	-0.112	-1.35
	Σ = -0.017			Σ = -0.603	
ΔST_{t-1}	-0.008	-1.81	ΔST_{t-1}	-0.031	-0.73
ΔST_{t-2}	-0.015	-3.41	ΔST_{t-2}	-0.052	-1.23
ΔST_{t-3}	-0.006	-1.42	ΔST_{t-3}	-0.022	-0.53
ΔST_{t-4}	-0.002	-0.53	ΔST_{t-4}	-0.076	-1.78
ΔST_{t-5}	-0.003	-0.69	ΔST_{t-5}	-0.007	-0.17
ΔST_{t-6}	-0.011	-2.28	ΔST_{t-6}	-0.131	-3.00
ΔST_{t-7}	-0.003	-0.61	ΔST_{t-7}	-0.015	-0.35
ΔST_{t-8}	-0.006	-1.31	ΔST_{t-8}	-0.094	-2.30
	Σ = -0.054			Σ = -0.428	
IP_{t-1}	0.024	1.81	IP_{t-1}	-0.075	-0.61
ST_{t-1}	-0.000	-0.01	ST_{t-1}	0.004	0.12
MB_{t-1}	-0.006	-1.42	MB_{t-1}	0.057	1.38
SPR_{t-1}	-0.005	-1.73	SPR_{t-1}	-0.011	-0.39
Adjusted R^2 = 0.87, DW = 1.9436 Normality $\chi^2[2]$ = 10.03, ARCH $\chi^2[1]$ = 3.197 RESET F[1,150] = 4.33			Adjusted R^2 = 0.12, DW = 1.9910 Normality $\chi^2[2]$ = 64.62, ARCH $\chi^2[1]$ = 0.114 RESET F[1,150] = 5.73		

Notes: VECM(8) using Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), and 3-Month Treasury Bill (ST). Quarterly data in the 1950.1-1996.4 period. DW is the Durbin-Watson test of first-order residual autocorrelation.

Normality $\chi^2[2]$ is the Jarque-Bera test for skewness and excess kurtosis.

ARCH $\chi^2[1]$ is the test for autoregressive conditional heteroskedasticity.

RESET F[q,T-k-Q] is the qth order Ramsey-Reset Statistic.

Table 13. VECM(8) Saikkonen-Lütkepohl Method (EI)

Dependent Variable = ΔEI			Dependent Variable = ΔIP		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-8.388	-1.97	Constant	0.071	0.86
ΔEI_{t-1}	-0.085	-0.63	ΔEI_{t-1}	0.004	1.70
ΔEI_{t-2}	0.189	1.44	ΔEI_{t-2}	0.004	1.61
ΔEI_{t-3}	0.283	2.18	ΔEI_{t-3}	0.000	0.05
ΔEI_{t-4}	-0.060	-0.50	ΔEI_{t-4}	-0.003	-1.11
ΔEI_{t-5}	-0.092	-0.80	ΔEI_{t-5}	-0.002	-0.92
ΔEI_{t-6}	0.051	0.44	ΔEI_{t-6}	-0.001	-0.24
ΔEI_{t-7}	0.174	1.70	ΔEI_{t-7}	0.001	0.73
ΔEI_{t-8}	0.065	0.78	ΔEI_{t-8}	0.001	0.68
	Σ = 0.525			Σ = 0.004	
ΔIP_{t-1}	4.594	1.00	ΔIP_{t-1}	-0.013	-0.15
ΔIP_{t-2}	4.394	0.96	ΔIP_{t-2}	-0.212	-2.36
ΔIP_{t-3}	-1.099	-0.23	ΔIP_{t-3}	-0.085	-0.92
ΔIP_{t-4}	-4.006	-0.87	ΔIP_{t-4}	0.172	1.91
ΔIP_{t-5}	-0.934	-0.19	ΔIP_{t-5}	-0.121	-1.29
ΔIP_{t-6}	4.928	1.05	ΔIP_{t-6}	0.009	0.10
ΔIP_{t-7}	-2.912	-0.67	ΔIP_{t-7}	-0.196	-2.30
ΔIP_{t-8}	-5.055	-1.23	ΔIP_{t-8}	0.065	0.80
	Σ = -0.090			Σ = -0.381	
ΔMB_{t-1}	-3.411	-0.31	ΔMB_{t-1}	0.209	0.95
ΔMB_{t-2}	28.722	2.58	ΔMB_{t-2}	0.159	0.73
ΔMB_{t-3}	-27.206	-2.34	ΔMB_{t-3}	0.285	1.25
ΔMB_{t-4}	-36.861	-3.07	ΔMB_{t-4}	0.052	0.22
ΔMB_{t-5}	19.476	1.59	ΔMB_{t-5}	0.164	0.68
ΔMB_{t-6}	36.828	2.97	ΔMB_{t-6}	0.516	2.12
ΔMB_{t-7}	5.507	0.45	ΔMB_{t-7}	0.243	1.01
ΔMB_{t-8}	-18.151	-1.51	ΔMB_{t-8}	-0.292	-1.24
	Σ = 4.904			Σ = 1.336	
ΔSPR_{t-1}	4.907	3.44	ΔSPR_{t-1}	0.114	4.08
ΔSPR_{t-2}	1.958	1.29	ΔSPR_{t-2}	0.094	3.16
ΔSPR_{t-3}	0.661	0.44	ΔSPR_{t-3}	0.014	0.46
ΔSPR_{t-4}	-1.599	-1.07	ΔSPR_{t-4}	0.056	1.91
ΔSPR_{t-5}	1.109	0.75	ΔSPR_{t-5}	0.015	0.54
ΔSPR_{t-6}	-1.262	-0.86	ΔSPR_{t-6}	-0.002	-0.06
ΔSPR_{t-7}	0.954	0.66	ΔSPR_{t-7}	0.018	0.62
ΔSPR_{t-8}	0.312	0.22	ΔSPR_{t-8}	0.027	1.00
	Σ = 7.040			Σ = 0.336	
EI_{t-1}	-0.298	-2.26	EI_{t-1}	-0.001	-0.31
IP_{t-1}	4.557	2.16	IP_{t-1}	-0.014	-0.34
MB_{t-1}	-1.847	-2.44	MB_{t-1}	-0.005	-0.36
SPR_{t-1}	-1.205	-1.67	SPR_{t-1}	0.005	0.33
Adjusted R^2 = 0.50, DW = 2.0157			Adjusted R^2 = 0.63, DW = 2.0031		
Normality $\chi^2[2]$ = 3.40, ARCH $\chi^2[1]$ = 13.600			Normality $\chi^2[2]$ = 27.99, ARCH $\chi^2[1]$ = 6.585		
RESET F[1,150] = 1.25			RESET F[1,150] = 4.46		

Continued

Table 13. (Cont.) VECM(8) Saikkonen-Lütkepohl Method (EI)

Dependent Variable = ΔMB			Dependent Variable = ΔSPR		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.065	-2.25	Constant	-0.526	-2.00
ΔEI_{t-1}	-0.000	-0.25	ΔEI_{t-1}	0.015	1.81
ΔEI_{t-2}	0.001	0.60	ΔEI_{t-2}	0.020	2.41
ΔEI_{t-3}	0.002	1.78	ΔEI_{t-3}	0.006	0.79
ΔEI_{t-4}	0.001	1.35	ΔEI_{t-4}	0.007	0.96
ΔEI_{t-5}	-0.001	-1.34	ΔEI_{t-5}	0.012	1.74
ΔEI_{t-6}	0.000	0.18	ΔEI_{t-6}	0.007	0.93
ΔEI_{t-7}	0.001	1.67	ΔEI_{t-7}	0.009	1.37
ΔEI_{t-8}	0.001	0.95	ΔEI_{t-8}	-0.000	-0.09
	Σ = 0.005			Σ = 0.076	
ΔIP_{t-1}	0.001	0.04	ΔIP_{t-1}	-0.384	-1.35
ΔIP_{t-2}	-0.030	-0.96	ΔIP_{t-2}	-0.413	-1.46
ΔIP_{t-3}	0.013	0.42	ΔIP_{t-3}	0.055	0.19
ΔIP_{t-4}	-0.065	-2.08	ΔIP_{t-4}	-0.337	-1.18
ΔIP_{t-5}	0.028	0.86	ΔIP_{t-5}	-0.316	-1.06
ΔIP_{t-6}	-0.008	-0.26	ΔIP_{t-6}	0.006	0.02
ΔIP_{t-7}	0.008	0.28	ΔIP_{t-7}	-0.105	-0.39
ΔIP_{t-8}	-0.027	-0.95	ΔIP_{t-8}	0.068	0.27
	Σ = -0.080			Σ = -1.426	
ΔMB_{t-1}	0.034	0.44	ΔMB_{t-1}	-0.431	-0.62
ΔMB_{t-2}	0.168	2.19	ΔMB_{t-2}	1.147	1.66
ΔMB_{t-3}	0.024	0.31	ΔMB_{t-3}	-0.141	-0.20
ΔMB_{t-4}	0.489	5.95	ΔMB_{t-4}	-0.915	-1.23
ΔMB_{t-5}	-0.275	-3.29	ΔMB_{t-5}	0.125	0.16
ΔMB_{t-6}	-0.166	-1.95	ΔMB_{t-6}	-2.025	-2.63
ΔMB_{t-7}	0.009	0.11	ΔMB_{t-7}	-0.778	-1.02
ΔMB_{t-8}	0.042	0.51	ΔMB_{t-8}	0.658	0.88
	Σ = 0.325			Σ = -2.360	
ΔSPR_{t-1}	-0.009	-0.90	ΔSPR_{t-1}	0.031	0.35
ΔSPR_{t-2}	0.002	0.17	ΔSPR_{t-2}	-0.035	-0.37
ΔSPR_{t-3}	0.013	1.24	ΔSPR_{t-3}	-0.069	-0.74
ΔSPR_{t-4}	0.005	0.50	ΔSPR_{t-4}	-0.000	-0.00
ΔSPR_{t-5}	-0.013	-1.30	ΔSPR_{t-5}	0.006	0.06
ΔSPR_{t-6}	0.017	1.70	ΔSPR_{t-6}	-0.060	-0.66
ΔSPR_{t-7}	-0.004	-0.44	ΔSPR_{t-7}	-0.137	-1.54
ΔSPR_{t-8}	-0.011	-1.15	ΔSPR_{t-8}	-0.161	-1.85
	Σ = 0.000			Σ = -0.425	
EI_{t-1}	-0.001	-1.31	EI_{t-1}	-0.026	-3.17
IP_{t-1}	0.032	2.21	IP_{t-1}	0.260	1.99
MB_{t-1}	-0.010	-1.86	MB_{t-1}	-0.064	-1.37
SPR_{t-1}	-0.009	-1.87	SPR_{t-1}	-0.126	-2.82
Adjusted R^2 = 0.87, DW = 1.9129			Adjusted R^2 = 0.13, DW = 1.9959		
Normality $\chi^2[2]$ = 1.64, ARCH $\chi^2[1]$ = 0.102			Normality $\chi^2[2]$ = 106.3, ARCH $\chi^2[1]$ = 0.046		
RESET F[1,150] = 2.77			RESET F[1,150] = 4.20		

Notes: VECM(8) using Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), and Expected Inflation (EI). Quarterly data in the 1950.1-1996.4 period.

DW is the Durbin-Watson test of first-order residual autocorrelation.

Normality $\chi^2[2]$ is the Jarque-Bera test for skewness and excess kurtosis.

ARCH $\chi^2[1]$ is the test for autoregressive conditional heteroskedasticity.

RESET F[q,T-k-Q] is the qth order Ramsey-Reset Statistic.

APPENDIX D

SHORT-RUN CAUSALITY TESTS

Table 14. SR Causality Tests VECM(6) - TP Method

Expected Inflation = ST

	Dependent Variable			
	ΔIP	ΔST	ΔMB	ΔSPR
ΔIP	-	14.315^b	26.195^a	4.296
ΔST	26.967^a	-	20.154^a	9.525
ΔMB	62.532^a	11.943	-	12.137
ΔSPR	39.300^a	16.679^b	3.307	-

Expected Inflation = EI

	Dependent Variable			
	ΔIP	ΔEI	ΔMB	ΔSPR
ΔIP	-	21.311^a	15.482^b	12.857^b
ΔEI	13.484^b	-	19.326^a	10.369
ΔMB	29.601^a	76.191^a	-	10.892
ΔSPR	38.569^a	17.577^a	7.292	-

Notes: Causality tests within VECM(6) using Toda and Phillips (TP) Method.
a and b imply significantly different from zero at 1% and 5% level respectively.
The test statistics have a $\chi^2(6)$ distribution under the null hypothesis.
Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), 3-month Treasury Bill Yield (ST), and Estimated Expected Inflation (EI).
Quarterly data in the 1950.1-1996.4 period.

Table 15. SR Causality Tests VECM(8) - TP Method

Expected Inflation = ST

	Dependent Variable			
	ΔIP	ΔST	ΔMB	ΔSPR
ΔIP	-	24.669[a]	18.311[b]	10.477
ΔST	31.040[a]	-	20.825[a]	18.725[b]
ΔMB	51.065[a]	11.525	-	16.952[b]
ΔSPR	40.468[a]	18.421[b]	5.055	-

Expected Inflation = EI

	Dependent Variable			
	ΔIP	ΔEI	ΔMB	ΔSPR
ΔIP	-	20.208[a]	12.212	14.585
ΔEI	12.826	-	20.061[a]	17.115[b]
ΔMB	20.844[a]	73.300[a]	-	12.382
ΔSPR	37.671[a]	19.740[b]	11.198	-

Notes: Causality tests within VECM(8) using Toda and Phillips (TP) Method.
a and b imply significantly different from zero at 1% and 5% level respectively.
The test statistics have a $\chi^2(8)$ distribution under the null hypothesis.
Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), 3-month Treasury Bill Yield (ST), and Estimated Expected Inflation (EI).
Quarterly data in the 1950.1-1996.4 period.

Table 16. SR Causality Tests VECM(6) - SL Method

Expected Inflation = ST

	Dependent Variable			
	ΔIP	ΔST	ΔMB	ΔSPR
ΔIP	-	0.370	1.979	1.605
ΔST	0.527	-	10.354[a]	2.469
ΔMB	10.692[a]	0.953	-	6.013[b]
ΔSPR	22.391[a]	6.010[b]	0.044	-

Expected Inflation = EI

	Dependent Variable			
	ΔIP	ΔEI	ΔMB	ΔSPR
ΔIP	-	2.976	0.526	8.012[a]
ΔEI	0.153	-	0.197	4.043[b]
ΔMB	17.549[a]	0.618	-	5.337[b]
ΔSPR	19.984[a]	2.425	0.439	-

Notes: Causality tests within VECM(6) using Saikkonen and Lütkepohl (SL) Method.
a and b imply significantly different from zero at 1% and 5% level respectively.
The test statistics have a $\chi^2(1)$ distribution under the null hypothesis.
Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), 3-month Treasury Bill Yield (ST), and Estimated Expected Inflation (EI).
Quarterly data in the 1950.1-1996.4 period.

Table 17. SR Causality Tests VECM(8) - SL Method

Expected Inflation = ST

Dependent Variable

	ΔIP	ΔST	ΔMB	ΔSPR
ΔIP	-	0.061	2.121	0.780
ΔST	1.383	-	12.048[a]	10.606[a]
ΔMB	5.231[b]	3.633	-	6.492[b]
ΔSPR	21.476[a]	8.595[a]	0.327	-

Expected Inflation = EI

Dependent Variable

	ΔIP	ΔEI	ΔMB	ΔSPR
ΔIP	-	0.001	0.752	3.070
ΔEI	0.343	-	1.044	5.239[b]
ΔMB	17.986[a]	0.122	-	6.192[b]
ΔSPR	20.243[a]	3.382	0.001	-

Notes: Causality tests within VECM(8) using Saikkonen and Lütkepohl (SL) Method.
a and b imply significantly different from zero at 1% and 5% level respectively.
The test statistics have a $\chi^2(1)$ distribution under the null hypothesis.
Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), 3-month Treasury Bill Yield (ST), and Estimated Expected Inflation (EI).
Quarterly data in the 1950.1-1996.4 period.

Table 18. Summary of Significant Causal Relations

Hypothesis		VECM Method	
		Toda and Phillips	Saikkonen and Lütkepohl
H_1	(SPR→IP w/ST)	VECM(6), VECM(8)	VECM(6), VECM(8)
	(SPR→IP w/EI)	VECM(6), VECM(8)	VECM(6), VECM(8)
H_2	(ST→IP)	VECM(6), VECM(8)	-
	(EI→IP)	VECM(6)	-
H_3	(MB→IP w/ST)	VECM(6), VECM(8)	VECM(6), VECM(8)
	(MB→IP w/EI)	VECM(6), VECM(8)	VECM(6), VECM(8)
H_4	(SPR→MB w/ST)	-	-
	(SPR→MB w/EI)	-	-
H_5	(ST→MB)	VECM(6), VECM(8)	VECM(6), VECM(8)
	(EI→MB)	VECM(6), VECM(8)	-
H_6	(ST→SPR)	VECM(8)	VECM(8)
	(EI→SPR)	VECM(8)	VECM(6), VECM(8)
H_7	(SPR→ST)	VECM(6), VECM(8)	VECM(6), VECM(8)
	(SPR→EI)	VECM(6), VECM(8)	-

Notes: Significant causality tests from Tables 14-17 within a VECM of order 6 or 8 using the methods of Toda and Phillips (1993, 1994) and Saikkonen and Lütkepohl (1996). A dash (-) denotes the hypothesis test was insignificant using both 6 and 8 lags.

APPENDIX E

TP AND SL VECM ESTIMATES WITH DUMMY VARIABLE

Table 19. VECM(6) w/ Dummy Variable TP Method (ST)

Dependent Variable = ΔSPR			Dependent Variable = ΔSPR		
Graham D:1976.1-1982.1			**Kaul D:1979.1-1986.4**		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.114	-0.49	Constant	-0.158	-0.67
ΔIP_{t-1}	-0.236	-0.76	ΔIP_{t-1}	-0.239	-0.78
ΔIP_{t-2}	-0.344	-1.19	ΔIP_{t-2}	-0.376	-1.31
ΔIP_{t-3}	0.055	0.20	ΔIP_{t-3}	0.026	0.09
ΔIP_{t-4}	-0.309	-1.16	ΔIP_{t-4}	-0.317	-1.21
ΔIP_{t-5}	-0.150	-0.59	ΔIP_{t-5}	-0.147	-0.58
ΔIP_{t-6}	0.158	0.59	ΔIP_{t-6}	0.123	0.46
	Σ = -0.826			Σ = -0.930	
ΔMB_{t-1}	-1.206	-1.64	ΔMB_{t-1}	-1.381	-1.87
ΔMB_{t-2}	0.834	1.19	ΔMB_{t-2}	0.732	1.02
ΔMB_{t-3}	-0.700	-1.36	ΔMB_{t-3}	-0.789	-1.54
ΔMB_{t-4}	-0.725	-1.27	ΔMB_{t-4}	-0.752	-1.33
ΔMB_{t-5}	0.454	0.66	ΔMB_{t-5}	0.651	0.93
ΔMB_{t-6}	-1.624	-2.32	ΔMB_{t-6}	-1.586	-2.27
	Σ = -2.967			Σ = -3.125	
ΔSPR_{t-1}	0.082	1.03	ΔSPR_{t-1}	0.064	0.80
ΔSPR_{t-2}	-0.128	-1.53	ΔSPR_{t-2}	-0.138	-1.65
ΔSPR_{t-3}	0.038	0.44	ΔSPR_{t-3}	0.029	0.34
ΔSPR_{t-4}	-0.000	-0.00	ΔSPR_{t-4}	-0.006	-0.07
ΔSPR_{t-5}	0.037	0.44	ΔSPR_{t-5}	0.049	0.57
ΔSPR_{t-6}	-0.031	-0.36	ΔSPR_{t-6}	-0.021	-0.25
	Σ = -0.002			Σ = -0.023	
ΔST_{t-1}	-0.022	-0.49	ΔST_{t-1}	-0.009	-0.21
ΔST_{t-2}	-0.051	-1.15	ΔST_{t-2}	-0.045	-0.98
ΔST_{t-3}	-0.010	-0.21	ΔST_{t-3}	-0.002	-0.04
ΔST_{t-4}	-0.076	-1.68	ΔST_{t-4}	-0.071	-1.54
ΔST_{t-5}	-0.001	-0.02	ΔST_{t-5}	0.004	0.09
ΔST_{t-6}	-0.091	-2.04	ΔST_{t-6}	-0.096	-2.08
	Σ = -0.251			Σ = -0.219	
$D_1\Delta ST_{t-1}$	0.004	0.04	$D_2\Delta ST_{t-1}$	-0.042	-0.53
$D_1\Delta ST_{t-2}$	0.002	0.02	$D_2\Delta ST_{t-2}$	-0.049	-0.59
$D_1\Delta ST_{t-3}$	-0.043	-0.43	$D_2\Delta ST_{t-3}$	-0.112	-1.29
$D_1\Delta ST_{t-4}$	0.039	0.41	$D_2\Delta ST_{t-4}$	-0.026	-0.30
$D_1\Delta ST_{t-5}$	0.005	0.05	$D_2\Delta ST_{t-5}$	-0.036	-0.43
$D_1\Delta ST_{t-6}$	-0.052	-0.56	$D_2\Delta ST_{t-6}$	-0.010	-0.12
	Σ = -0.045			Σ = -0.275	

Continued

Table 19. (Cont.) VECM(6) w/ Dummy Variable TP Method (ST)

Dependent Variable = ΔSPR			Dependent Variable = ΔSPR		
Graham D:1976.1-1982.1			**Kaul D:1979.1-1986.4**		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
$ECT1_{t-1}$	0.046	0.84	$ECT1_{t-1}$	0.048	0.90
$ECT2_{t-1}$	0.023	0.28	$ECT2_{t-1}$	0.040	0.47
Adjusted R^2 = 0.05, DW = 2.0061			Adjusted R^2 = 0.05, DW = 2.0074		
Normality $\chi^2[2]$ = 100.90, ARCH $\chi^2[1]$ = 0.005			Normality $\chi^2[2]$ = 107.3, ARCH $\chi^2[1]$ = 0.002		
RESET F[1,154] = 0.49			RESET F[1,154] = 0.63		

VECM(6) using Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), and 3-Month Treasury Bill (ST). Quarterly data in the 1950.1-1996.4 period.

DW is the Durbin-Watson test of first-order residual autocorrelation.

Normality $\chi^2[2]$ is the Jarque-Bera test for skewness and excess kurtosis.

ARCH $\chi^2[1]$ is the test for autoregressive conditional heteroskedasticity.

RESET F[q,T-k-Q] is the qth order Ramsey-Reset Statistic.

Table 20. VECM(6) w/ Dummy Variable TP Method (EI)

Dependent Variable = ΔSPR			Dependent Variable = ΔSPR		
Graham D:1976.1-1982.1			**Kaul D:1979.1-1986.4**		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.547	-2.85	Constant	-0.603	-3.05
ΔEI_{t-1}	0.010	1.29	ΔEI_{t-1}	0.013	1.64
ΔEI_{t-2}	0.015	2.02	ΔEI_{t-2}	0.015	2.05
ΔEI_{t-3}	0.005	0.77	ΔEI_{t-3}	0.006	0.92
ΔEI_{t-4}	0.008	1.17	ΔEI_{t-4}	0.006	0.91
ΔEI_{t-5}	0.009	1.35	ΔEI_{t-5}	0.007	1.05
ΔEI_{t-6}	0.000	0.02	ΔEI_{t-6}	-0.000	-0.02
	Σ = 0.047			Σ = 0.047	
ΔIP_{t-1}	-0.509	-1.85	ΔIP_{t-1}	-0.554	-1.99
ΔIP_{t-2}	-0.417	-1.53	ΔIP_{t-2}	-0.455	-1.67
ΔIP_{t-3}	-0.192	-0.72	ΔIP_{t-3}	-0.175	-0.65
ΔIP_{t-4}	-0.572	-2.15	ΔIP_{t-4}	-0.537	-2.05
ΔIP_{t-5}	-0.303	-1.10	ΔIP_{t-5}	-0.295	-1.09
ΔIP_{t-6}	-0.231	-0.88	ΔIP_{t-6}	-0.188	-0.73
	Σ = -2.224			Σ = -2.204	
ΔMB_{t-1}	-0.667	-0.97	ΔMB_{t-1}	-0.469	-0.68
ΔMB_{t-2}	0.867	1.29	ΔMB_{t-2}	1.070	1.59
ΔMB_{t-3}	-0.475	-0.84	ΔMB_{t-3}	-0.418	-0.76
ΔMB_{t-4}	-0.408	-0.67	ΔMB_{t-4}	-0.395	-0.65
ΔMB_{t-5}	0.085	0.12	ΔMB_{t-5}	-0.305	-0.40
ΔMB_{t-6}	-2.018	-2.74	ΔMB_{t-6}	-2.248	-3.00
	Σ = -2.616			Σ = -2.765	
ΔSPR_{t-1}	0.061	0.72	ΔSPR_{t-1}	0.068	0.79
ΔSPR_{t-2}	-0.027	-0.30	ΔSPR_{t-2}	-0.036	-0.41
ΔSPR_{t-3}	-0.038	-0.43	ΔSPR_{t-3}	-0.001	-0.02
ΔSPR_{t-4}	0.035	0.40	ΔSPR_{t-4}	0.025	0.28
ΔSPR_{t-5}	0.062	0.69	ΔSPR_{t-5}	0.051	0.58
ΔSPR_{t-6}	-0.025	-0.27	ΔSPR_{t-6}	-0.063	-0.72
	Σ = 0.068			Σ = 0.044	
$D_1\Delta EI_{t-1}$	0.003	0.21	$D_2\Delta EI_{t-1}$	-0.004	-0.38
$D_1\Delta EI_{t-2}$	0.015	1.15	$D_2\Delta EI_{t-2}$	0.009	0.86
$D_1\Delta EI_{t-3}$	-0.000	-0.01	$D_2\Delta EI_{t-3}$	0.003	0.27
$D_1\Delta EI_{t-4}$	0.016	1.09	$D_2\Delta EI_{t-4}$	0.021	1.82
$D_1\Delta EI_{t-5}$	-0.007	-0.60	$D_2\Delta EI_{t-5}$	0.007	0.64
$D_1\Delta EI_{t-6}$	0.017	1.32	$D_2\Delta EI_{t-6}$	0.007	0.68
	Σ = 0.044			Σ = 0.043	
$ECT1_{t-1}$	0.271	3.23	$ECT1_{t-1}$	0.295	3.42
$ECT2_{t-1}$	0.015	1.41	$ECT2_{t-1}$	0.015	1.39
Adjusted R^2 = 0.09, DW = 2.0387			Adjusted R^2 = 0.09, DW = 2.0754		
Normality $\chi^2[2]$ = 136.5, ARCH $\chi^2[1]$ = 0.013			Normality $\chi^2[2]$ = 145.2, ARCH $\chi^2[1]$ = 0.069		
RESET F[1,154] = 0.001			RESET F[1,154] = 0.89		

VECM(6) using Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), and Estimated Expected Inflation (EI). Quarterly data in the 1950.1-1996.4 period. DW is the Durbin-Watson test of first-order residual autocorrelation.

Normality $\chi^2[2]$ is the Jarque-Bera test for skewness and excess kurtosis.

ARCH $\chi^2[1]$ is the test for autoregressive conditional heteroskedasticity.

RESET F[q,T-k-Q] is the qth order Ramsey-Reset Statistic.

Table 21. VECM(8) w/ Dummy Variable TP Method (ST)

Dependent Variable = ΔSPR			Dependent Variable = ΔSPR		
	Graham D:1976.1-1982.1			Kaul D:1979.1-1986.4	
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	0.040	0.15	Constant	0.115	0.41
ΔIP_{t-1}	-0.120	-0.38	ΔIP_{t-1}	-0.076	-0.24
ΔIP_{t-2}	-0.230	-0.72	ΔIP_{t-2}	-0.232	-0.73
ΔIP_{t-3}	0.338	1.07	ΔIP_{t-3}	0.290	0.92
ΔIP_{t-4}	-0.324	-1.08	ΔIP_{t-4}	-0.306	-1.02
ΔIP_{t-5}	0.048	0.16	ΔIP_{t-5}	0.048	0.16
ΔIP_{t-6}	0.301	1.01	ΔIP_{t-6}	0.306	1.03
ΔIP_{t-7}	0.340	1.22	ΔIP_{t-7}	0.273	0.99
ΔIP_{t-8}	0.370	1.38	ΔIP_{t-8}	0.376	1.42
	Σ = 0.723			Σ = 0.679	
ΔMB_{t-1}	-1.327	-1.74	ΔMB_{t-1}	-1.524	-1.97
ΔMB_{t-2}	0.418	0.55	ΔMB_{t-2}	0.409	0.53
ΔMB_{t-3}	-0.563	-0.77	ΔMB_{t-3}	-0.532	-0.71
ΔMB_{t-4}	-1.102	-1.48	ΔMB_{t-4}	-0.786	-1.04
ΔMB_{t-5}	0.259	0.36	ΔMB_{t-5}	0.684	0.93
ΔMB_{t-6}	-2.072	-2.83	ΔMB_{t-6}	-1.793	-2.43
ΔMB_{t-7}	-0.184	-0.24	ΔMB_{t-7}	-0.210	-0.27
ΔMB_{t-8}	0.600	0.79	ΔMB_{t-8}	0.380	0.49
	Σ = -3.971			Σ = -3.372	
ΔSPR_{t-1}	0.054	0.65	ΔSPR_{t-1}	0.029	0.34
ΔSPR_{t-2}	-0.156	-1.76	ΔSPR_{t-2}	-0.168	-1.94
ΔSPR_{t-3}	0.011	0.12	ΔSPR_{t-3}	0.015	0.17
ΔSPR_{t-4}	-0.053	-0.61	ΔSPR_{t-4}	-0.036	-0.41
ΔSPR_{t-5}	-0.001	-0.01	ΔSPR_{t-5}	0.036	0.42
ΔSPR_{t-6}	-0.062	-0.71	ΔSPR_{t-6}	-0.040	-0.45
ΔSPR_{t-7}	-0.098	-1.13	ΔSPR_{t-7}	-0.089	-1.03
ΔSPR_{t-8}	-0.063	-0.71	ΔSPR_{t-8}	-0.096	-1.10
	Σ = -0.368			Σ = -0.349	
ΔST_{t-1}	-0.053	-1.13	ΔST_{t-1}	-0.049	-0.97
ΔST_{t-2}	-0.077	-1.66	ΔST_{t-2}	-0.087	-1.74
ΔST_{t-3}	-0.028	-0.60	ΔST_{t-3}	-0.028	-0.59
ΔST_{t-4}	-0.110	-2.33	ΔST_{t-4}	-0.107	-2.19
ΔST_{t-5}	-0.021	-0.43	ΔST_{t-5}	-0.019	-0.39
ΔST_{t-6}	-0.144	-2.94	ΔST_{t-6}	-0.137	-2.67
ΔST_{t-7}	-0.033	-0.70	ΔST_{t-7}	-0.035	-0.72
ΔST_{t-8}	-0.112	-2.55	ΔST_{t-8}	-0.104	-2.16
	Σ = -0.578			Σ = -0.566	

Continued

Table 21. (Cont.) VECM(8) w/ Dummy Variable TP Method (ST)

Dependent Variable = ΔSPR			Dependent Variable = ΔSPR		
Graham D:1976.1-1982.1			**Kaul D:1979.1-1986.4**		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
$D_1\Delta ST_{t-1}$	-0.016	-0.17	$D_2\Delta ST_{t-1}$	-0.043	-0.52
$D_1\Delta ST_{t-2}$	-0.037	-0.36	$D_2\Delta ST_{t-2}$	-0.043	-0.49
$D_1\Delta ST_{t-3}$	-0.123	-1.11	$D_2\Delta ST_{t-3}$	-0.119	-1.32
$D_1\Delta ST_{t-4}$	0.018	0.17	$D_2\Delta ST_{t-4}$	-0.010	-0.12
$D_1\Delta ST_{t-5}$	0.017	0.17	$D_2\Delta ST_{t-5}$	0.004	0.04
$D_1\Delta ST_{t-6}$	0.036	0.33	$D_2\Delta ST_{t-6}$	0.057	0.64
$D_1\Delta ST_{t-7}$	0.085	0.71	$D_2\Delta ST_{t-7}$	0.114	1.31
$D_1\Delta ST_{t-8}$	0.176	1.07	$D_2\Delta ST_{t-8}$	0.078	0.93
	$\Sigma = 0.156$			$\Sigma = 0.038$	
$ECT1_{t-1}$	0.066	0.95	$ECT1_{t-1}$	0.045	0.66
$ECT2_{t-1}$	-0.061	-0.65	$ECT2_{t-1}$	-0.073	-0.75
Adjusted $R^2 = 0.05$, DW = 1.9919 Normality $\chi^2[2] = 62.4$, ARCH $\chi^2[1] = 0.010$ RESET F[1,144] = 6.48			Adjusted $R^2 = 0.05$, DW = 1.9748 Normality $\chi^2[2] = 61.43$, ARCH $\chi^2[1] = 0.042$ RESET F[1,144] = 2.61		

VECM(8) using Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), and 3-Month Treasury Bill (ST). Quarterly data in the 1950.1-1996.4 period.
DW is the Durbin-Watson test of first-order residual autocorrelation.
Normality $\chi^2[2]$ is the Jarque-Bera test for skewness and excess kurtosis.
ARCH $\chi^2[1]$ is the test for autoregressive conditional heteroskedasticity.
RESET F[q,T-k-Q] is the qth order Ramsey-Reset Statistic.

Table 22. VECM(8) w/ Dummy Variable TP Method (EI)

Dependent Variable = ΔSPR			Dependent Variable = ΔSPR		
	Graham D:1976.1-1982.1			**Kaul D:1979.1-1986.4**	
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.723	-3.01	Constant	-0.861	-3.56
ΔEI_{t-1}	0.017	2.03	ΔEI_{t-1}	0.020	2.38
ΔEI_{t-2}	0.022	2.60	ΔEI_{t-2}	0.023	2.82
ΔEI_{t-3}	0.007	0.84	ΔEI_{t-3}	0.011	1.25
ΔEI_{t-4}	0.009	1.19	ΔEI_{t-4}	0.007	0.93
ΔEI_{t-5}	0.015	2.03	ΔEI_{t-5}	0.012	1.70
ΔEI_{t-6}	0.007	0.99	ΔEI_{t-6}	0.007	1.02
ΔEI_{t-7}	0.010	1.49	ΔEI_{t-7}	0.009	1.31
ΔEI_{t-8}	0.000	0.06	ΔEI_{t-8}	-0.000	-0.00
	Σ = 0.087			Σ = 0.089	
ΔIP_{t-1}	-0.497	-1.79	ΔIP_{t-1}	-0.559	-2.00
ΔIP_{t-2}	-0.491	-1.76	ΔIP_{t-2}	-0.578	-2.05
ΔIP_{t-3}	-0.024	-0.08	ΔIP_{t-3}	-0.033	-0.12
ΔIP_{t-4}	-0.371	-1.28	ΔIP_{t-4}	-0.381	-1.35
ΔIP_{t-5}	-0.408	-1.34	ΔIP_{t-5}	-0.417	-1.40
ΔIP_{t-6}	-0.129	-0.43	ΔIP_{t-6}	-0.049	-0.17
ΔIP_{t-7}	-0.144	-0.52	ΔIP_{t-7}	-0.151	-0.55
ΔIP_{t-8}	0.008	0.03	ΔIP_{t-8}	-0.018	-0.07
	Σ = -2.056			Σ = -2.186	
ΔMB_{t-1}	-0.544	-0.77	ΔMB_{t-1}	-0.332	-0.47
ΔMB_{t-2}	1.050	1.49	ΔMB_{t-2}	1.189	1.68
ΔMB_{t-3}	-0.159	-0.21	ΔMB_{t-3}	0.176	0.23
ΔMB_{t-4}	-1.062	-1.36	ΔMB_{t-4}	-1.007	-1.30
ΔMB_{t-5}	0.233	0.30	ΔMB_{t-5}	-0.252	-0.31
ΔMB_{t-6}	-2.100	-2.65	ΔMB_{t-6}	-2.175	-2.70
ΔMB_{t-7}	-0.717	-0.93	ΔMB_{t-7}	-1.126	-1.42
ΔMB_{t-8}	0.766	1.01	ΔMB_{t-8}	0.381	0.49
	Σ = -2.533			Σ = -3.146	
ΔSPR_{t-1}	0.055	0.62	ΔSPR_{t-1}	0.035	0.40
ΔSPR_{t-2}	0.009	0.10	ΔSPR_{t-2}	0.006	0.06
ΔSPR_{t-3}	-0.071	-0.76	ΔSPR_{t-3}	-0.024	-0.25
ΔSPR_{t-4}	0.045	0.49	ΔSPR_{t-4}	0.014	0.15
ΔSPR_{t-5}	0.029	0.33	ΔSPR_{t-5}	0.034	0.37
ΔSPR_{t-6}	-0.028	-0.30	ΔSPR_{t-6}	-0.050	-0.56
ΔSPR_{t-7}	-0.111	-1.22	ΔSPR_{t-7}	-0.132	-1.48
ΔSPR_{t-8}	-0.141	-1.53	ΔSPR_{t-8}	-0.167	-1.87
	Σ = -0.213			Σ = -0.284	

Continued

Table 22. (Cont.) VECM(8) w/ Dummy Variable TP Method (EI)

Dependent Variable = ΔSPR		
	Graham D:1976.1-1982.1	
Variable	Coefficient	T-Ratio
$D_1\Delta EI_{t-1}$	-0.006	-0.40
$D_1\Delta EI_{t-2}$	0.014	1.04
$D_1\Delta EI_{t-3}$	-0.004	-0.23
$D_1\Delta EI_{t-4}$	0.022	1.43
$D_1\Delta EI_{t-5}$	-0.011	-0.77
$D_1\Delta EI_{t-6}$	0.028	1.95
$D_1\Delta EI_{t-7}$	-0.010	-0.79
$D_1\Delta EI_{t-8}$	0.015	1.08
	Σ = 0.048	
$ECT1_{t-1}$	0.354	3.39
$ECT2_{t-1}$	0.024	1.97

Adjusted R^2 = 0.11, DW = 1.9953
Normality $\chi^2[2]$ = 124.2, ARCH $\chi^2[1]$ = 0.001
RESET F[1,144] = 6.24

Dependent Variable = ΔSPR		
	Kaul D:1979.1-1986.4	
Variable	Coefficient	T-Ratio
$D_2\Delta EI_{t-1}$	-0.005	-0.48
$D_2\Delta EI_{t-2}$	0.007	0.62
$D_2\Delta EI_{t-3}$	0.001	0.07
$D_2\Delta EI_{t-4}$	0.023	1.94
$D_2\Delta EI_{t-5}$	0.012	0.92
$D_2\Delta EI_{t-6}$	0.016	1.30
$D_2\Delta EI_{t-7}$	0.010	0.89
$D_2\Delta EI_{t-8}$	0.008	0.71
	Σ = 0.072	
$ECT1_{t-1}$	0.415	3.93
$ECT2_{t-1}$	0.023	1.87

Adjusted R^2 = 0.11, DW = 2.0230
Normality $\chi^2[2]$ = 114.9, ARCH $\chi^2[1]$ = 0.035
RESET F[1,144] = 8.82

VECM(8) using Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), and Estimated Expected Inflation (EI). Quarterly data in the 1950.1-1996.4 period. DW is the Durbin-Watson test of first-order residual autocorrelation.

Normality $\chi^2[2]$ is the Jarque-Bera test for skewness and excess kurtosis.

ARCH $\chi^2[1]$ is the test for autoregressive conditional heteroskedasticity.
RESET F[q,T-k-Q] is the qth order Ramsey-Reset Statistic.

Table 23. VECM(6) w/ Dummy Variable SL Method (ST)

Dependent Variable = ΔSPR			Dependent Variable = ΔSPR		
	Graham D:1976.1-1982.1			**Kaul D:1979.1-1986.4**	
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.134	-0.66	Constant	-0.146	-0.73
ΔIP_{t-1}	-0.225	-0.80	ΔIP_{t-1}	-0.174	-0.62
ΔIP_{t-2}	-0.209	-0.80	ΔIP_{t-2}	-0.293	-1.11
ΔIP_{t-3}	0.027	0.11	ΔIP_{t-3}	-0.021	-0.08
ΔIP_{t-4}	-0.253	-1.01	ΔIP_{t-4}	-0.303	-1.22
ΔIP_{t-5}	-0.211	-0.89	ΔIP_{t-5}	-0.232	-0.97
ΔIP_{t-6}	0.072	0.30	ΔIP_{t-6}	0.135	0.54
	Σ = -0.799			Σ = -0.888	
ΔMB_{t-1}	-1.261	-1.69	ΔMB_{t-1}	-1.161	-1.60
ΔMB_{t-2}	0.519	0.71	ΔMB_{t-2}	0.767	1.08
ΔMB_{t-3}	-0.815	-1.55	ΔMB_{t-3}	-0.959	-1.88
ΔMB_{t-4}	-0.654	-1.19	ΔMB_{t-4}	-0.777	-1.42
ΔMB_{t-5}	0.294	0.42	ΔMB_{t-5}	0.264	0.38
ΔMB_{t-6}	-1.498	-2.13	ΔMB_{t-6}	-1.672	-2.42
	Σ = -3.415			Σ = -3.538	
ΔSPR_{t-1}	0.039	0.48	ΔSPR_{t-1}	0.058	0.72
ΔSPR_{t-2}	-0.163	-1.91	ΔSPR_{t-2}	-0.168	-2.00
ΔSPR_{t-3}	-0.014	-0.15	ΔSPR_{t-3}	0.006	0.07
ΔSPR_{t-4}	-0.037	-0.43	ΔSPR_{t-4}	-0.039	-0.45
ΔSPR_{t-5}	0.018	0.20	ΔSPR_{t-5}	0.002	0.02
ΔSPR_{t-6}	-0.043	-0.50	ΔSPR_{t-6}	-0.040	-0.48
	Σ = -0.200			Σ = -0.181	
ΔST_{t-1}	-0.006	-0.55	ΔST_{t-1}	-0.009	-0.68
ΔST_{t-2}	-0.012	-1.24	ΔST_{t-2}	-0.009	-0.67
ΔST_{t-3}	-0.002	-0.17	ΔST_{t-3}	0.009	0.71
ΔST_{t-4}	-0.018	-1.72	ΔST_{t-4}	-0.022	-1.67
ΔST_{t-5}	-0.001	-0.13	ΔST_{t-5}	0.010	0.77
ΔST_{t-6}	-0.016	-1.87	ΔST_{t-6}	-0.034	-2.60
	Σ = -0.055			Σ = -0.055	
$D_1\Delta ST_{t-1}$	0.009	0.74	$D_2\Delta ST_{t-1}$	0.008	0.59
$D_1\Delta ST_{t-2}$	0.011	0.85	$D_2\Delta ST_{t-2}$	0.003	0.26
$D_1\Delta ST_{t-3}$	-0.001	-0.09	$D_2\Delta ST_{t-3}$	-0.017	-1.23
$D_1\Delta ST_{t-4}$	0.015	1.06	$D_2\Delta ST_{t-4}$	0.014	1.03
$D_1\Delta ST_{t-5}$	0.001	0.11	$D_2\Delta ST_{t-5}$	-0.014	-0.99
$D_1\Delta ST_{t-6}$	0.003	0.24	$D_2\Delta ST_{t-6}$	0.023	1.66
	Σ = 0.038			Σ = 0.017	
IP_{t-1}	0.051	0.54	IP_{t-1}	0.055	0.59
MB_{t-1}	0.011	0.35	MB_{t-1}	0.011	0.33
SPR_{t-1}	-0.039	-1.23	SPR_{t-1}	-0.043	-1.39
ST_{t-1}	-0.006	-1.29	ST_{t-1}	-0.006	-1.16
Adjusted R^2 = 0.09, DW = 1.9756			Adjusted R^2 = 0.11, DW = 1.9868		
Normality $\chi^2[2]$ = 100.04, ARCH $\chi^2[1]$ = 0.291			Normality $\chi^2[2]$ = 77.74, ARCH $\chi^2[1]$ = 0.364		
RESET F[1,152] = 1.09			RESET F[1,152] = 0.87		

VECM(6) using Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), and 3-Month Treasury Bill (ST). Quarterly data in the 1950.1-1996.4 period.
DW is the Durbin-Watson test of first-order residual autocorrelation.
Normality $\chi^2[2]$ is the Jarque-Bera test for skewness and excess kurtosis.
ARCH $\chi^2[1]$ is the test for autoregressive conditional heteroskedasticity.
RESET F[q,T-k-Q] is the qth order Ramsey-Reset Statistic.

Table 24. VECM(6) w/ Dummy Variable SL Method (EI)

Dependent Variable = ΔSPR			Dependent Variable = ΔSPR		
Graham D:1976.1-1982.1			**Kaul D:1979.1-1986.4**		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.401	-1.74	Constant	-0.467	-1.98
ΔEI_{t-1}	0.008	0.92	ΔEI_{t-1}	0.010	1.27
ΔEI_{t-2}	0.012	1.66	ΔEI_{t-2}	0.013	1.72
ΔEI_{t-3}	0.004	0.49	ΔEI_{t-3}	0.005	0.67
ΔEI_{t-4}	0.006	0.87	ΔEI_{t-4}	0.005	0.63
ΔEI_{t-5}	0.007	1.12	ΔEI_{t-5}	0.006	0.83
ΔEI_{t-6}	-0.000	-0.09	ΔEI_{t-6}	-0.001	-0.12
	Σ = 0.037			Σ = 0.038	
ΔIP_{t-1}	-0.411	-1.42	ΔIP_{t-1}	-0.462	-1.59
ΔIP_{t-2}	-0.338	-1.20	ΔIP_{t-2}	-0.382	-1.35
ΔIP_{t-3}	-0.120	-0.44	ΔIP_{t-3}	-0.107	-0.39
ΔIP_{t-4}	-0.508	-1.87	ΔIP_{t-4}	-0.476	-1.77
ΔIP_{t-5}	-0.260	-0.94	ΔIP_{t-5}	-0.254	-0.93
ΔIP_{t-6}	-0.205	-0.78	ΔIP_{t-6}	-0.161	-0.62
	Σ = -1.842			Σ = -1.842	
ΔMB_{t-1}	-0.599	-0.87	ΔMB_{t-1}	-0.399	-0.57
ΔMB_{t-2}	0.928	1.37	ΔMB_{t-2}	1.125	1.67
ΔMB_{t-3}	-0.471	-0.83	ΔMB_{t-3}	-0.411	-0.74
ΔMB_{t-4}	-0.394	-0.64	ΔMB_{t-4}	-0.379	-0.62
ΔMB_{t-5}	0.082	0.11	ΔMB_{t-5}	-0.304	-0.40
ΔMB_{t-6}	-1.987	-2.69	ΔMB_{t-6}	-2.208	-2.94
	Σ = -2.441			Σ = -2.576	
ΔSPR_{t-1}	0.045	0.52	ΔSPR_{t-1}	0.055	0.62
ΔSPR_{t-2}	-0.047	-0.50	ΔSPR_{t-2}	-0.052	-0.56
ΔSPR_{t-3}	-0.056	-0.61	ΔSPR_{t-3}	-0.018	-0.19
ΔSPR_{t-4}	0.015	0.16	ΔSPR_{t-4}	0.007	0.07
ΔSPR_{t-5}	0.045	0.49	ΔSPR_{t-5}	0.036	0.39
ΔSPR_{t-6}	-0.039	-0.42	ΔSPR_{t-6}	-0.074	-0.83
	Σ = -0.037			Σ = -0.046	
$D_1\Delta EI_{t-1}$	0.003	0.23	$D_2\Delta EI_{t-1}$	-0.004	-0.37
$D_1\Delta EI_{t-2}$	0.016	1.17	$D_2\Delta EI_{t-2}$	0.009	0.88
$D_1\Delta EI_{t-3}$	0.001	0.04	$D_2\Delta EI_{t-3}$	0.003	0.30
$D_1\Delta EI_{t-4}$	0.016	1.10	$D_2\Delta EI_{t-4}$	0.021	1.83
$D_1\Delta EI_{t-5}$	-0.007	-0.59	$D_2\Delta EI_{t-5}$	0.007	0.64
$D_1\Delta EI_{t-6}$	0.017	1.28	$D_2\Delta EI_{t-6}$	0.007	0.65
	Σ = 0.046			Σ = 0.043	
EI_{t-1}	-0.019	-2.65	EI_{t-1}	-0.021	-2.88
IP_{t-1}	0.202	1.73	IP_{t-1}	0.232	1.97
MB_{t-1}	-0.049	-1.13	MB_{t-1}	-0.058	-1.34
SPR_{t-1}	-0.099	-2.46	SPR_{t-1}	-0.112	-2.73
Adjusted R^2 = 0.09, DW = 2.0408			Adjusted R^2 = 0.09, DW = 2.0775		
Normality $\chi^2[2]$ = 138.8, ARCH $\chi^2[1]$ = 0.053			Normality $\chi^2[2]$ = 145.9, ARCH $\chi^2[1]$ = 0.130		
RESET F[1,152] = 1.42			RESET F[1,152] = 1.10		

VECM(6) using Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), and Estimated Expected Inflation (EI). Quarterly data in the 1950.1-1996.4 period.
DW is the Durbin-Watson test of first-order residual autocorrelation.

Normality $\chi^2[2]$ is the Jarque-Bera test for skewness and excess kurtosis.

ARCH $\chi^2[1]$ is the test for autoregressive conditional heteroskedasticity.
RESET F[q,T-k-Q] is the qth. order Ramsey-Reset Statistic.

Table 25. VECM(8) w/ Dummy Variable SL Method (ST)

Dependent Variable = ΔSPR			Dependent Variable = ΔSPR		
Graham D:1976.1-1982.1			**Kaul D:1979.1-1986.4**		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.103	-0.42	Constant	0.045	0.19
ΔIP_{t-1}	-0.110	-0.38	ΔIP_{t-1}	-0.014	-0.05
ΔIP_{t-2}	-0.179	-0.63	ΔIP_{t-2}	-0.173	-0.60
ΔIP_{t-3}	0.256	0.89	ΔIP_{t-3}	0.182	0.63
ΔIP_{t-4}	-0.146	-0.53	ΔIP_{t-4}	-0.133	-0.47
ΔIP_{t-5}	-0.070	-0.26	ΔIP_{t-5}	-0.075	-0.27
ΔIP_{t-6}	0.247	0.90	ΔIP_{t-6}	0.363	1.28
ΔIP_{t-7}	0.174	0.69	ΔIP_{t-7}	0.240	0.92
ΔIP_{t-8}	0.195	0.79	ΔIP_{t-8}	0.285	1.13
	Σ = 0.367			Σ = 0.675	
ΔMB_{t-1}	-1.174	-1.52	ΔMB_{t-1}	-1.167	-1.54
ΔMB_{t-2}	0.369	0.47	ΔMB_{t-2}	0.712	0.93
ΔMB_{t-3}	-0.738	-0.98	ΔMB_{t-3}	-0.651	-0.89
ΔMB_{t-4}	-1.274	-1.70	ΔMB_{t-4}	-1.046	-1.43
ΔMB_{t-5}	0.094	0.13	ΔMB_{t-5}	0.251	0.34
ΔMB_{t-6}	-1.898	-2.56	ΔMB_{t-6}	-1.925	-2.65
ΔMB_{t-7}	-0.278	-0.37	ΔMB_{t-7}	-0.323	-0.44
ΔMB_{t-8}	0.721	0.98	ΔMB_{t-8}	0.624	0.85
	Σ = -4.178			Σ = -3.525	
ΔSPR_{t-1}	0.029	0.34	ΔSPR_{t-1}	0.014	0.17
ΔSPR_{t-2}	-0.191	-2.10	ΔSPR_{t-2}	-0.186	-2.09
ΔSPR_{t-3}	-0.024	-0.26	ΔSPR_{t-3}	-0.015	-0.16
ΔSPR_{t-4}	-0.092	-0.99	ΔSPR_{t-4}	-0.069	-0.75
ΔSPR_{t-5}	-0.045	-0.49	ΔSPR_{t-5}	-0.040	-0.43
ΔSPR_{t-6}	-0.073	-0.83	ΔSPR_{t-6}	-0.076	-0.84
ΔSPR_{t-7}	-0.123	-1.40	ΔSPR_{t-7}	-0.139	-1.57
ΔSPR_{t-8}	-0.095	-1.09	ΔSPR_{t-8}	-0.128	-1.46
	Σ = -0.614			Σ = -0.639	
ΔST_{t-1}	-0.014	-1.25	ΔST_{t-1}	-0.016	-1.22
ΔST_{t-2}	-0.011	-1.05	ΔST_{t-2}	-0.012	-0.90
ΔST_{t-3}	-0.001	-0.10	ΔST_{t-3}	0.005	0.33
ΔST_{t-4}	-0.025	-2.28	ΔST_{t-4}	-0.028	-2.01
ΔST_{t-5}	0.000	0.04	ΔST_{t-5}	0.008	0.55
ΔST_{t-6}	-0.025	-2.49	ΔST_{t-6}	-0.037	-2.59
ΔST_{t-7}	0.000	0.02	ΔST_{t-7}	-0.010	-0.69
ΔST_{t-8}	-0.017	-2.01	ΔST_{t-8}	-0.013	-0.96
	Σ = -0.093			Σ = -0.103	

Continued

Table 25. (Cont.) VECM(8) w/ Dummy Variable SL Method (ST)

Dependent Variable = ΔSPR			Dependent Variable = ΔSPR		
Graham D:1976.1-1982.1			**Kaul D:1979.1-1986.4**		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
$D_1\Delta ST_{t-1}$	0.010	0.75	$D_2\Delta ST_{t-1}$	0.010	0.73
$D_1\Delta ST_{t-2}$	0.000	0.03	$D_2\Delta ST_{t-2}$	0.003	0.23
$D_1\Delta ST_{t-3}$	-0.015	-0.93	$D_2\Delta ST_{t-3}$	-0.014	-1.00
$D_1\Delta ST_{t-4}$	0.014	0.83	$D_2\Delta ST_{t-4}$	0.018	1.26
$D_1\Delta ST_{t-5}$	0.001	0.08	$D_2\Delta ST_{t-5}$	-0.009	-0.64
$D_1\Delta ST_{t-6}$	0.023	1.44	$D_2\Delta ST_{t-6}$	0.027	1.88
$D_1\Delta ST_{t-7}$	0.017	1.02	$D_2\Delta ST_{t-7}$	0.015	1.03
$D_1\Delta ST_{t-8}$	0.035	1.29	$D_2\Delta ST_{t-8}$	0.008	0.60
	Σ = 0.085			Σ = 0.058	
IP_{t-1}	0.028	0.25	IP_{t-1}	-0.044	-0.41
MB_{t-1}	0.023	0.63	MB_{t-1}	0.046	1.27
SPR_{t-1}	-0.031	-0.86	SPR_{t-1}	-0.013	-0.39
ST_{t-1}	-0.005	-0.90	ST_{t-1}	-0.001	-0.12
Adjusted R^2 = 0.09, DW = 2.0274 Normality $\chi^2[2]$ = 54.34, ARCH $\chi^2[1]$ = 0.309 RESET F[1,142] = 3.55			Adjusted R^2 = 0.09, DW = 1.9847 Normality $\chi^2[2]$ = 39.94, ARCH $\chi^2[1]$ = 0.415 RESET F[1,142] = 1.83		

VECM(8) using Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), and 3-Month Treasury Bill (ST). Quarterly data in the 1950.1-1996.4 period.
DW is the Durbin-Watson test of first-order residual autocorrelation.
Normality $\chi^2[2]$ is the Jarque-Bera test for skewness and excess kurtosis.
ARCH $\chi^2[1]$ is the test for autoregressive conditional heteroskedasticity.
RESET F[q,T-k-Q] is the qth order Ramsey-Reset Statistic.

Table 26. VECM(8) w/ Dummy Variable SL Method (EI)

Dependent Variable = ΔSPR			Dependent Variable = ΔSPR		
	Graham D:1976.1-1982.1			**Kaul D:1979.1-1986.4**	
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
Constant	-0.511	-1.87	Constant	-0.656	-2.38
ΔEI_{t-1}	0.013	1.49	ΔEI_{t-1}	0.016	1.84
ΔEI_{t-2}	0.018	2.07	ΔEI_{t-2}	0.020	2.29
ΔEI_{t-3}	0.004	0.43	ΔEI_{t-3}	0.007	0.84
ΔEI_{t-4}	0.006	0.75	ΔEI_{t-4}	0.004	0.51
ΔEI_{t-5}	0.012	1.62	ΔEI_{t-5}	0.010	1.32
ΔEI_{t-6}	0.005	0.71	ΔEI_{t-6}	0.005	0.74
ΔEI_{t-7}	0.008	1.26	ΔEI_{t-7}	0.007	1.09
ΔEI_{t-8}	-0.001	-0.13	ΔEI_{t-8}	-0.001	-0.19
	Σ = 0.065			Σ = 0.068	
ΔIP_{t-1}	-0.362	-1.25	ΔIP_{t-1}	-0.426	-1.46
ΔIP_{t-2}	-0.374	-1.29	ΔIP_{t-2}	-0.465	-1.60
ΔIP_{t-3}	0.093	0.31	ΔIP_{t-3}	0.084	0.28
ΔIP_{t-4}	-0.273	-0.92	ΔIP_{t-4}	-0.281	-0.97
ΔIP_{t-5}	-0.310	-1.00	ΔIP_{t-5}	-0.320	-1.05
ΔIP_{t-6}	-0.044	-0.15	ΔIP_{t-6}	0.037	0.12
ΔIP_{t-7}	-0.098	-0.35	ΔIP_{t-7}	-0.107	-0.39
ΔIP_{t-8}	0.041	0.15	ΔIP_{t-8}	0.016	0.06
	Σ = -1.327			Σ = -1.462	
ΔMB_{t-1}	-0.472	-0.67	ΔMB_{t-1}	-0.244	-0.34
ΔMB_{t-2}	1.115	1.58	ΔMB_{t-2}	1.256	1.77
ΔMB_{t-3}	-0.160	-0.21	ΔMB_{t-3}	0.171	0.23
ΔMB_{t-4}	-1.025	-1.31	ΔMB_{t-4}	-0.969	-1.25
ΔMB_{t-5}	0.201	0.26	ΔMB_{t-5}	-0.286	-0.35
ΔMB_{t-6}	-2.144	-2.70	ΔMB_{t-6}	-2.213	-2.74
ΔMB_{t-7}	-0.749	-0.96	ΔMB_{t-7}	-1.139	-1.43
ΔMB_{t-8}	0.771	1.01	ΔMB_{t-8}	0.406	0.52
	Σ = -2.463			Σ = -3.018	
ΔSPR_{t-1}	0.025	0.28	ΔSPR_{t-1}	0.009	0.10
ΔSPR_{t-2}	-0.024	-0.24	ΔSPR_{t-2}	-0.024	-0.25
ΔSPR_{t-3}	-0.100	-1.04	ΔSPR_{t-3}	-0.049	-0.50
ΔSPR_{t-4}	0.013	0.14	ΔSPR_{t-4}	-0.015	-0.16
ΔSPR_{t-5}	0.001	0.01	ΔSPR_{t-5}	0.006	0.06
ΔSPR_{t-6}	-0.054	-0.57	ΔSPR_{t-6}	-0.075	-0.81
ΔSPR_{t-7}	-0.137	-1.48	ΔSPR_{t-7}	-0.156	-1.72
ΔSPR_{t-8}	-0.163	-1.75	ΔSPR_{t-8}	-0.187	-2.07
	Σ = -0.439			Σ = -0.491	

Continued

Table 26. (Cont.) VECM(8) w/ Dummy Variable SL Method (EI)

Dependent Variable = ΔSPR			Dependent Variable = ΔSPR		
Graham D:1976.1-1982.1			**Kaul D:1979.1-1986.4**		
Variable	Coefficient	T-Ratio	Variable	Coefficient	T-Ratio
$D_1\Delta EI_{t-1}$	-0.005	-0.37	$D_2\Delta EI_{t-1}$	-0.005	-0.52
$D_1\Delta EI_{t-2}$	0.015	1.04	$D_2\Delta EI_{t-2}$	0.007	0.64
$D_1\Delta EI_{t-3}$	-0.003	-0.17	$D_2\Delta EI_{t-3}$	0.001	0.10
$D_1\Delta EI_{t-4}$	0.023	1.47	$D_2\Delta EI_{t-4}$	0.024	1.97
$D_1\Delta EI_{t-5}$	-0.011	-0.77	$D_2\Delta EI_{t-5}$	0.012	0.93
$D_1\Delta EI_{t-6}$	0.027	1.92	$D_2\Delta EI_{t-6}$	0.016	1.27
$D_1\Delta EI_{t-7}$	-0.011	-0.85	$D_2\Delta EI_{t-7}$	0.010	0.87
$D_1\Delta EI_{t-8}$	0.013	0.94	$D_2\Delta EI_{t-8}$	0.007	0.62
	$\Sigma = 0.048$			$\Sigma = 0.072$	
EI_{t-1}	-0.026	-3.01	EI_{t-1}	-0.029	-3.47
IP_{t-1}	0.253	1.86	IP_{t-1}	0.320	2.35
MB_{t-1}	-0.062	-1.28	MB_{t-1}	-0.081	-1.68
SPR_{t-1}	-0.121	-2.61	SPR_{t-1}	-0.148	-3.16
Adjusted R^2 = 0.12, DW = 1.9989			Adjusted R^2 = 0.12, DW = 2.0304		
Normality $\chi^2[2]$ = 121.6, ARCH $\chi^2[1]$ = 0.028			Normality $\chi^2[2]$ = 110.9, ARCH $\chi^2[1]$ = 0.080		
RESET F[1,142] = 5.64			RESET F[1,142] = 4.59		

VECM(8) using Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR), and Estimated Expected Inflation (EI). Quarterly data in the 1950.1-1996.4 period. DW is the Durbin-Watson test of first-order residual autocorrelation.

Normality $\chi^2[2]$ is the Jarque-Bera test for skewness and excess kurtosis.

ARCH $\chi^2[1]$ is the test for autoregressive conditional heteroskedasticity.
RESET F[q,T-k-Q] is the qth order Ramsey-Reset Statistic.

APPENDIX F

SHORT-RUN CAUSALITY TESTS WITH DUMMY VARIABLE

Table 27. Dummy Variable Hypothesis Tests

Toda and Phillips Method

Model	Variables	Graham D:1976.1-1982.1	Kaul D:1979.1-1986.4
VECM(6)	SPR IP MB ST	2.216	2.881
	SPR IP MB EI	3.924	0.991
VECM(8)	SPR IP MB ST	0.007	1.655
	SPR IP MB EI	2.474	0.858

Notes: The test statistics have $\chi^2(6)$ and $\chi^2(8)$ distributions under the null hypothesis in the VECM(6) and VECM(8) models respectively.
Quarterly data in the 1950.1-1996.4 period.
SPR = real S&P 500 stock index, IP = Industrial Production, MB = Monetary Base, ST = 3-month Treasury Bill yield, EI = Estimated Expected Inflation series.

Saikkonen and Lütkepohl Method

Model	Variables	Graham D:1976.1-1982.1	Kaul D:1979.1-1986.4
VECM(6)	SPR IP MB ST	1.024	0.341
	SPR IP MB EI	1.286	2.067
VECM(8)	SPR IP MB ST	4.064^b	2.744
	SPR IP MB EI	1.099	3.702

Notes: The test statistics have a $\chi^2(1)$ distribution under the null hypothesis in both the VECM(6) and VECM(8) models.
b implies significantly different from zero at 5% level.
Quarterly data in the 1950.1-1996.4 period.
SPR = real S&P 500 stock index, IP = Industrial Production, MB = Monetary Base, ST = 3-month Treasury Bill yield, EI = Estimated Expected Inflation series.

Table 28. Short-Run Granger-Causality Tests VECM(6) - TP Method

Graham D:1976.1-1982.1

Expected Inflation = ST

	Dependent Variable	
	ΔSPR	ΔST
ΔSPR	-	8.407
ΔST	7.400	-

Expected Inflation = EI

	Dependent Variable	
	ΔSPR	ΔEI
ΔSPR	-	22.015[a]
ΔEI	4.854	-

Kaul D:1979.1-1986.4

Expected Inflation = ST

	Dependent Variable	
	ΔSPR	ΔST
ΔSPR	-	7.353
ΔST	5.996	-

Expected Inflation = EI

	Dependent Variable	
	ΔSPR	ΔEI
ΔSPR	-	27.839[a]
ΔEI	5.352	-

Notes: Causality tests within VECM(6) using Toda and Phillips (TP) Method.
a and b imply significantly different from zero at 1% and 5% level respectively.
The test statistics have a $\chi^2(6)$ distribution under the null hypothesis.
Real S&P 500 Stock Index (SPR), 3-month Treasury Bill Yield (ST), and Estimated Expected Inflation (EI). Quarterly data in the 1950.1-1996.4 period.

Table 29. Short-Run Granger-Causality Tests VECM(8) - TP Method

Graham D:1976.1-1982.1

Expected Inflation = ST

	Dependent Variable	
	ΔSPR	ΔST
ΔSPR	-	5.104
ΔST	20.869[a]	-

Expected Inflation = EI

	Dependent Variable	
	ΔSPR	ΔEI
ΔSPR	-	4.899
ΔEI	0.739	-

Kaul D:1979.1-1986.4

Expected Inflation = ST

	Dependent Variable	
	ΔSPR	ΔST
ΔSPR	-	3.911
ΔST	19.394[b]	-

Expected Inflation = EI

	Dependent Variable	
	ΔSPR	ΔEI
ΔSPR	-	5.165
ΔEI	1.618	-

Notes: Causality tests within VECM(8) using Toda and Phillips (TP) Method.
a and b imply significantly different from zero at 1% and 5% level respectively.
The test statistics have a $\chi^2(8)$ distribution under the null hypothesis.
Real S&P 500 Stock Index (SPR), 3-month Treasury Bill Yield (ST), and Estimated Expected Inflation (EI). Quarterly data in the 1950.1-1996.4 period.

Table 30. Short-Run Granger-Causality Tests VECM(6) - SL Method

Graham D:1976.1-1982.1

Expected Inflation = ST

	Dependent Variable	
	ΔSPR	ΔST
ΔSPR	-	12.872^a
ΔST	2.682	-

Expected Inflation = EI

	Dependent Variable	
	ΔSPR	ΔEI
ΔSPR	-	2.875
ΔEI	7.594^a	-

Kaul D:1979.1-1986.4

Expected Inflation = ST

	Dependent Variable	
	ΔSPR	ΔST
ΔSPR	-	32.450^a
ΔST	1.121	-

Expected Inflation = EI

	Dependent Variable	
	ΔSPR	ΔEI
ΔSPR	-	1.866
ΔEI	4.417^b	-

Notes: Causality tests within VECM(6) using Saikkonen and Lütkepohl (SL) Method.
a and b imply significantly different from zero at 1% and 5% level respectively.
The test statistics have a $\chi^2(1)$ distribution under the null hypothesis.
Real S&P 500 Stock Index (SPR), 3-month Treasury Bill Yield (ST), and Estimated Expected Inflation (EI). Quarterly data in the 1950.1-1996.4 period.

Table 31. Short-Run Granger-Causality Tests VECM(8) - SL Method

Graham D:1976.1-1982.1

Expected Inflation = ST

	Dependent Variable	
	ΔSPR	ΔST
ΔSPR	-	5.929^b
ΔST	8.871^a	-

Expected Inflation = EI

	Dependent Variable	
	ΔSPR	ΔEI
ΔSPR	-	2.668
ΔEI	4.798^b	-

Kaul D:1979.1-1986.4

Expected Inflation = ST

	Dependent Variable	
	ΔSPR	ΔST
ΔSPR	-	9.009^a
ΔST	7.968^a	-

Expected Inflation = EI

	Dependent Variable	
	ΔSPR	ΔEI
ΔSPR	-	5.936^b
ΔEI	4.261^b	-

Notes: Causality tests within VECM(8) using Saikkonen and Lütkepohl (SL) Method.
a and b imply significantly different from zero at 1% and 5% level respectively.
The test statistics have a $\chi^2(1)$ distribution under the null hypothesis.
Real S&P 500 Stock Index (SPR), 3-month Treasury Bill Yield (ST), and Estimated Expected Inflation (EI). Quarterly data in the 1950.1-1996.4 period.

APPENDIX G

FIGURES

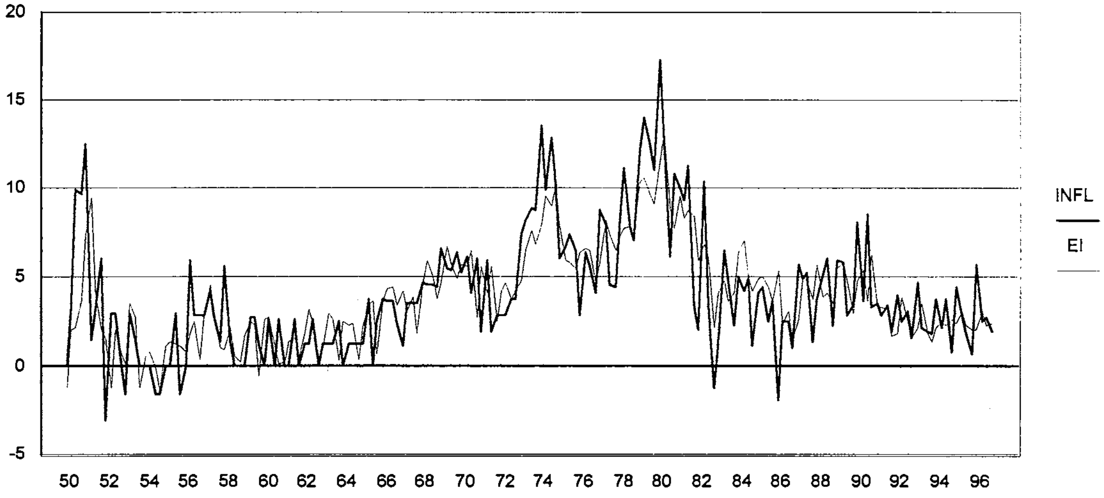

Figure 1. Estimated Expected Inflation (EI) and Next Period CPI Inflation (INFL) (Quarterly 1950.1-1996.4)

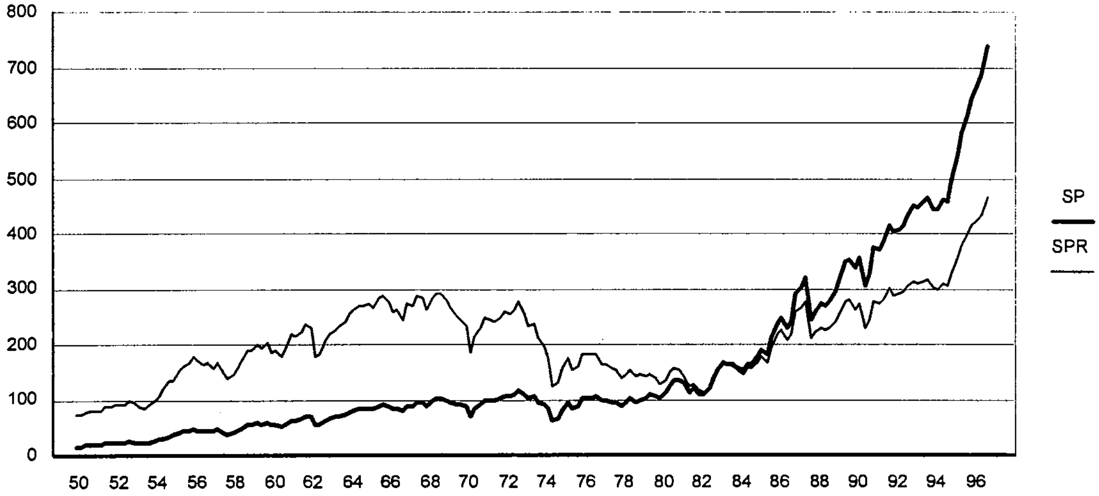

Figure 2. Nominal (SP) and Real (SPR) S&P 500 Composite Stock Price Index (Quarterly 1950.1-1996.4)

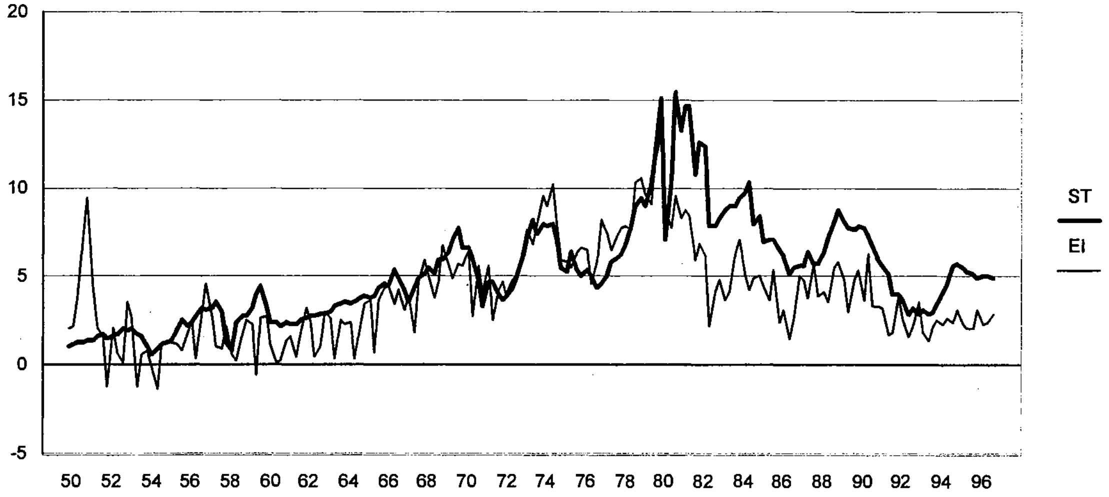

Figure 3. 3-Month Treasury Bill Yield (ST) and Estimated Expected Inflation (EI) (Quarterly 1950.1-1996.4)

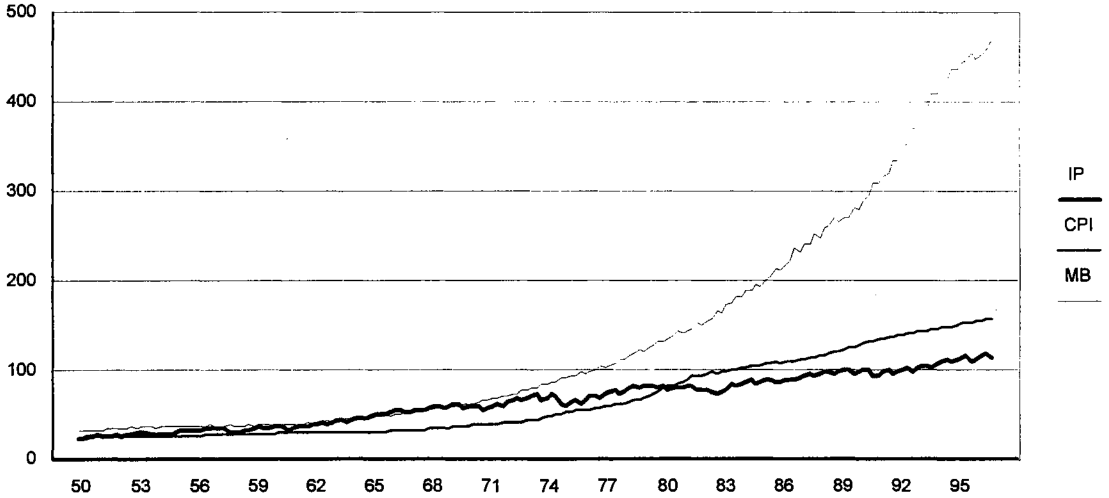

Figure 4. Industrial Production (IP), Consumer Price Index (CPI), and Monetary Base (MB) (Quarterly 1950.1-1996.4)

APPENDIX H

DATASET

Series:

OBS = observation number
QTR = quarter
YR = year
SP = nominal S&P 500 Composite stock index
ST = 3-Month Treasury Bill yield
IP = Industrial Production
CPI = Consumer Price Index
MB = Monetary Base
EI = estimated expected inflation series
SPR = real S&P 500 Composite stock index

OBS	QTR	YR	SP	ST	IP	CPI	MB	EI	SPR
1	1	47	15.17	0.38	21.732	21.9	33.169	-	69.27
2	2	47	15.21	0.38	21.353	22.0	33.257	-	69.14
3	3	47	15.11	0.80	22.195	23.0	33.967	-	65.70
4	4	47	15.30	0.95	22.237	23.4	34.410	-	65.38
5	1	48	15.08	1.00	22.279	23.4	33.169	-	64.44
6	2	48	16.74	1.00	22.659	24.1	32.903	6.82	69.46
7	3	48	15.49	1.09	23.290	24.5	32.282	0.45	63.22
8	4	48	15.20	1.16	22.279	24.1	33.701	-1.60	63.07
9	1	49	15.06	1.17	21.648	23.8	32.637	0.45	63.28
10	2	49	14.16	1.17	20.848	23.9	33.257	-2.75	59.25
11	3	49	15.58	1.07	22.027	23.9	32.903	-5.09	65.19
12	4	49	16.76	1.10	21.353	23.6	33.257	-1.23	71.02
13	1	50	17.29	1.12	22.911	23.6	32.548	2.05	73.26
14	2	50	17.69	1.15	24.596	23.8	32.548	2.23	74.33
15	3	50	19.45	1.30	26.786	24.4	32.903	3.74	79.71
16	4	50	20.41	1.34	26.533	25.0	33.257	7.36	81.64
17	1	51	21.40	1.40	27.502	25.8	33.169	9.51	82.95
18	2	51	20.96	1.45	27.039	25.9	33.612	4.21	80.93
19	3	51	23.26	1.63	27.039	26.1	34.144	2.15	89.12
20	4	51	23.77	1.73	26.533	26.5	35.475	1.59	89.70
21	1	52	24.37	1.59	27.755	26.3	34.765	-1.22	92.66
22	2	52	24.96	1.70	26.660	26.5	35.031	2.07	94.19
23	3	52	24.54	1.71	29.397	26.7	35.741	0.77	91.91
24	4	52	26.57	2.09	29.523	26.7	36.982	0.22	99.51
25	1	53	25.29	2.01	30.998	26.6	35.918	3.59	95.08
26	2	53	24.14	2.11	30.787	26.8	36.982	2.83	90.07
27	3	53	23.35	1.79	30.534	26.9	36.628	-1.15	86.80
28	4	53	24.81	1.60	28.092	26.9	37.337	0.59	92.23
29	1	54	26.94	1.03	28.513	26.9	36.184	0.80	100.15
30	2	54	29.21	0.64	28.555	26.9	36.894	-0.10	108.59
31	3	54	32.31	1.01	28.807	26.8	36.539	-1.35	120.56
32	4	54	35.98	1.14	29.397	26.7	37.692	1.18	134.76
33	1	55	36.58	1.28	31.629	26.7	36.450	1.43	137.00

34	2	55	41.03	1.41	32.514	26.7	36.716	1.34	153.67
35	3	55	43.67	2.07	33.061	26.9	37.071	1.14	162.34
36	4	55	45.48	2.54	33.230	26.8	38.047	0.90	169.70
37	1	56	48.48	2.25	33.693	26.8	36.982	1.83	180.90
38	2	56	46.97	2.49	33.567	27.2	37.248	2.55	172.68
39	3	56	45.35	2.84	34.451	27.4	37.514	0.37	165.51
40	4	56	46.67	3.21	34.114	27.6	38.667	3.05	169.09
41	1	57	44.11	3.08	34.999	27.8	37.248	4.58	158.67
42	2	57	47.37	3.29	34.746	28.1	37.603	2.73	168.58
43	3	57	42.42	3.53	34.662	28.3	37.781	1.07	149.89
44	4	57	39.99	3.04	31.798	28.4	38.755	1.01	140.81
45	1	58	42.10	1.30	30.703	28.8	37.958	2.22	146.18
46	2	58	45.24	0.83	31.713	28.9	38.313	0.66	156.54
47	3	58	50.06	2.44	33.398	28.9	38.490	0.33	173.22
48	4	58	55.21	2.77	33.482	28.9	39.643	1.80	191.04
49	1	59	55.44	2.80	35.883	28.9	38.294	2.52	191.83
50	2	59	58.47	3.21	37.694	29.1	38.821	2.31	200.93
51	3	59	56.88	4.04	35.504	29.3	39.121	-0.47	194.13
52	4	59	59.89	4.49	36.262	29.4	40.004	2.65	203.71
53	1	60	55.34	3.31	37.441	29.4	38.384	2.82	188.23
54	2	60	56.92	2.46	37.146	29.6	38.831	1.17	192.30
55	3	60	53.52	2.48	36.641	29.6	39.348	0.12	180.81
56	4	60	58.11	2.25	33.946	29.8	40.493	0.30	195.00
57	1	61	65.06	2.39	34.956	29.8	39.109	1.41	218.32
58	2	61	64.64	2.33	37.441	29.8	39.617	1.63	216.91
59	3	61	66.73	2.28	38.242	30.0	40.143	0.50	222.43
60	4	61	71.55	2.60	38.199	30.0	41.655	1.85	238.50
61	1	62	69.55	2.72	39.673	30.1	40.511	3.25	231.06
62	2	62	54.75	2.73	40.389	30.2	41.213	2.47	181.29
63	3	62	56.27	2.78	41.105	30.4	41.666	0.48	185.10
64	4	62	63.10	2.87	39.505	30.4	43.224	1.06	207.57
65	1	63	66.57	2.89	41.695	30.5	42.176	3.02	218.26
66	2	63	69.37	2.99	43.253	30.6	42.996	2.69	226.70
67	3	63	71.70	3.38	43.422	30.7	43.779	0.35	233.55
68	4	63	75.02	3.52	42.116	30.9	45.672	2.52	242.78
69	1	64	78.98	3.54	44.138	30.9	44.481	2.38	255.60
70	2	64	81.69	3.48	45.780	31.0	45.520	2.40	263.52
71	3	64	84.18	3.53	46.581	31.1	46.349	0.37	270.68
72	4	64	84.75	3.84	45.907	31.2	48.038	2.35	271.63
73	1	65	86.16	3.93	48.897	31.3	47.063	3.41	275.27
74	2	65	84.12	3.80	50.455	31.6	47.938	3.66	266.20
75	3	65	89.96	3.92	50.834	31.6	48.778	0.72	284.68
76	4	65	92.43	4.38	50.329	31.8	50.961	3.66	290.66
77	1	66	89.23	4.59	53.530	32.1	49.936	4.40	277.98
78	2	66	84.74	4.50	55.046	32.4	50.736	4.46	261.54
79	3	66	86.56	5.37	55.972	32.7	51.597	3.47	264.71
80	4	66	80.33	4.96	53.656	32.9	53.233	4.30	244.16
81	1	67	90.20	4.26	54.466	33.0	52.566	3.12	273.33
82	2	67	90.64	3.54	55.572	33.3	53.502	3.96	272.19
83	3	67	96.71	4.42	56.364	33.6	54.393	1.88	287.83
84	4	67	96.47	4.97	55.534	33.9	56.447	4.67	284.57
85	1	68	90.20	5.17	57.608	34.3	55.599	5.96	262.97
86	2	68	99.58	5.52	59.638	34.7	56.927	5.03	286.97
87	3	68	102.67	5.19	59.790	35.1	57.885	3.77	292.51

88	4	68	103.86	5.96	58.012	35.5	60.574	4.69	292.56
89	1	69	101.51	6.02	61.109	36.1	59.266	6.78	281.19
90	2	69	97.71	6.44	62.377	36.6	60.290	5.72	266.97
91	3	69	93.12	7.09	62.860	37.1	60.888	4.91	251.00
92	4	69	92.06	7.82	58.941	37.7	63.100	5.74	244.19
93	1	70	89.63	6.63	59.636	38.2	61.788	5.58	234.63
94	2	70	72.72	6.68	60.449	38.8	63.430	6.54	187.42
95	3	70	84.21	6.13	60.109	39.2	64.823	2.82	214.82
96	4	70	92.15	4.87	56.605	39.8	67.230	5.66	231.53
97	1	71	100.31	3.38	58.918	40.0	66.799	4.11	250.78
98	2	71	99.70	4.75	61.011	40.6	68.638	5.66	245.57
99	3	71	98.34	4.69	61.679	40.8	69.980	2.53	241.03
100	4	71	102.09	4.01	59.173	41.1	72.051	4.29	248.39
101	1	72	107.20	3.73	63.879	41.4	71.557	4.73	258.94
102	2	72	107.14	3.91	66.432	41.7	73.550	3.76	256.93
103	3	72	110.55	4.66	68.275	42.1	74.740	4.29	262.59
104	4	72	118.05	5.07	66.072	42.5	78.949	4.80	277.76
105	1	73	111.52	6.09	69.945	43.3	78.492	6.59	257.55
106	2	73	104.26	7.19	72.701	44.2	80.576	7.69	235.88
107	3	73	108.43	8.29	73.716	45.2	81.585	6.84	239.89
108	4	73	97.55	7.45	67.825	46.2	84.787	8.01	211.15
109	1	74	93.98	7.96	70.070	47.8	84.353	9.60	196.61
110	2	74	86.00	7.90	72.784	49.0	87.265	9.03	175.51
111	3	74	63.54	8.06	72.630	50.6	88.625	10.29	125.57
112	4	74	68.56	7.15	62.639	51.9	92.582	7.87	132.10
113	1	75	83.36	5.49	61.324	52.7	91.212	5.94	158.18
114	2	75	95.19	5.34	64.311	53.6	93.644	5.84	177.59
115	3	75	83.87	6.42	66.697	54.6	94.326	5.50	153.61
116	4	75	90.19	5.44	63.520	55.5	98.123	6.46	162.50
117	1	76	102.77	5.00	68.050	55.9	96.895	6.68	183.85
118	2	76	104.28	5.41	70.957	56.8	99.618	6.56	183.59
119	3	76	105.24	5.08	72.020	57.6	100.664	4.60	182.71
120	4	76	107.46	4.35	69.205	58.2	104.846	5.89	184.64
121	1	77	98.42	4.60	73.725	59.5	103.860	8.19	165.41
122	2	77	100.48	5.02	77.151	60.7	106.587	7.47	165.54
123	3	77	96.53	5.81	77.879	61.4	108.763	6.51	157.21
124	4	77	95.10	6.07	74.403	62.1	113.576	7.31	153.14
125	1	78	89.21	6.29	77.062	63.4	112.833	7.73	140.71
126	2	78	95.53	6.73	81.340	65.2	116.811	7.93	146.52
127	3	78	102.54	7.85	82.439	66.5	119.019	7.72	154.20
128	4	78	96.11	9.08	80.354	67.7	123.889	10.41	141.96
129	1	79	101.59	9.48	83.144	69.8	121.781	10.66	145.54
130	2	79	102.91	9.06	83.911	72.3	125.141	9.76	142.34
131	3	79	109.32	10.26	83.455	74.6	128.254	9.12	146.54
132	4	79	107.94	12.04	80.102	76.7	133.817	11.68	140.73
133	1	80	102.09	15.20	82.630	80.1	132.207	13.20	127.45
134	2	80	114.24	7.07	78.257	82.7	134.997	8.97	138.14
135	3	80	125.46	10.27	80.560	84.0	139.174	7.75	149.36
136	4	80	135.76	15.49	79.943	86.3	144.849	9.63	157.31
137	1	81	136.00	13.36	81.690	88.5	141.449	8.35	153.67
138	2	81	131.21	14.73	82.721	90.6	145.221	8.78	144.82
139	3	81	116.18	14.70	83.095	93.2	147.210	8.48	124.66
140	4	81	122.55	10.85	77.884	94.0	152.827	5.97	130.37
141	1	82	111.96	12.68	78.977	94.5	150.191	6.90	118.48

142	2	82	109.61	12.47	77.837	97.0	155.555	6.23	113.00
143	3	82	120.42	7.92	77.091	97.9	158.505	2.27	123.00
144	4	82	140.64	7.94	73.024	97.6	166.109	4.10	144.10
145	1	83	152.96	8.35	76.346	97.9	165.864	4.80	156.24
146	2	83	168.11	8.79	79.210	99.5	172.758	3.66	168.95
147	3	83	166.07	9.00	84.292	100.7	175.957	4.17	164.92
148	4	83	164.93	9.00	82.435	101.3	183.550	6.40	162.81
149	1	84	159.18	9.52	86.126	102.6	182.655	7.14	155.15
150	2	84	153.18	9.87	88.148	103.7	188.940	5.01	147.71
151	3	84	166.10	10.37	89.320	105.0	190.076	4.22	158.19
152	4	84	167.24	8.06	85.216	105.3	196.484	4.98	158.82
153	1	85	180.66	8.52	87.923	106.4	194.105	5.09	169.79
154	2	85	191.85	6.95	88.993	107.6	201.707	4.54	178.30
155	3	85	182.08	7.10	90.669	108.3	205.524	3.69	168.13
156	4	85	211.28	7.10	87.801	109.3	214.868	5.39	193.30
157	1	86	238.90	6.56	87.912	108.8	211.499	2.49	219.58
158	2	86	250.84	6.21	89.547	109.5	220.218	3.14	229.08
159	3	86	231.32	5.21	90.773	110.2	224.193	1.57	209.91
160	4	86	242.17	5.53	89.217	110.5	236.750	2.63	219.16
161	1	87	291.70	5.59	91.611	112.1	233.221	5.08	260.21
162	2	87	304.00	5.67	94.767	113.5	241.218	4.79	267.84
163	3	87	321.83	6.40	95.950	115.0	243.015	3.81	279.85
164	4	87	247.08	5.77	93.997	115.4	253.124	5.71	214.11
165	1	88	258.89	5.70	96.120	116.5	249.971	3.95	222.22
166	2	88	273.50	6.46	98.422	118.0	260.020	4.15	231.78
167	3	88	271.91	7.24	99.922	119.8	261.917	3.63	226.97
168	4	88	277.72	8.07	97.284	120.5	271.035	5.51	230.47
169	1	89	294.87	8.82	99.000	122.3	266.540	5.80	241.10
170	2	89	317.98	8.15	100.999	124.1	271.403	4.86	256.23
171	3	89	349.15	7.75	100.888	125.0	271.664	3.05	279.32
172	4	89	353.40	7.63	97.404	126.1	281.879	4.86	280.25
173	1	90	339.94	7.90	99.171	128.7	280.245	5.45	264.13
174	2	90	358.02	7.73	101.107	129.9	289.792	3.74	275.61
175	3	90	306.05	7.36	102.093	132.7	296.402	6.25	230.63
176	4	90	330.22	6.74	95.367	133.8	309.213	3.38	246.80
177	1	91	375.22	5.91	94.282	135.0	311.100	3.35	277.94
178	2	91	371.16	5.57	98.753	136.0	317.395	3.19	272.91
179	3	91	387.86	5.22	100.773	137.2	321.823	1.74	282.70
180	4	91	417.09	4.07	95.636	137.9	335.968	1.85	302.46
181	1	92	403.69	4.04	98.744	139.3	335.643	3.88	289.80
182	2	92	408.14	3.66	101.658	140.2	344.449	2.61	291.11
183	3	92	417.80	2.91	102.835	141.3	355.429	1.66	295.68
184	4	92	435.71	3.22	99.885	141.9	371.085	2.21	307.05
185	1	93	451.67	2.95	102.929	143.6	371.537	3.56	314.53
186	2	93	450.53	3.07	104.728	144.4	385.123	1.85	312.00
187	3	93	458.93	2.95	106.390	145.1	394.316	1.37	316.29
188	4	93	466.45	3.06	103.019	145.8	409.307	2.21	319.92
189	1	94	445.77	3.50	106.993	147.2	410.956	2.56	302.83
190	2	94	444.27	4.14	110.705	148.0	421.157	2.27	300.18
191	3	94	462.69	4.62	112.234	149.4	426.800	2.62	309.70
192	4	94	459.27	5.60	109.118	149.7	438.145	2.48	306.79
193	1	95	500.71	5.73	111.810	151.4	437.497	3.11	330.72
194	2	95	544.75	5.47	113.923	152.5	444.261	2.37	357.21
195	3	95	584.41	5.28	116.143	153.2	445.488	2.13	381.47

196	4	95	615.93	5.14	110.681	153.5	454.574	2.09	401.26
197	1	96	645.50	4.96	113.283	155.7	448.783	3.07	414.58
198	2	96	670.63	5.09	117.644	156.7	454.405	2.31	427.97
199	3	96	687.31	5.09	119.073	157.8	458.606	2.49	435.56
200	4	96	740.74	4.91	115.257	158.6	471.530	2.85	467.05

APPENDIX I

MEASURING EXPECTED INFLATION WITH LONG-TERM INTEREST RATES

This appendix supplements the results in chapter V by using long-term nominal interest rates as an additional measure of expected inflation. This third measure is used because three causal conclusions in chapter 5 are sensitive to the measure of expected inflation. Short-term nominal rates (ST) are found to be positively, and the estimated expected inflation series (EI) negatively, related to future real activity. Neither measure, however, is strongly causal for real activity. Similarly, the findings indicate that short-term rates (ST) are negatively, and the estimated expected inflation series (EI) positively, related to future stock returns. Both of these relationships are found to be Granger-causal. The third link is from expected inflation to the monetary base (MB). Short-term rates (ST) are inversely related to, and Granger-causal for, the monetary base, while the estimated series (EI) is ambiguous in sign and not causal.

The unit root tests, cointegration tests, and VECM-based causality tests performed in chapter 5 are repeated using long-term interest rates (LT) as a measure of expected inflation. The long-term interest rate series is constructed using the 20-

year Constant Maturity Treasury Bond yield in the 1950Q1-1977Q1 period and the 30-year Constant Maturity Treasury Bond yield through 1996Q4. (The yield curve was flat between the 20-year and 30-year maturity at the splice point.) First, the ADF unit root test is applied to the long-term interest rate series (LT). As shown in Table 32, the null hypothesis of two unit roots is rejected at the 5 percent level of significance for long-term rates (LT). A subsequent test for a single unit root fails to reject the null hypothesis. This suggests that the long-term interest rate series is nonstationary in levels and stationary in differences, i.e. is I(1).

Table 33 contains the results from cointegration tests using the real S&P 500 stock price index (SPR), Industrial Production (IP), the Monetary Base (MB), and the long-term interest rate (LT). Two significant cointegrating vectors are found in the 1950Q1-1996Q4 period. The normalized vectors are presented in Table 34 along with likelihood ratio tests of the null hypothesis that the coefficients within the cointegrating vectors for an individual variable are zero. The results indicate that each variable enters both vectors significantly, and that stock prices increase along with real activity and decline in response to increases in both expected inflation and the monetary base in the long-run. These findings are consistent with the earlier cointegration results using short-term rates (ST) and the estimated expected inflation series (EI).

The results of the short-run causality tests are contained in Tables 35-38. These tests indicate that the vital link from expected inflation to real activity is inverse as suggested by both Fama and Geske-Roll. This finding is consistent with the relation found in earlier tests using the estimated expected inflation series (EI), but opposite the positive relation found using short-term rates. Expected inflation, however, remains noncausal using long-term rates and confirms the earlier finding that the key link suggested by both models is not present in the postwar period.

The data also indicate an inverse causal link from expected inflation to stock prices using long-term rates (LT) as a measure of expected inflation. This is consistent with the earlier finding of an inverse causal link from short-term rates (ST) to stock prices (SPR), but opposite the positive link found with the estimated expected inflation series (EI). It is also consistent with Geske-Roll's argument that an observed inverse relationship between stock prices and nominal interest rates is possible even if the link from stock prices to the expected inflation component of nominal rates is insignificant.

The third link from expected inflation to the monetary base indicates that long-term rates are inversely related to, and Granger-causal for, the monetary base. This result, again, is consistent with the inverse causal relationship found in earlier tests using short-term interest rates (ST). Further, it provides additional evidence supporting the money supply linkages in the Geske-Roll model.

For completeness, the dummy variable tests for the policy-change effects suggested by Kaul and Graham are repeated using long-term interest rates as a measure of expected inflation. Table 39 contains hypothesis tests that the estimated coefficients on the multiplicative dummy variables are jointly equal to zero. Tables 40-43 contains the results of causality tests between stock prices and expected inflation in the presence of the dummy variables. The findings indicate, again, that the dummy variables are insignificant in the policy-change periods proposed by Kaul and Graham, and the causal conclusions from the original tests are unchanged.

Table 32. ADF Unit Root Tests

Variables	Two Unit Roots	Single Unit Root
LT	-3.9074[a] (12)	-2.0007 (12)

Notes: Significant lags in parenthesis.
a denotes rejection of the null at the 5% level.
Data are quarterly in the 1950.1-1996.4 period.
LT = 20/30-year Constant Maturity Treasury Bond yield (20-year Treasury Constant Maturity yield through 1977Q2 and 30-year yield thereafter. Series is spliced at a point when the 20 to 30-year section of the yield curve is flat.)

Table 33. Johansen-Juselius Cointegration Tests

	Maximum Eigenvalue Test			
Variables	$H_0: r=0$ $H_1: r>0$	$H_0: r\leq 1$ $H_1: r>1$	$H_0: r\leq 2$ $H_1: r>2$	$H_0: r\leq 3$ $H_1: r>3$
SPR IP MB LT	37.7622 [a]	18.8952 [b]	7.1662	1.0714
CV(95%)	27.0670	20.9670	14.0690	3.7620
CV(90%)	24.7340	18.5980	12.0710	2.6870

	Trace Test			
Variables	$H_0: r=0$ $H_1: r>0$	$H_0: r\leq 1$ $H_1: r>1$	$H_0: r\leq 2$ $H_1: r>2$	$H_0: r\leq 3$ $H_1: r>3$
SPR IP MB LT	64.8951 [a]	27.1328 [b]	8.2376	1.0714
CV(95%)	47.2100	29.6800	15.4100	3.7620
CV(90%)	43.9490	26.7850	13.3250	2.6870

Notes: VECM with 8 lags selected with Akaike's AIC.
r denotes the number of significant cointegrating vectors.
a and **b** denote rejection of the null at the 5% and 10% levels, respectively.
CV(90%) and CV(95%) are critical values at the 90% and 95% confidence levels.
Data are quarterly in the 1950.1-1996.4 period.
SPR = real S&P 500 stock index, IP = Industrial Production, MB = Monetary Base, LT = 20/30-year Constant Maturity Treasury Bond yield.

Table 34. Cointegrating Vectors and Likelihood Ratio Tests

Variables		Normalized Cointegrating Vectors			
		SPR	IP	MB	LT
SPR IP MB LT	(1)	-1.0000	3.8142	-0.6966	0.3705
	(2)	-1.0000	4.5725	-1.4667	-1.6086

or

(1) $SPR_t = 3.8142IP_t - 0.6966MB_t + 0.3705LT_t$

(2) $SPR_t = 4.5725IP_t - 1.4667MB_t - 1.6086LT_t$

Variables	Likelihood Ratio Tests			
	$H_o: B_{SPR1}=B_{SPR2}=0$	$H_o: B_{IP1}=B_{IP2}=0$	$H_o: B_{MB1}=B_{MB2}=0$	$H_o: B_{LT1}=B_{LT2}=0$
SPR IP MB LT	9.6081 [a]	13.3323 [a]	12.5684 [a]	6.3242 [b]

Notes: The test statistics have a $\chi^2(2)$ distribution under the null hypothesis.
a and **b** denote rejection of the null at the 1% and 5% levels, respectively.
Data are quarterly in the 1950.1-1996.4 period.
SPR = real S&P 500 stock index, IP = Industrial Production, MB = Monetary Base, LT = 20/30-year Constant Maturity Treasury Bond yield.

Table 35. SR Causality Tests VECM(6) - TP Method

Expected Inflation = LT

	Dependent Variable			
	ΔIP	ΔLT	ΔMB	ΔSPR
ΔIP	-	12.531	14.304[b]	2.187
ΔLT	7.893	-	22.441[a]	24.356[a]
ΔMB	53.125[a]	7.799	-	10.017
ΔSPR	26.065[a]	25.512[a]	4.681	-

Notes: Causality tests within VECM(6) using Toda and Phillips (TP) Method.
a and **b** imply significantly different from zero at 1% and 5% level respectively.
The test statistics have a $\chi^2(6)$ distribution under the null hypothesis.
Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR),
LT = 20/30-year Constant Maturity Treasury Bond yield.
Quarterly data in the 1950.1-1996.4 period.

Table 36. SR Causality Tests VECM(8) - TP Method

Expected Inflation = LT

	Dependent Variable			
	ΔIP	ΔLT	ΔMB	ΔSPR
ΔIP	-	14.582	10.671	3.464
ΔLT	11.327	-	32.900[a]	24.596[a]
ΔMB	40.782[a]	10.303	-	12.766
ΔSPR	27.477[a]	29.121[a]	8.072	-

Notes: Causality tests within VECM(8) using Toda and Phillips (TP) Method.
a and **b** imply significantly different from zero at 1% and 5% level respectively.
The test statistics have a $\chi^2(8)$ distribution under the null hypothesis.
Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR),
LT = 20/30-year Constant Maturity Treasury Bond yield.
Quarterly data in the 1950.1-1996.4 period.

Table 37. SR Causality Tests VECM(6) - SL Method

Expected Inflation = LT

	Dependent Variable			
	ΔIP	ΔLT	ΔMB	ΔSPR
ΔIP	-	4.213^b	0.049	1.786
ΔLT	1.421	-	14.463^a	8.534^a
ΔMB	13.513^a	0.912	-	5.344^b
ΔSPR	9.333^a	10.830^a	0.091	-

Notes: Causality tests within VECM(6) using Saikkonen and Lütkepohl (SL) Method.
a and **b** imply significantly different from zero at 1% and 5% level respectively.
The test statistics have a $\chi^2(1)$ distribution under the null hypothesis.
Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR),
LT = 20/30-year Constant Maturity Treasury Bond yield.
Quarterly data in the 1950.1-1996.4 period.

Table 38. SR Causality Tests VECM(8) - SL Method

Expected Inflation = LT

	Dependent Variable			
	ΔIP	ΔLT	ΔMB	ΔSPR
ΔIP	-	5.057^b	0.153	0.025
ΔLT	0.925	-	31.649^a	8.914^a
ΔMB	11.622^a	4.676^b	-	4.653^b
ΔSPR	9.093^a	11.862^a	1.811	-

Notes: Causality tests within VECM(8) using Saikkonen and Lütkepohl (SL) Method.
a and **b** imply significantly different from zero at 1% and 5% level respectively.
The test statistics have a $\chi^2(1)$ distribution under the null hypothesis.
Industrial Production (IP), Monetary Base (MB), Real S&P 500 Stock Index (SPR),
LT = 20/30-year Constant Maturity Treasury Bond yield.
Quarterly data in the 1950.1-1996.4 period.

Table 39. Dummy Variable Hypothesis Tests

Toda and Phillips Method

Model	Variables	Graham D:1976.1-1982.1	Kaul D:1979.1-1986.4
VECM(6)	SPR IP MB LT	1.956	0.651
VECM(8)	SPR IP MB LT	1.080	2.504

Notes: The test statistics have $\chi^2(6)$ and $\chi^2(8)$ distributions under the null hypothesis in the VECM(6) and VECM(8) models respectively.
Quarterly data in the 1950.1-1996.4 period.
SPR = real S&P 500 stock index, IP = Industrial Production, MB = Monetary Base, LT = 20/30-year Constant Maturity Treasury Bond yield.

Saikkonen and Lütkepohl Method

Model	Variables	Graham D:1976.1-1982.1	Kaul D:1979.1-1986.4
VECM(6)	SPR IP MB LT	3.177	0.300
VECM(8)	SPR IP MB LT	1.140	2.597

Notes: The test statistics have a $\chi^2(1)$ distribution under the null hypothesis in both the VECM(6) and VECM(8) models.
Quarterly data in the 1950.1-1996.4 period.
SPR = real S&P 500 stock index, IP = Industrial Production, MB = Monetary Base, LT = 20/30-year Constant Maturity Treasury Bond yield.

Table 40. Short-Run Granger-Causality Tests VECM(6) - TP Method

Graham D:1976.1-1982.1

Expected Inflation = LT

	Dependent Variable	
	ΔSPR	ΔLT
ΔSPR	-	8.964
ΔLT	17.077^a	-

Kaul D:1979.1-1986.4

Expected Inflation = LT

	Dependent Variable	
	ΔSPR	ΔLT
ΔSPR	-	9.453
ΔLT	12.971^b	-

Notes: Causality tests within VECM(6) using Toda and Phillips (TP) Method.
a and **b** imply significantly different from zero at 1% and 5% level respectively.
The test statistics have a $\chi^2(6)$ distribution under the null hypothesis.
Real S&P 500 Stock Index (SPR) and 20/30-year Constant Maturity Treasury Bond yield (LT).
Quarterly data in the 1950.1-1996.4 period.

Table 41. Short-Run Granger-Causality Tests VECM(8) - TP Method

Graham D:1976.1-1982.1

Expected Inflation = LT

	Dependent Variable	
	ΔSPR	ΔLT
ΔSPR	-	3.976
ΔLT	17.649[a]	-

Kaul D:1979.1-1986.4

Expected Inflation = LT

	Dependent Variable	
	ΔSPR	ΔLT
ΔSPR	-	3.400
ΔLT	13.721[b]	-

Notes: Causality tests within VECM(8) using Toda and Phillips (TP) Method.
a and **b** imply significantly different from zero at 1% and 5% level respectively.
The test statistics have a $\chi^2(8)$ distribution under the null hypothesis.
Real S&P 500 Stock Index (SPR) and 20/30-year Constant Maturity Treasury Bond yield (LT).
Quarterly data in the 1950.1-1996.4 period.

Table 42. Short-Run Granger-Causality Tests VECM(6) - SL Method

Graham D:1976.1-1982.1

Expected Inflation = LT

	Dependent Variable	
	ΔSPR	ΔLT
ΔSPR	-	13.688[a]
ΔLT	10.612[a]	-

Kaul D:1979.1-1986.4

Expected Inflation = LT

	Dependent Variable	
	ΔSPR	ΔLT
ΔSPR	-	10.634[a]
ΔLT	7.975[a]	-

Notes: Causality tests within VECM(6) using Saikkonen and Lütkepohl (SL) Method.
a implies significantly different from zero at 1% level.
The test statistics have a $\chi^2(1)$ distribution under the null hypothesis.
Real S&P 500 Stock Index (SPR) and 20/30-year Constant Maturity Treasury Bond yield (LT).
Quarterly data in the 1950.1-1996.4 period.

Table 43. Short-Run Granger-Causality Tests VECM(8) - SL Method

Graham D:1976.1-1982.1

Expected Inflation = LT

	Dependent Variable	
	ΔSPR	ΔLT
ΔSPR	-	10.499[a]
ΔLT	9.925[a]	-

Kaul D:1979.1-1986.4

Expected Inflation = LT

	Dependent Variable	
	ΔSPR	ΔLT
ΔSPR	-	13.537[a]
ΔLT	8.215[a]	-

Notes: Causality tests within VECM(8) using Saikkonen and Lütkepohl (SL) Method.
a implies significantly different from zero at 1% level.
The test statistics have a $\chi^2(1)$ distribution under the null hypothesis.
Real S&P 500 Stock Index (SPR) and 20/30-year Constant Maturity Treasury Bond yield (LT).
Quarterly data in the 1950.1-1996.4 period.

APPENDIX J

SHAZAM PROGRAMS

Toda and Phillips Method

The following SHAZAM program tests short-run Granger-causality within a 4-variable VECM with lag lengths of either 6 or 8 and with two significant cointegrating vectors. Refer to Toda and Phillips (1993, 1994) for additional details concerning the procedure.

```
SAMPLE 1 200
TIME 1947 4
SAMPLE 1947.1 1996.4
READ REC MO YR  SP     ST     LT      IP      CPI      MB     EI
    1    1 47  15.17  0.38   2.19   21.732   21.9   33.169  0.00
    2    2 47  15.21  0.38   2.22   21.353   22.0   33.257  0.00
    3    3 47  15.11  0.80   2.24   22.195   23.0   33.967  0.00
    4    4 47  15.30  0.95   2.39   22.237   23.4   34.410  0.00
    5    1 48  15.08  1.00   2.44   22.279   23.4   33.169  0.00
    6    2 48  16.74  1.00   2.41   22.659   24.1   32.903  6.82
    7    3 48  15.49  1.09   2.45   23.290   24.5   32.282  0.45
    8    4 48  15.20  1.16   2.44   22.279   24.1   33.701 -1.60
    9    1 49  15.06  1.17   2.38   21.648   23.8   32.637  0.45
   10    2 49  14.16  1.17   2.38   20.848   23.9   33.257 -2.75
    .
    .
    .
  199    3 96 687.31  5.09   7.13  119.073  157.8  458.606  2.49
  200    4 96 740.74  4.91   6.63  115.257  158.6  471.530  2.85

SET NODOECHO
SET NOECHO
SET NOOUTPUT
DELETE REC MO YR ST EI

* Temporary cointegrating vector storage
*  LNSPR     LNIP      LNMB      LNLT    -   8 LAGS
* -1.0000   3.8142  -0.69663    0.37052
* -1.0000   4.5725  -1.4667    -1.6086
* -1.0000   1.7323   0.21797   -1.7042
* -1.0000  -2.2636  -0.022407   2.0754

* Create selector matrices
READ S1 / ROWS=4 COLS=1
1
0
0
0
READ S2 / ROWS=4 COLS=1
0
1
0
0
READ S3 / ROWS=4 COLS=1
0
0
1
```

```
0
READ S4 / ROWS=4 COLS=1
0
0
0
1

* Generate intercept
DIM INT 200
GENR INT=1
DIM INT50 188
GENR INT50=1

* Create real stock returns
GENR SPR=SP/CPI

* Take logs of series
SAMPLE 1 200
GENR SP=LOG(SP)
GENR LT=LOG(LT)
GENR SPR=LOG(SPR)
GENR IP=LOG(IP)
GENR MB=LOG(MB)

* Select variables for VAR
VARS: SPR IP LT MB

* Read cointegrating vectors into individual arrays
SAMPLE 1 4
READ A1_0 / ROWS=4 COLS=1
 -1.0000
  3.8142
  0.37052
 -0.69663
READ A2_0 / ROWS=4 COLS=1
 -1.0000
  4.5725
 -1.6086
 -1.4667
READ A3_0 / ROWS=4 COLS=1
 -1.0000
  1.7323
 -1.7042
 0.21797
READ A4_0 / ROWS=4 COLS=1
 -1.0000
 -2.2636
  2.0754
 -0.022407

* Take logs of the data matrix IF NOT DONE ABOVE
SAMPLE 1 200
COPY [VARS] Y / TROW=1,200
MATRIX LOGY=Y

* Generate first difference of data matrix
SAMPLE 1 200
MATRIX DY=LOGY-LAG(LOGY)
* Set first period differences equal to zero
MATRIX DY(1,1)=0
MATRIX DY(1,2)=0
MATRIX DY(1,3)=0
MATRIX DY(1,4)=0

* Generate lagged LEVEL variables
MATRIX LY1=LAG(LOGY,1)
MATRIX LY2=LAG(LOGY,2)
```

```
MATRIX LY3=LAG(LOGY,3)
MATRIX LY4=LAG(LOGY,4)

* Generate N lagged DIFFERENCE variables
MATRIX DY1=LAG(DY,1)
MATRIX DY2=LAG(DY,2)
MATRIX DY3=LAG(DY,3)
MATRIX DY4=LAG(DY,4)
MATRIX DY5=LAG(DY,5)
MATRIX DY6=LAG(DY,6)
MATRIX DY7=LAG(DY,7)
MATRIX DY8=LAG(DY,8)

*********************************************************************
* Normalize the estimated cointegrating vectors using Johansen method
*********************************************************************
* Create matrix of lagged differences
MATRIX DY14=(DY1|DY2|DY3|DY4|DY5|DY6|DY7|DY8)

* Compute covariance matrix for normalizing cointegrating vectors
DIM LY150 188 4
COPY LY1 LY150 / FROW=13;200 TROW=1;188 FCOL=1;4 TCOL=1;4
*DIM DY1450 188 16
*COPY DY14 DY1450 / FROW=13;200 TROW=1;188 FCOL=1;16 TCOL=1;16
DIM DY1450 188 32
COPY DY14 DY1450 / FROW=13;200 TROW=1;188 FCOL=1;32 TCOL=1;32

MATRIX R2B=LY150'*DY1450*INV(DY1450'*DY1450)
MATRIX SIGMA_R2=((LY150'*LY150)-(LY150'*DY1450*INV(DY1450'*DY1450)*DY1450'*LY150))/188

* Compute normalized cointegrating vectors
MATRIX A1=A1_0/(SQRT(A1_0'*SIGMA_R2*A1_0))
MATRIX A2=A2_0/(SQRT(A2_0'*SIGMA_R2*A2_0))
MATRIX A3=A3_0/(SQRT(A3_0'*SIGMA_R2*A3_0))
MATRIX A4=A4_0/(SQRT(A4_0'*SIGMA_R2*A4_0))

*************************************************************
* Create data matrices for Diagnostics & Toda/Phillips method
*************************************************************
* Create AHat matrices
MATRIX AHAT=(A1|A2)
MATRIX AHAT1=(A3|A4)

* CREATE ERROR CORRECTION TERM
MATRIX ECT=(AHAT'*LY1')'
*PRINT ECT

* CREATE NON COINTEGRATING VECTOR TERMS
MATRIX Z2HAT=(AHAT1'*LY1')'

* Create matrix of ind. vars for ECM
MATRIX Z1HAT=(INT|DY1|DY2|DY3|DY4|DY5|DY6|ECT)
*MATRIX Z1HAT=(INT|DY1|DY2|DY3|DY4|DY5|DY6|DY7|DY8|ECT)

* Allocate WORK arrays for 1950Q1 to 1996Q4 estimation (188 obs.)
DIM DY50 188 4
COPY DY DY50 / FROW=13;200 TROW=1;188 FCOL=1;4 TCOL=1;4

DIM Z1HAT50 188 27
COPY Z1HAT Z1HAT50 / FROW=13;200 TROW=1;188 FCOL=1;27 TCOL=1;27
*DIM Z1HAT50 188 35
*COPY Z1HAT Z1HAT50 / FROW=13;200 TROW=1;188 FCOL=1;35 TCOL=1;35

DIM Z2HAT50 188 2
COPY Z2HAT Z2HAT50 / FROW=13;200 TROW=1;188 FCOL=1;2 TCOL=1;2

************************
```

```
* ECM Diagnostic Testing
************************
MATRIX Z1HATA=(INT|DY1|DY2|DY3|DY4|DY5|DY6|DY7|DY8|ECT)
*DIM Z1HATA50 188 34
*COPY Z1HATA Z1HATA50 / FROW=13;200 TROW=1;188 FCOL=1;34 TCOL=1;34
DIM Z1HATA50 188 35
COPY Z1HATA Z1HATA50 / FROW=13;200 TROW=1;188 FCOL=1;35 TCOL=1;35

* Select individual vars for diagnostics
DO #=1,4
MATRIX VY#=DY50(0,#)
ENDO
DO #=1,35
MATRIX X#=Z1HATA50(0,#)
ENDO

* Find optimum length lag (1-8 qtrs) for ECM
SAMPLE 1 188
OLS VY1 X2 X3 X4 X5 X34 X35 / RESID=R11
OLS VY2 X2 X3 X4 X5 X34 X35 / RESID=R12
OLS VY3 X2 X3 X4 X5 X34 X35 / RESID=R13
OLS VY4 X2 X3 X4 X5 X34 X35 / RESID=R14
OLS VY1 X2 X3 X4 X5 X6 X7 X8 X9 X34 X35 / RESID=R21
OLS VY2 X2 X3 X4 X5 X6 X7 X8 X9 X34 X35 / RESID=R22
OLS VY3 X2 X3 X4 X5 X6 X7 X8 X9 X34 X35 / RESID=R23
OLS VY4 X2 X3 X4 X5 X6 X7 X8 X9 X34 X35 / RESID=R24
OLS VY1 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X34 X35 / RESID=R31
OLS VY2 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X34 X35 / RESID=R32
OLS VY3 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X34 X35 / RESID=R33
OLS VY4 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X34 X35 / RESID=R34
OLS VY1 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X34 X35 / RESID=R41 LM
OLS VY2 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X34 X35 / RESID=R42 LM
OLS VY3 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X34 X35 / RESID=R43 LM
OLS VY4 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X34 X35 / RESID=R44 LM
=OLS VY1 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X34 X35 /
RESID=R51
=OLS VY2 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X34 X35 /
RESID=R52
=OLS VY3 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X34 X35 /
RESID=R53
=OLS VY4 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X34 X35 /
RESID=R54
SET OUTPUT
=OLS VY1 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X34 X35 / RESID=R61 LM
DIAGNOS / HET ACF RESET
=OLS VY2 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X34 X35 / RESID=R62 LM
DIAGNOS / HET ACF RESET
=OLS VY3 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X34 X35 / RESID=R63 LM
DIAGNOS / HET ACF RESET
=OLS VY4 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X34 X35 / RESID=R64 LM
DIAGNOS / HET ACF RESET
SET NOOUTPUT
=OLS VY1 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X26 X27 X28 X29 X34 X35 / RESID=R71
=OLS VY2 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X26 X27 X28 X29 X34 X35 / RESID=R72
=OLS VY3 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X26 X27 X28 X29 X34 X35 / RESID=R73
=OLS VY4 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X26 X27 X28 X29 X34 X35 / RESID=R74
=OLS VY1 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X26 X27 X28 X29 X30 X31 X32 X33 X34 X35 / RESID=R81 LM
```

```
=OLS VY2 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X26 X27 X28 X29 X30 X31 X32 X33 X34 X35 / RESID=R82 LM
=OLS VY3 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X26 X27 X28 X29 X30 X31 X32 X33 X34 X35 / RESID=R83 LM
=OLS VY4 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X26 X27 X28 X29 X30 X31 X32 X33 X34 X35 / RESID=R84 LM

* Recapture memory
DELETE Z1HATA Z1HATA50 VY1 VY2 VY3 VY4 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16
X17 X18 X19 X20 X21 X22 X23 X24 X25 X26 X27 X28 X29 X30 X31 X32 X33 X34 X35 DY1 DY2 DY3
DY4 DY DY6 DY7 DY8
COMPRESS

* Create cov matrices for AIC and SC calculations
DO #=1,8
 DIM COV# 4 4
ENDO
DO #=1,4
 DO %=1,4
  MATRIX COV1(#,%)=(R1#'*R1%)/188
  MATRIX COV2(#,%)=(R2#'*R2%)/188
  MATRIX COV3(#,%)=(R3#'*R3%)/188
  MATRIX COV4(#,%)=(R4#'*R4%)/188
  MATRIX COV5(#,%)=(R5#'*R5%)/188
  MATRIX COV6(#,%)=(R6#'*R6%)/188
  MATRIX COV7(#,%)=(R7#'*R7%)/188
  MATRIX COV8(#,%)=(R8#'*R8%)/188
 ENDO
ENDO

DIM AIC 8
DIM SC 8

* Print AIC and SC Model Fit Test Results
DO #=1,8
 MATRIX AIC(#)=LOG(DET(COV#))+(2*4*4*#/188)
 MATRIX SC(#)=LOG(DET(COV#))+(((4*4*#)*LOG(188))/188)
ENDO

****************************
* Estimate Toda/Phillips ECM
****************************
SAMPLE 1 200
MATRIX J_GAMMA=DY50'*Z1HAT50*INV(Z1HAT50'*Z1HAT50)
MATRIX SIGMA_U=((DY50'*DY50)-(DY50'*Z1HAT50*INV(Z1HAT50'*Z1HAT50)*Z1HAT50'*DY50))/188

*MATRIX GAMMA=J_GAMMA(0,18)
DIM GAMMA 4 2
COPY J_GAMMA GAMMA / FROW=1;4 TROW=1;4 FCOL=26;27 TCOL=1;2
*COPY J_GAMMA GAMMA / FROW=1;4 TROW=1;4 FCOL=34;35 TCOL=1;2

MATRIX OMEGA_C=INV(GAMMA'*INV(SIGMA_U)*GAMMA)

MATRIX Z1Z1=INV(Z1HAT50'*Z1HAT50)
MATRIX Z2Z2=INV(Z2HAT50'*Z2HAT50)
MATRIX AHAT1_4=AHAT1(4,0)
MATRIX AHAT4=AHAT(4,0)
MATRIX GAMMA1=GAMMA(1,0)

DIM PSTAR 7 112
*DIM PSTAR 9 144

MATRIX I6=IDEN(6)
MATRIX PSTARU=I6@S4'@S1'
*MATRIX I8=IDEN(8)
*MATRIX PSTARU=I8@S4'@S1'
MATRIX PSTARL1=AHAT4@S1'
```

```
MATRIX PSTARL2=AHAT1_4@GAMMA1

COPY PSTARU PSTAR / FROW=1;6 TROW=1;6 FCOL=1;96 TCOL=5;100
COPY PSTARL1 PSTAR / FROW=1;1 TROW=7;7 FCOL=1;8 TCOL=101;108
COPY PSTARL2 PSTAR / FROW=1;1 TROW=7;7 FCOL=1;4 TCOL=109;112
*COPY PSTARU PSTAR / FROW=1;8 TROW=1;8 FCOL=1;128 TCOL=5;132
*COPY PSTARL1 PSTAR / FROW=1;1 TROW=9;9 FCOL=1;8 TCOL=133;140
*COPY PSTARL2 PSTAR / FROW=1;1 TROW=9;9 FCOL=1;4 TCOL=141;144
*PRINT PSTARL2 PSTAR

DIM OMEGA_S 112 112
*DIM OMEGA_S 144 144

MATRIX OMEGA_SU=(Z1Z1)@SIGMA_U
MATRIX OMEGA_SL=(Z2Z2)@OMEGA_C
COPY OMEGA_SU OMEGA_S / FROW=1;108 TROW=1;108 FCOL=1;108 TCOL=1;108
COPY OMEGA_SL OMEGA_S / FROW=1;4 TROW=109;112 FCOL=1;4 TCOL=109;112
*COPY OMEGA_SU OMEGA_S / FROW=1;140 TROW=1;140 FCOL=1;140 TCOL=1;140
*COPY OMEGA_SL OMEGA_S / FROW=1;4 TROW=141;144 FCOL=1;4 TCOL=141;144

*MATRIX SIGMA_TA=Z1Z1(18,18)
DIM SIGMA_TA 2 2
COPY Z1Z1 SIGMA_TA / FROW=26;27 TROW=1;2 FCOL=26;27 TCOL=1;2
*COPY Z1Z1 SIGMA_TA / FROW=34;35 TROW=1;2 FCOL=34;35 TCOL=1;2

DIM PSI 7 1
*DIM PSI 9 1

MATRIX PSI(1,1)=J_GAMMA(1,5)
MATRIX PSI(2,1)=J_GAMMA(1,9)
MATRIX PSI(3,1)=J_GAMMA(1,13)
MATRIX PSI(4,1)=J_GAMMA(1,17)
MATRIX PSI(5,1)=J_GAMMA(1,21)
MATRIX PSI(6,1)=J_GAMMA(1,25)
*MATRIX PSI(7,1)=J_GAMMA(1,29)
*MATRIX PSI(8,1)=J_GAMMA(1,33)

MATRIX PSI(7,1)=GAMMA1*AHAT4'
*MATRIX PSI(9,1)=GAMMA1*AHAT4'

DIM SIGMAt 24 24
COPY Z1Z1 SIGMAt / FROW=2;25 TROW=1;24 FCOL=2;25 TCOL=1;24
*DIM SIGMAt 32 32
*COPY Z1Z1 SIGMAt / FROW=2;33 TROW=1;32 FCOL=2;33 TCOL=1;32

DIM PHI 6 1
*DIM PHI 8 1
MATRIX PHI(1,1)=J_GAMMA(1,5)
MATRIX PHI(2,1)=J_GAMMA(1,9)
MATRIX PHI(3,1)=J_GAMMA(1,13)
MATRIX PHI(4,1)=J_GAMMA(1,17)
MATRIX PHI(5,1)=J_GAMMA(1,21)
MATRIX PHI(6,1)=J_GAMMA(1,25)
*MATRIX PHI(7,1)=J_GAMMA(1,29)
*MATRIX PHI(8,1)=J_GAMMA(1,33)

*****************
* Causality Tests
*****************
MATRIX FSTAR1=GAMMA1*INV((S1'*SIGMA_U*S1)@SIGMA_TA)*GAMMA1'
MATRIX FSTAR3=AHAT4*INV((AHAT1_4*Z2Z2*AHAT1_4')@OMEGA_C)*AHAT4'
MATRIX FSTAR=PSI'*INV(PSTAR*OMEGA_S*PSTAR')*PSI
MATRIX FSTARt=PHI'*INV((S1'*SIGMA_U*S1)@((I6@S4')*SIGMAt*(I6@S4)))*PHI
*MATRIX FSTARt=PHI'*INV((S1'*SIGMA_U*S1)@((I8@S4')*SIGMAt*(I8@S4)))*PHI
MATRIX
FSTAR13=(GAMMA1*AHAT4')*INV(S1'*SIGMA_U*S1@AHAT4*SIGMA_TA*AHAT4'+GAMMA1*OMEGA_C*GAMMA1'@AH
AT1_4*Z2Z2*AHAT1_4')*(GAMMA1*AHAT4')
```

```
=SET OUTPUT
=PRINT AIC SC
=PRINT A1 A2 A3 A4 J_GAMMA GAMMA SIGMA_U OMEGA_C AHAT1_4 AHAT4 GAMMA1 SIGMA_TA PSI PHI
=PRINT VARS
=PRINT FSTAR1 FSTAR3 FSTAR FSTARt FSTAR13
=STOP
```

Saikkonen and Lütkepohl Method

The following SHAZAM program tests short-run Granger-causality within a 4-variable VECM with lag lengths of either 6 or 8 and with two significant cointegrating vectors. Refer to Saikkonen and Lütkepohl (1996) for additional details concerning the procedure.

```
SAMPLE 1 200
TIME 1947 4
SAMPLE 1947.1 1996.4
READ REC MO YR  SP     ST     LT     IP      CPI     MB     EI
   1    1 47  15.17  0.38  2.19  21.732  21.9  33.169  0.00
   2    2 47  15.21  0.38  2.22  21.353  22.0  33.257  0.00
   3    3 47  15.11  0.80  2.24  22.195  23.0  33.967  0.00
   4    4 47  15.30  0.95  2.39  22.237  23.4  34.410  0.00
   5    1 48  15.08  1.00  2.44  22.279  23.4  33.169  0.00
   6    2 48  16.74  1.00  2.41  22.659  24.1  32.903  6.82
   7    3 48  15.49  1.09  2.45  23.290  24.5  32.282  0.45
   8    4 48  15.20  1.16  2.44  22.279  24.1  33.701 -1.60
   9    1 49  15.06  1.17  2.38  21.648  23.8  32.637  0.45
  10    2 49  14.16  1.17  2.38  20.848  23.9  33.257 -2.75
   .
   .
   .
 199    3 96 687.31  5.09  7.13 119.073 157.8 458.606  2.49
 200    4 96 740.74  4.91  6.63 115.257 158.6 471.530  2.85

DELETE REC MO YR ST EI

SET NOECHO
SET NOOUTPUT

* Create real stock returns
GENR SPR=SP/CPI

* Generate intercept
DIM INT 200
GENR INT=1
DIM INT50 188
GENR INT50=1

* Take logs of series
SAMPLE 2 200
GENR INF=(LOG(CPI)-LOG(LAG(CPI)))*400
SAMPLE 1 200
GENR SP=LOG(SP)
GENR LT=LOG(LT)
GENR SPR=LOG(SPR)
GENR IP=LOG(IP)
GENR MB=LOG(MB)

* Select variables for VAR
VAR:    MB IP LT SPR
Y1VAR: MB
Y2VAR: IP LT SPR

SAMPLE 1 200
COPY [VAR] Y / TROW=1,200
COPY [Y1VAR] Y1 / TROW=1,200
COPY [Y2VAR] Y2 / TROW=1,200
```

```
* Take logs of the data IF NEEDED
MATRIX LOGY=Y
MATRIX LOGY1=Y1
MATRIX LOGY2=Y2

* Generate first differences
SAMPLE 1 200
MATRIX DY=LOGY-LAG(LOGY)
  * Set first period differences equal to zero
MATRIX DY(1,1)=0
MATRIX DY(1,2)=0
MATRIX DY(1,3)=0
MATRIX DY(1,4)=0

* Generate NLAG-period lagged DIFFERENCE variables
SET NOWARN
MATRIX DY1=LAG(DY,1)
MATRIX DY2=LAG(DY,2)
MATRIX DY3=LAG(DY,3)
MATRIX DY4=LAG(DY,4)
MATRIX DY5=LAG(DY,5)
MATRIX DY6=LAG(DY,6)
MATRIX DY7=LAG(DY,7)
MATRIX DY8=LAG(DY,8)

* Generate 1-period lagged levels variables
MATRIX LY=LAG(LOGY,1)
MATRIX LY1=LAG(LOGY1,1)
MATRIX LY2=LAG(LOGY2,1)

* Create matrix of ind variables for VAR
MATRIX Z1HAT=(INT|LY|DY1|DY2|DY3|DY4|DY5|DY6)
DIM Z1HAT50 188 29
COPY Z1HAT Z1HAT50 / FROW=13;200 TROW=1;188 FCOL=1;29 TCOL=1;29
*MATRIX Z1HAT=(INT|LY|DY1|DY2|DY3|DY4|DY5|DY6|DY7|DY8)
*DIM Z1HAT50 188 37
*COPY Z1HAT Z1HAT50 / FROW=13;200 TROW=1;188 FCOL=1;37 TCOL=1;37

* Create matrix of dep variables for VAR
DIM DY50 188 4
COPY DY DY50 / FROW=13;200 TROW=1;188 FCOL=1;4 TCOL=1;4

************************
* ECM Diagnostic Testing
************************
MATRIX Z1HATA=(INT|DY1|DY2|DY3|DY4|DY5|DY6|DY7|DY8|LY)
DIM Z1HATA50 188 37
COPY Z1HATA Z1HATA50 / FROW=13;200 TROW=1;188 FCOL=1;37 TCOL=1;37

SET NODOECHO

* Select individual vars for diagnostics
DO #=1,4
MATRIX VY#=DY50(0,#)
ENDO
DO #=1,37
MATRIX X#=Z1HATA50(0,#)
ENDO

* Find optimum length lag (1-8 qtrs) for ECM
SET NOOUTPUT
SAMPLE 1 188
?OLS VY1 X2 X3 X4 X5 X34 X35 X36 X37 / RESID=R11
?OLS VY2 X2 X3 X4 X5 X34 X35 X36 X37 / RESID=R12
?OLS VY3 X2 X3 X4 X5 X34 X35 X36 X37 / RESID=R13
?OLS VY4 X2 X3 X4 X5 X34 X35 X36 X37 / RESID=R14
```

```
?OLS VY1 X2 X3 X4 X5 X6 X7 X8 X9 X34 X35 X36 X37 / RESID=R21
?OLS VY2 X2 X3 X4 X5 X6 X7 X8 X9 X34 X35 X36 X37 / RESID=R22
?OLS VY3 X2 X3 X4 X5 X6 X7 X8 X9 X34 X35 X36 X37 / RESID=R23
?OLS VY4 X2 X3 X4 X5 X6 X7 X8 X9 X34 X35 X36 X37 / RESID=R24
?OLS VY1 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X34 X35 X36 X37 / RESID=R31
?OLS VY2 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X34 X35 X36 X37 / RESID=R32
?OLS VY3 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X34 X35 X36 X37 / RESID=R33
?OLS VY4 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X34 X35 X36 X37 / RESID=R34
OLS VY1 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X34 X35 X36 X37 /
RESID=R41 LM
OLS VY2 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X34 X35 X36 X37 /
RESID=R42 LM
OLS VY3 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X34 X35 X36 X37 /
RESID=R43 LM
OLS VY4 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X34 X35 X36 X37 /
RESID=R44 LM
?OLS VY1 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X34 X35 X36
X37 / RESID=R51
?OLS VY2 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X34 X35 X36
X37 / RESID=R52
?OLS VY3 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X34 X35 X36
X37 / RESID=R53
?OLS VY4 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X34 X35 X36
X37 / RESID=R54
SET OUTPUT
OLS VY1 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X34 X35 X36 X37 / RESID=R61 LM
DIAGNOS / HET ACF RESET
OLS VY2 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X34 X35 X36 X37 / RESID=R62 LM
DIAGNOS / HET ACF RESET
OLS VY3 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X34 X35 X36 X37 / RESID=R63 LM
DIAGNOS / HET ACF RESET
OLS VY4 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X34 X35 X36 X37 / RESID=R64 LM
DIAGNOS / HET ACF RESET
SET NOOUTPUT
?OLS VY1 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X26 X27 X28 X29 X34 X35 X36 X37 / RESID=R71
?OLS VY2 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X26 X27 X28 X29 X34 X35 X36 X37 / RESID=R72
?OLS VY3 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X26 X27 X28 X29 X34 X35 X36 X37 / RESID=R73
?OLS VY4 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X26 X27 X28 X29 X34 X35 X36 X37 / RESID=R74
OLS VY1 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X26 X27 X28 X29 X30 X31 X32 X33 X34 X35 X36 X37 / RESID=R81 LM
OLS VY2 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X26 X27 X28 X29 X30 X31 X32 X33 X34 X35 X36 X37 / RESID=R82 LM
OLS VY3 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X26 X27 X28 X29 X30 X31 X32 X33 X34 X35 X36 X37 / RESID=R83 LM
OLS VY4 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16 X17 X18 X19 X20 X21 X22 X23
X24 X25 X26 X27 X28 X29 X30 X31 X32 X33 X34 X35 X36 X37 / RESID=R84 LM

* Recapture memory
DELETE Z1HATA Z1HATA50 VY1 VY2 VY3 VY4 X2 X3 X4 X5 X6 X7 X8 X9 X10 X11 X12 X13 X14 X15 X16
X17 X18 X19 X20 X21 X22 X23 X24 X25 X26 X27 X28 X29 X30 X31 X32 X33 X34 X35 X36 X37
COMPRESS

* Create cov matrices for AIC and SC calculations
*SET OUTPUT
DO #=1,8
 DIM COV# 4 4
ENDO
DO #=1,4
DO %=1,4
```

```
  MATRIX COV1(#,%)=(R1#'*R1%)/188
  MATRIX COV2(#,%)=(R2#'*R2%)/188
  MATRIX COV3(#,%)=(R3#'*R3%)/188
  MATRIX COV4(#,%)=(R4#'*R4%)/188
  MATRIX COV5(#,%)=(R5#'*R5%)/188
  MATRIX COV6(#,%)=(R6#'*R6%)/188
  MATRIX COV7(#,%)=(R7#'*R7%)/188
  MATRIX COV8(#,%)=(R8#'*R8%)/188
 ENDO
ENDO
DIM AIC 8
DIM SC 8

* Print AIC and SC Model Fit Test Results
DO #=1,8
 MATRIX AIC(#)=LOG(DET(COV#))+(2*4*4*#/188)
 MATRIX SC(#)=LOG(DET(COV#))+(((4*4*#)*LOG(188))/188)
ENDO

=PRINT AIC SC

**********************************
* Estimate Saikkonen/Lutkepohl ECM
**********************************
* OLS ESTIMATION OF PSI_PI MATRIX (4x21)
MATRIX PSI_PI=DY50'*Z1HAT50*INV(Z1HAT50'*Z1HAT50)

* COMPUTE COVARIANCE MATRIX SIGMA_E(2 METHODS) (4x4)
MATRIX SIGMA_E=((DY50'*DY50)-(DY50'*Z1HAT50*INV(Z1HAT50'*Z1HAT50)*Z1HAT50'*DY50))/183

* SELECT B MATRIX
DIM B 4 1
COPY PSI_PI B / FROW=1;4 TROW=1;4 FCOL=2;2 TCOL=1;1

* SELECT PSI2 MATRIX
DIM PSI2 4 3
COPY PSI_PI PSI2 / FROW=1;4 TROW=1;4 FCOL=3;5 TCOL=1;3

* SELECT BPI MATRIX
DIM BPI 4 25
*DIM BPI 4 33
COPY PSI_PI BPI / FROW=1;4 TROW=1;4 FCOL=2;2 TCOL=1;1
COPY PSI_PI BPI / FROW=1;4 TROW=1;4 FCOL=6;29 TCOL=2;25
*COPY PSI_PI BPI / FROW=1;4 TROW=1;4 FCOL=6;37 TCOL=2;33

* COMPUTE C1 MATRIX
MATRIX C1=-(INV(B'*INV(SIGMA_E)*B)*B'*INV(SIGMA_E)*PSI2)

* COMPUTE GAMMAECM USING 4.2
MATRIX X=(INT|LY1|DY1|DY2|DY3|DY4|DY5|DY6)
*MATRIX X=(INT|LY1|DY1|DY2|DY3|DY4|DY5|DY6|DY7|DY8)
DIM X50 188 26
COPY X X50 / FROW=13;200 TROW=1;188 FCOL=1;26 TCOL=1;26
*DIM X50 188 34
*COPY X X50 / FROW=13;200 TROW=1;188 FCOL=1;34 TCOL=1;34

MATRIX LY2A=LY2
DIM Y250 188 3
COPY LY2A Y250 / FROW=13;200 TROW=1;188 FCOL=1;3 TCOL=1;3
MATRIX GECM=(X50'*X50-X50'*Y250*INV(Y250'*Y250)*Y250'*X50)/183
MATRIX IGECM=INV(GECM)
DIM GECMINT 25 25
COPY IGECM GECMINT / FROW=2;19 TROW=1;18 FCOL=2;26 TCOL=1;25
*DIM GECMINT 33 33
*COPY IGECM GECMINT / FROW=2;19 TROW=1;18 FCOL=2;34 TCOL=1;33

* COMPUTE GAMMAECM USING 4.3
```

```
DIM Y150 188 1
COPY LY1 Y150 / FROW=13;200 TROW=1;188 FCOL=1;1 TCOL=1;1
MATRIX U1=Y150'-C1*Y250'
MATRIX DYALL=(DY1|DY2|DY3|DY4|DY5|DY6)
*MATRIX DYALL=(DY1|DY2|DY3|DY4|DY5|DY6|DY7|DY8)
DIM DYALL50 188 24
COPY DYALL DYALL50 / FROW=13;200 TROW=1;188 FCOL=1;24 TCOL=1;24
*DIM DYALL50 188 32
*COPY DYALL DYALL50 / FROW=13;200 TROW=1;188 FCOL=1;32 TCOL=1;32

MATRIX UDY=(INT50|U1'|DYALL50)
MATRIX GECM1=(UDY'UDY)/183
MATRIX IGECM1=INV(GECM1)
DIM GECM1INT 25 25
COPY IGECM1 GECM1INT / FROW=2;26 TROW=1;25 FCOL=2;26 TCOL=1;25
*DIM GECM1INT 33 33
*COPY IGECM1 GECM1INT / FROW=2;34 TROW=1;33 FCOL=2;34 TCOL=1;33

MATRIX VECBPI=VEC(BPI)

DIM BIGR 100 1
*DIM BIGR 132 1

DIM LAMBDA 4

MATRIX BIGR(5,1)=1
MATRIX BIGR(21,1)=1
MATRIX BIGR(37,1)=1
MATRIX BIGR(53,1)=1
MATRIX BIGR(69,1)=1
MATRIX BIGR(85,1)=1
*MATRIX BIGR(101,1)=1
*MATRIX BIGR(117,1)=1

MATRIX LAMBDA(1)=183*VECBPI'*BIGR*INV(BIGR'*(GECM1INT@SIGMA_E)*BIGR)*BIGR'*VECBPI

* INITIALIZE BIGR MATRIX TO ZEROS
*SET NODOECHO
DO # = 1,100
  MATRIX BIGR(#,1)=0
ENDO

MATRIX BIGR(9,1)=1
MATRIX BIGR(25,1)=1
MATRIX BIGR(41,1)=1
MATRIX BIGR(57,1)=1
MATRIX BIGR(73,1)=1
MATRIX BIGR(89,1)=1
*MATRIX BIGR(105,1)=1
*MATRIX BIGR(121,1)=1

MATRIX LAMBDA(2)=183*VECBPI'*BIGR*INV(BIGR'*(GECM1INT@SIGMA_E)*BIGR)*BIGR'*VECBPI

* INITIALIZE BIGR MATRIX TO ZEROS
DO # = 1,100
  MATRIX BIGR(#,1)=0
ENDO

MATRIX BIGR(13,1)=1
MATRIX BIGR(29,1)=1
MATRIX BIGR(45,1)=1
MATRIX BIGR(61,1)=1
MATRIX BIGR(77,1)=1
MATRIX BIGR(93,1)=1
*MATRIX BIGR(109,1)=1
*MATRIX BIGR(125,1)=1
```

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MATRIX LAMBDA(3)=183*VECBPI'*BIGR*INV(BIGR'*(GECM1INT@SIGMA_E)*BIGR)*BIGR'*VECBPI

* INITIALIZE BIGR MATRIX TO ZEROS
DO # = 1,100
  MATRIX BIGR(#,1)=0
ENDO

MATRIX BIGR(17,1)=1
MATRIX BIGR(33,1)=1
MATRIX BIGR(49,1)=1
MATRIX BIGR(65,1)=1
MATRIX BIGR(81,1)=1
MATRIX BIGR(97,1)=1
*MATRIX BIGR(113,1)=1
*MATRIX BIGR(129,1)=1

MATRIX LAMBDA(4)=183*VECBPI'*BIGR*INV(BIGR'*(GECM1INT@SIGMA_E)*BIGR)*BIGR'*VECBPI

SET ECHO

=PRINT PSI_PI
=PRINT SIGMA_E
=PRINT B
=PRINT PSI2
=PRINT BPI
=PRINT C1
=PRINT VECBPI
=PRINT VAR
=PRINT LAMBDA
=STOP
```

VITA

Mark C. Snead

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Doctor of Philosophy

Thesis: CAUSALITY TESTS OF THE STOCK PRICE-INFLATION RELATION

Major Field: Economics

Biographical:

Education: Graduated from Morrow High School, Morrow, Georgia in May 1982; received Bachelor of Business Administration degree in Economics from the University of Georgia in May 1986 and a Master of Science degree in Economics and Finance from the Georgia Institute of Technology in May 1988. Completed the requirements for the Doctor of Philosophy degree in Economics at Oklahoma State University in July 1998.

Experience: Graduate Teaching Assistant, Georgia Institute of Technology, September 1986 to June 1988; Investment Broker, July 1988 to August 1991; Graduate Teaching Associate, Oklahoma State University, Economics Department, August 1991 to May 1995; Adjunct Instructor of Economics, University of Central Oklahoma, August 1994 to May 1995; Assistant Professor of Economics, Phillips Unversity, Enid, Oklahoma, August 1995 to present.