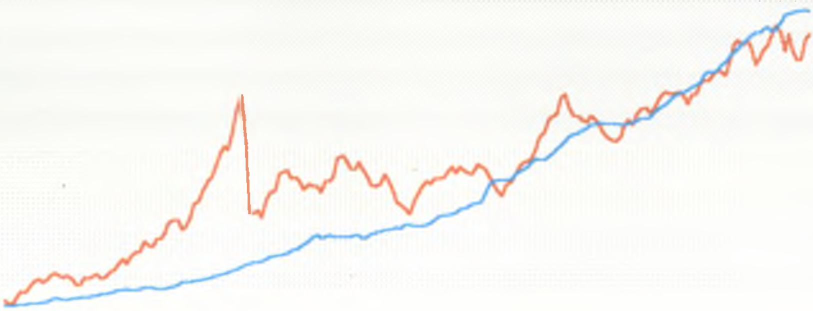
University of Macedonia
Department of Economics
Postgraduate Program in Economic Science

MA Dissertation

Does Monetary Policy Affect Stock Prices?

An Empirical Analysis For Five Countries



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1. Introduction

The relation of money to stock prices has been a subject of academic research for many years. This research was based especially on two competing hypotheses regarding the effect of money on stock prices. One hypothesis, referred to as the *Monetary Portfolio Hypothesis* suggests that changes in the money supply result in changes in the equilibrium position of money with respect to other assets in the portfolio of investors. As a result, investors adjust the proportion of the asset portfolios represented by money balances, but since the system cannot adjust because all money balances must be held, a new equilibrium is established by changes in the prices of their various assets.

The alternative to the monetary portfolio hypothesis is the *Efficient Market Hypothesis*. This hypothesis suggests that competition among profit-maximizing investors in an efficient market will ensure that all the relevant information currently known about changes in the money supply is fully reflected in current stock prices, so that investors will not be able to develop profitable trading rules with this information. The efficient market hypothesis implies that stock prices are serially random, meaning that they follow a random walk.

Apparently, there is a conflict between the monetary portfolio and efficient market hypotheses, although the majority of the more recent studies are in favor of the efficient market hypothesis. The money-stock prices dynamics is examined here with an econometric methodology that combines long-run trend relationships to short-run dynamic adjustments. In particular, cointegration theory which allows an analysis of the long-run steady-state properties, together with short-run dynamics within one framework, is used for the case of five countries (USA, Australia, France, Italy, Switzerland), which differ among them regarding the size of their economies and their stock exchange markets, respectively.

The paper is organized as follows. In section 2, an analytical and detailed description of the two conflicting hypotheses is presented. In section 3, the most fundamental studies of the relation between money and stock prices are described. Section 4, analyses an intertemporal asset pricing model with money, which examines the response of equilibrium stock prices to money supply changes. Section 5, discusses the econometric methodology that will be followed. Section 6, develops the empirical analysis of the model. Finally, section 7 provides the conclusions of the paper.

2. The Two Alternate Hypotheses

The monetary portfolio hypothesis was developed by Brunner (1961), Friedman (1961), Friedman and Schwartz (1963), and Tobin (1963) among other economists. In this model, an investor reaches an equilibrium position in which, in general, holds a number of assets including money in his portfolio of assets. A monetary disturbance such as an unexpected increase (or decrease) in the growth rate of the money supply causes disequilibrium in asset portfolios by making actual money balances depart from desired money balances. The attempt by investors as a group to attain their desired money positions then transmits the monetary change to markets at large. Investors respond to that wealth effect of increased money growth by exchanging money for a variety of assets in asset markets: short- and long-term bonds, stocks, real estate, durable goods, capital goods, and human capital. The time response of investors has been viewed as sufficiently delayed, that asset prices respond to the monetary disturbance with a *lag* usually characterized as long and positive, on average.

Empirical studies of the monetary portfolio hypothesis, including those by Keran (1971), Homa and Jaffee (1971), Hamburger and Kochin (1972), Malkiel and Quandt (1972), Asprem (1981) and Apergis (1997), confirmed a strong linkage between money supply and stock prices. More particularly, these studies have concluded that changes in monetary variables do result in stock price changes. This empirical work has nurtured the widespread view that monetary policy has a lagged effect on the stock market and that astute investors can use the lag in trading rules. In general, this body of evidence has also increased the acceptance of the view that monetary policy has a long lagged effect on other markets in the economy as well.

On the other hand, the efficient market hypothesis implies that in an efficient stock market, the lag of stock price change behind monetary change cannot on average be positive and cannot allow the formulation of trading rules which earn excess profits. Competition among profit-maximizing investors in an efficient market will ensure that current and past information is fully reflected in current security prices so that investors will *not* be able to develop profitable trading rules with this information. The time sequence of prices conditioned upon current and past information will consist of competitively determined equilibrium prices which fully reflect available information and leave investors able to earn only normal rates of return, on average. Monetary policy will not have a systematic lagged effect of any economic importance in an efficient market.

Empirical studies on this hypothesis provided by Cooper (1974), Rozeff (1974), Pesando (1974), Auerbach (1976), Kraft and Kraft (1977), Sorensen (1982), Hafer (1986), and Serletis (1993), found evidence supportive to the efficient market hypothesis. Based on these studies we can see that the efficient market hypothesis and the monetary portfolio hypothesis give conflicting answers. In the following two paragraphs we will present the basic models of these two hypotheses as been developed by their supporters.

2.1. The Monetary Portfolio Model

The theoretical model of the monetary portfolio hypothesis can be constructed by two different approaches. The unusual is that both approaches begin from the same baseline, indicating that the dominant factors in stock price formation are the earnings expectations variable and the long-run interest rate. The difference that is developed between them has to do with the different variables that affect the above factors. The first approach that we will describe is formulated by Keran (1971) and the second by Homa and Jaffee (1971).

(i) According to Keran's approach, the price an individual is willing to pay for an equity share is equal to the discount to present value of both expected future dividends and the discount to present value of the expected stock price at the time of sale. In its simplest form, this relationship can be represented by the following equation:[1]

$$SP_t = \frac{D^e{}_{t+1}}{(1+R)} + \frac{D^e{}_{t+2}}{(1+R)^2} + \ldots + \frac{D^e{}_{t+n}}{(1+R)^n} + \left[\frac{SP^e{}_{t+n}}{(1+R)^n}\right] \qquad (1)$$

[1] This formulation asserts that each investor has an explicit time horizon which is equivalent to the date he expects to sell his stock. It is not necessary that the investor actually sell the stock in period t+n. It is possible the actual sale date to change.

where:

SP_t = current price of a share of common stock – as valued by the individual investor

SP^e_{t+n} = expected price of a share of common stock at time of sale

D^e = dividends expected

R = interest rate

The value which an individual will place on equities today will rise if dividends are expected to rise or if the stock price is expected to be higher at the date of sale. The value an individual attaches to equities today will fall if the interest rate increases.

This formulation stands for the case of the individual investor, but when we move to a description of aggregate or average investor behavior, the formulation of the discount to present value theory is somewhat modified. In the case of the individual investor, the price of the stock is given and the investor will either buy or sell, depending upon whether his individual evaluation of expected return (discounted to present value) is greater or less than the market price of the stock. In the case of aggregate investor behavior, it is the current quantity of equities outstanding which is relatively fixed in the short-run and the stock price which must move to clear the market. Therefore, the average discounted evaluation of expected returns (discounted to present value) will determine the price of the stock.

We have seen that for the individual investor investment decisions are made on the basis of an explicit or implicit time horizon, t+n. For average investor behavior, one must assume something approaching an infinite time horizon. Thus, we can rewrite the average investor equation with respect to the stock price as:

$$SP_t = \frac{(D^e + \Delta SP^e)_{t+1}}{(1+R)} + \frac{(D^e + \Delta SP^e)_{t+2}}{(1+R)^2} + \ldots \qquad (2)$$

where:

ΔSP^e_t = expected change in the stock price in each time period

$\Delta SP^e_{t+1} = SP^e_{t+1} - SP^e_t$

$\Delta SP^e_{t+2} = SP^e_{t+2} - SP^e_{t+1}$

A shift in emphasis also occurs when one moves from determination of the stock price for one firm to determination of the average stock price of all firms. In the case of the single firm, the primary factor in investor expectations of increases in the stock price is the relative competence of management in productively employing new capital. In the case of the average stock price of all firms, however, the differential management factor tends to remain constant. In this case is reasonable to postulate that the major factor in expected capital gains is the rate at which retained earnings are plowed back into the firm. If k is defined as the ratio of dividends to earnings (the expected payout ratio), then (1–k) is the expected retained earnings ratio, and the aggregate stock price equation (2) can be re-written as follows:

$$SP_t = \frac{[kE^e + (1-k)E^e]_{t+1}}{(1+R)} + \frac{[kE^e + (1-k)E^e]_{t+2}}{(1+R)^2} + \dots \qquad (3)$$

which simplifies to:

$$= \frac{E^e{}_{t+1}}{(1+R)} + \frac{E^e{}_{t+2}}{(1+R)^2} + \dots \qquad (4)$$

or

$$= \frac{\sum_{i=1}^{\infty} E^e{}_{t+i}}{(1+R)^i} \qquad (3a)$$

where:

E^e = expected future corporate earnings

The description of the stock price theory in equation (3) can't be used to an analysis of actual stock price movements, since the expected corporate earnings variable it is not known. So, we need to determine how earnings expectations are formed. According to this model, expectations are formed through the 'adaptive expectations hypothesis'. This hypothesis asserts that in forming expectations about the future, decision-making units are strongly influenced by current and recent past experience. As time goes on and new facts become available, expectations are adapted to accommodate them. On this basis, we will assert that expected corporate earnings, and through this the stock price, are significantly depended upon the actual level of current and past corporate earnings.

To put the stock price theory into a form which separates the earnings expectations hypothesis from the interest rate effect, it is specified as follows:

$$SP_t = a_0 + [\sum_{i=0}^{1} a_1] R_{t-i} + a_2 E^e_t \qquad a_1 < 0 \text{ and } a_2 > 0 \tag{4}$$

$$E^e_t = [\sum_{i=0}^{n} w_i] E_{t-i} \tag{5}$$

Equation (4) states that the stock price in the current time period (SPt), is a function of interest rates in the current and one lagged time period and current expectations about future corporate earnings (E^e). The one-quarter lag in (R) is designed to capture the possible lag in investor awareness of, and response to, changes in rates.

Equation (5) states that expectations of future corporate earnings after taxes are a weighted sum of current and past corporate earnings after taxes. The value w_i represents the weights applied in forming earnings expectations at various periods in the past and *n* indicates how many periods in the past are relevant in forming earnings expectations.

Substituting equation (5) into equation (4), yields a form of the stock price equation which can be estimated empirically:

$$SP_t = a_0 + [\sum_{i=0}^{1} a_1] R_{t-i} + [\sum_{i=0}^{n} a_2 w_i] E_{t-i} \tag{6}$$

As can be seen, in this equation the money variable is not present directly. This variable influences the stock prices indirectly through the interest rate variable. So, in order to understand how the stock market is affected by the money supply and to get the larger economic picture, we must consider the factors which explain the long-term interest rates and the corporate earnings.

Particularly, the explanation of interest rates can be illustrated with three equations:

$$R_t = r_t + \dot{P}^e_t \tag{7}$$

$$r_t = c_0 + c_1 \dot{m}_t + c_2 [\sum_{i=0}^{n} u_i] \dot{y}_{t-i} \qquad c_1 < 0 \text{ and } c_2 > 0 \tag{8}$$

$$\dot{P}^{e}_{t} = [\sum_{i=0}^{n} z_i]\dot{P}_{t-i} \quad (9)$$

Equation (7) is referred to as the "Fischer equation" and states that the observed market long-term interest rate (R_t) is equal to the real rate of interest (r_t) and the expected rate of change in prices (P^e_t). Equation (8) says that the real rate of interest (r_t) is a function of a short-run liquidity effect (m_t) and a real growth rate component (y_{t-i}). The real growth rate component is measured as a weighted average rate of change in real GNP, where u_i indicates the weights applied to past-time periods. The short-run liquidity effect is measured by the current rate of change in the real money stock (m_t). The real money stock is defined as the nominal money stock (M) divided by the price index (P), meaning:

$$m_t = \frac{M}{P}$$

This liquidity effect results from current investment being temporarily financed from sources other than intended savings, which is possible as a consequence of the creation of new money and is referred to as the "Wicksell effect".

In equation (9) we make use again of the 'adaptive expectations hypothesis' for the case of the expected rate of change in prices (P^e_t), which is a function of past price changes, where z_i is the weight of importance attached to each past time period in the formation of price expectations. Actual price changes are measured by the GNP implicit price deflator.

Substituting equations (8) and (9) into equation (7) yields the form of the interest rate equation, which can be estimated:

$$R_t = c_0 + c_1\dot{m}_t + [\sum_{i=0}^{n} c_2 u_i]\dot{y}_{t-i} + [\sum_{i=0}^{n} z_i]\dot{P}_{t-i} \quad (10)$$

Equation (10) asserts that the interest rate is influenced by three factors. The rate of change of past prices, which should be positively related to interest rates. The real growth of the economy (y) should also be positively related to the interest rate. The liquidity effect (m), on the other hand, is postulated to be negatively related to interest rate.

Now, we said that the second factor that affects stock prices are the corporate earnings (E_t), which can be thought of as the return to risk-taking capital. For the economy as a whole, this factor is explained by, and depended on, the total demand. In the short-run, earnings are sensitive to both changes in total demand and to the level of total demand. The most comprehensive measure of total demand is nominal GNP. In this way, we will assert that the current level of total demand (Y_t), and changes in total demand in the current and past periods ($\Sigma\Delta Y_{t-i}$), have distinct and positive influences on earnings in the current period (E_t).

The other explanatory variable in the corporate earnings equation is the corporate tax rate (tx), which is mainly dependent upon governmental legislation. A rise in the tax rate will lead to a fall in after-tax earnings, and vice versa.

Thus, the corporate after-tax earnings equation is specified in general terms as follows:

$$E_t = b_0 + b_1 tx_t + b_2 Y_t + b_3 \sum_{i=0}^{n} \Delta Y_{t-i} \qquad b_1 < 0,\ b_2 > 0 \ and\ b_3 > 0 \qquad (11)$$

where:

E = corporate earnings after taxes

tx = corporate tax rate

Y = nominal GNP

ΔY = change in nominal GNP

From the above equation, we can define real corporate earnings (e) as the ratio of nominal corporate earnings (E) to price index (P):

$$e = \frac{E}{P}$$

Now, we are in the position to reach a stock price equation, which will contain as an exogenous variable (directly) the money supply by just substituting the equations of the factors interest rate and corporate earnings, namely equations (10) and (11) in its real form, into equation (6). By this way, we will reach a 'semi-reduced form' equation of stock prices, which should be estimated with the following variables:

•Changes in the real money stock (m), because this is an argument in the interest rate equation

•Changes in real growth measured by changes in current and lagged real GNP (y), because this is also an argument in the interest rate equation

•Changes in the expected inflation measured by changes in current and lagged prices (P). This is both an argument in the interest rate equation and an element in the nominal earnings expectations variable through nominal GNP, since Y=Py

•Expected real corporate earnings (e^e) are measured as current and lagged values of real corporate earnings.

By this way, the semi-reduced form equation is as follows:

$$SP_t = a + d_1 \sum_{i=0}^{2} \dot{m}_{t-i} + d_2 \sum_{i=0}^{n} \dot{y}_{t-i} + d_3 \sum_{i=0}^{n} \dot{P}_{t-i} + d_4 \sum_{i=0}^{n} e_{t-i} \qquad (12)$$

We would expect the coefficients associated with the rate of change in the real money stock (m) and level of expected real earnings (e) to be positive, and the coefficient associated with real growth (y) to be negative. The coefficient measuring expectations of inflation (P) could be positive, negative or zero, depending on the dominating impact of price changes in the interest rate equation and the corporate earnings equation, which participate to the stock price equation.

So, by Keran's approach we have reached to equation (12), in which stock prices are explained by the money supply variable, but only partly, and this is because some other explanatory variables are considered as well. Besides that approach to monetary portfolio hypothesis, another one has been developed by Homa and Jaffee (1971), which explains the stock price movements explicitly by the money supply variable.

(ii) As it has already been said, the two approaches depart from the same basis, namely that stock price formation depends on corporate earnings and the interest rate. But in this case, it takes the following form:

$$SP_t = \sum_{t=0}^{\infty} \frac{D_0(1+g_t)^t}{(1+i_t+\rho_t)^t} \qquad (13)$$

where:

SP_t = current price of a share of common stock

D_0 = current level of dividends

g_t = rate of growth of dividends

i_t = riskless rate of interest

ρ_t = risk premium

Models (13) and (3a) differ only in their proxies for the dividend growth rate, the riskless rate of interest, and the risk premium. In Keran's model that we described, the dividend growth rate is proxied by a distributed lag on current and past values of real corporate earnings, while the long-term interest rate is used to measure both the riskless interest rate and the risk premium.

Homa and Jaffee, beginning from equation (13) determined that all the factors in it, influencing stock prices, were related to the money supply variable. More particularly, they have shown that the money supply is positively related to the level (D_0) and growth rate of dividends (g_t), and negatively related to the riskless rate of interest (i_t) and the risk premium (p_t). Consequently, the average level of stock prices will be positively related to the money supply.

The main channel for the influence of the money supply on dividends operates through the firm's current and expected earnings. Given the demand for money, a decrease in the supply of money will raise interest rates and reduce interest rate sensitive expenditures such as capital investment. The decrease in expenditures will then cause a reduction in the firm's sales and thus a decrease in its earnings. The full effect of decreased earning on dividends will be a decrease in dividends. Although the current price of the common stock share will fall if current dividends are reduced, the main point of leverage for the effect of the money supply is on the expected growth rate of dividends, which will also decrease.

The influence of the money supply on the riskless interest rate component of the investor's discount rate is a direct function of the effect of the money supply on market interest rates. The explicit increase in market interest rates caused by increased monetary tightness may, moreover, be reinforced by credit rationing on the loan markets. In this case, monetary tightness will raise the discount rate by an amount greater than would otherwise be indicated by the level of market interest rates alone.

The influence of the money supply on the risk premium component of the investor's discount rate is more difficult to quantify. The risk component arises because of the uncertainty associated with future values of the growth rate of dividends and the level of the riskless interest rate. Assuming that the investor is a risk-averter, the risk premium will be positive and it will be positively associated with increased uncertainty. The effect of monetary tightness on the risk premium thus, must operate by increasing the uncertainty with which the investor's expectations are held.

So, it is deduced that the money supply is employed as a proxy for the three key variables in the valuation formula. By that, the three primary variables that they are going to be used in estimating the stock price equation (13) are the level of stock prices (SP), the level of the money supply (M), and the rate of growth of the money supply (M). The last one is calculated as:

$$\dot{M} = \frac{M - M_{-1}}{M_{-1}}$$

and is included in the equation because it may be particularly useful in accounting for short-run variations in expectations.

Thus, the equation that is formed and can be used for empirical estimation is, as follows:

$$SP_t = a + b_1 M_t + b_2 \dot{M}_t + b_3 \dot{M}_{t-1} + \ldots + b_{n+2} \dot{M}_{t-n} \qquad (14)$$

in which stock prices are explained exclusively by the money supply and its rate of growth. The coefficients of the money variables are all expected to have a positive sign, thus showing the positive exert of money supply to stock prices.

Finally, we have seen that according to the monetary portfolio hypothesis, money supply exerts some influence on the stock prices either partly (Keran's model) or fully (Homa-Jaffee's model) in a positive way. On the other hand, the efficient market hypothesis and its models, that will follow, is expected to reach a different conclusion.

2.2. The Efficient Market Hypothesis

A market is said to be *efficient* with respect to a data subset B_t, if price at time t 'fully reflects' B_t. 'Data subset B_t' refers to a subset of any data at time t that can possibly be used to provide relevant information about market value. 'Price' refers either to the price of a single asset or a price index of several assets. 'Fully reflects' means that investors have used the data subset to arrive at information respecting asset values and that current market price has been determined conditional upon this information. Therefore, if price fully reflects B_t, investors cannot earn excess profits using B_t. In defining data in B_t, *availability* is a relevant characteristic. Data available to a broad segment of the investing public is termed *publicly* available data. This kind of data is employed to 'weak' and 'semi-strong' tests of the efficient market model, while 'strong-form' tests of the model employ data that is not publicly available. By this way, money supply data is considered as publicly available if it is appearing in a country's Central Bank Bulletin.

Thus, it is deduced that an efficient market is a market in which prices always *fully reflect* available information. But this is too general to test, since no one can test the hypothesis with respect to *all* information. Instead, when a *particular* data set is specified, the efficient market model can be tested with respect to that data and the information obtained from it. Tests take the form of examining the profitability of specific trading rules or testing specific models, which could be used to earn excess profits. The existence of profitable trading rules refutes the efficient market hypothesis.

Let's consider a simplified version of the efficient market hypothesis, where we define the investor group as the 'market'. Assume that the market formulates a probability distribution of future prices and that the mathematical expectation of this distribution determines current market price. Assume that the market is efficient, that is, current price fully reflects the data subset B_t. Assume a zero rate of interest. These assumptions combined with the assumption that current price is determined conditional upon B_t, give the following:

$$E(SP_{t+1} / B_t) = SP_t \tag{15}$$

That is, the expected value of the probability distribution of future price, SP_{t+1}, conditional upon B_t, is current price SP_t. Define the change in price from time t to time $t+1$ as:

$$\Delta SP_{t+1} \equiv SP_{t+1} - SP_t \tag{16}$$

Then, the expected price change conditional upon B_t is given by:

$$E(\Delta SP_{t+1} / B_t) = 0 \tag{17}$$

Equation (17) is an implication of the efficient market model and the additional assumptions. It follows directly from (17) that a trading rule producing information from B_t cannot be used to increase expected gain, since the expectation of the distribution of price already incorporates B_t. Equations (15), (16) and (17) can be summed up by the statement that the price sequence is a 'fair game' with respect to B_t.

From the above, therefore, it is deduced that the stock market is said to be efficient in that stock prices are determined by market participants on the basis of all available information. The stock market also is said to be efficient in that the adjustment of stock prices to new information is so rapid that it can be treated as being almost simultaneous. Taken together, these conditions mean that if the public 'expected' a change in the money supply to occur that would ultimately affect price levels and corporate earnings, the public would immediately buy and sell stocks at prices that take account of these expected effects. That is, expected changes in money would immediately de discounted into the prices of stocks. Consequently, if subsequent changes in money were to occur as expected, stock prices would change before and not after observed changes in money.

There is also another aspect of the efficient market hypothesis, which involves an 'unexpected' change in the money supply. In this case, when the public observes an unexpected monetary change they would immediate discount this information into stock prices. Hence, an unexpected money supply change would produce a synchronous relationship, or at most a very short lag, between money supply changes and stock prices. Therefore, we can conclude that the efficient market hypothesis, by combining expected and unexpected changes in money, holds that stock prices should tend to be related to current and future changes in money and not to past money changes.

3. Past Studies of Money and Stock Prices

Empirical works referring to both monetary portfolio and efficient market hypotheses, were developed in the past by a considerable number of researchers. In this section we will present the most important studies of both sides, beginning with those which support the monetary portfolio hypothesis.

3.1 Monetary Portfolio Hypothesis Studies

Sprinkel's study

One of the first studies to draw popular attention to the simple relation between money and stock prices was conducted by Beryl Sprinkel in 1964. His study was the first to apply the monetary portfolio model to stock prices systematically and thoroughly. Changes in the money supply, he held, would influence the public's desire to substitute money balances for other financial assets, including stocks. This substitution process, in turn, would generate pressures leading to changes in the prices of stocks.

To examine this relation, Sprinkel compared the level of an index of stock prices with a moving average of rates of change in the narrowly defined money supply (M1) for the case of USA. He then compared selected turning points in each of these two series with turning points in the business cycle. By visual examination of the data, he observed that changes in both money and stock prices led business cycle turning points. He also observed that changes in money had a longer lead time over business cycle turning points than over stock price changes. Hence, money supply changes appeared to lead stock price changes.

From the above observations, Sprinkel asserted that "the average lead of changes in monetary growth prior to the business cycle peak is about 19 months compared to a 4-month average lead of stock prices. Changes in monetary growth lead cyclical upturns by an average period of about 7 months, whereas stock price upturns occur about 5 months prior to business upturns on average. Therefore, *changes in monetary growth lead changes in stock prices by an average of about 15 months prior to a bear market and by about 2 months prior to bull markets*".[2]

[2] Sprinkel, *Money and Stock Prices*, p.119. Also, his "Monetary Growth as a Cyclical Indicator", *The Journal of Finance*, September 1956, pp. 333-346, presents similar methodology.

Keran's study

A more rigorous statistical examination of money and stock prices was made by Michael Keran in 1971. In his model, the level of stock prices is expressed as a function of the real money supply (m), the current and past rates of growth of real income (y), the price level (P) and the level of real corporate earnings (e). The level of stock prices, therefore, was expressed as a function of these variables in the following manner

$$SP = f(\dot{m}, \dot{y}, \dot{P}, e) \tag{18}$$

and more specifically from equation (12), that was reached from the analysis in section 2.1.(i), in which it was concluded that the level of stock prices was expected to be positively related to the level of corporate earnings and the rate of change in money, and negatively related to the rate of change in real income and the rate of change of prices.

Using regression analysis, Keran estimated the values of stock price equation (12) employing quarterly data for the time period 1956:1–1970:2 for USA, and came with the following result:[3]

$$SP_t = \underset{(9.84)}{-30.68} + \underset{(4.14)}{1.31}\sum_{i=0}^{2}\dot{m}_{t-i} - \underset{(5.67)}{5.37}\sum_{i=0}^{7}\dot{y}_{t-i} - \underset{(7.93)}{11.96}\sum_{i=0}^{16}\dot{P}_{t-i} + \underset{(20.00)}{4.80}\sum_{i=0}^{19}\dot{e}_{t-i} \tag{19}$$

R^2=0.98 D.W.=1.71

His equation explained a remarkable 98 per cent of the valuation in the stock price index (Standard and Poor's composite stock price index). He also found that *a 1 per cent acceleration in real money will lead to a 1.31 per cent increase in the stock price index.* He described this direct effect of money on stock prices as significant but relatively small. However, he also claimed that money has an important influence on the other variables explaining stock prices, i.e., real output, prices, and earnings. "Through this process", he concluded, "changes in money are the dominant factor, both direct and indirect, influencing stock prices".

[3] The t-statistics are enclosed by parentheses and are significant at the 95 per cent level of confidence.

Hamburger and Kochin study

Hamburger and Kochin, in a later study (1972), expand the approach adopted by Keran and make two important alterations. Specifically, they add the current price level (P) to Keran's model, so that a once-and-for-all change in the price level will exert an impact on the level of stock prices. In addition, they reintroduce the interest rate variable into the model, ostensibly to help identify the direct as opposed to the indirect (i.e., operating through the interest rate) impact of the money supply on stock prices. So, according to them, the level of stock prices was a function of the following variables:

$$SP_t = f(P, r, \dot{m}, \dot{y}, \dot{P}, e) \tag{20}$$

In order to estimate their model, they employ quarterly data for the time period 1956:1–1970:2, for the case of USA, as Keran did, and their findings are as follows:

$$\begin{aligned} SP_t = & \underset{(2.65)}{-77.93} + \underset{(3.68)}{1.45}\, P_t \underset{(2.64)}{-9.67}\, r_t + \underset{(7.53)}{7.03} \sum_{i=0}^{7} \dot{m}_{t-i} \\ & \underset{(4.06)}{-4.14} \sum_{i=0}^{7} \dot{y}_{t-i} + \underset{(1.05)}{2.43} \sum_{i=0}^{16} \dot{P}_{t-i} + \underset{(7.66)}{1.42} \sum_{i=0}^{6} e_{t-i} \end{aligned} \tag{21}$$

R^2=0.9855 D.W.=1.82

Their results indicate a remarkable ability to track the observed behavior of stock prices in the sample period. Also, worth comment is the fact that the coefficients of the newly added variables – the price level and the long-term interest rate – have the anticipated signs and are statistically significant. Finally, both the quantitative importance and the statistical significance of the growth rate of the money supply are enhanced. *Taken together these results provide considerable support for the hypothesis that money has both direct and indirect effects on the stock market.*

Homa and Jaffee study

In a study appearing in 1971, Kenneth Homa and Dwight Jaffee made a difference in relation to the previous mentioned studies, and focused more explicitly on the direct relationship of money and stock prices. As described in section 2.1(ii), they claimed that money should serve as a proxy for both explanatory variables, expected earnings and the interest rate, in a way that should be positively related to corporate earnings and negatively related to the interest rate. Through this, the level of stock prices should be positively related to the money supply as shown in the following equation:

$$SP = f(M) \tag{22}$$

and more particularly from equation (14), in which stock price levels depend upon the current level of the money supply and growth rates of the money supply for the current and preceding quarters.

Homa and Jaffee selected the regression variables after a number of regressions were fitted with alternative lag structures on the money supply and monetary growth rate, and the entire body of data was used to select the variables which yielded the best fit. The relationship which yielded the best fit was found when the level on the money supply variable was included with its current value and the growth rate of the money supply was specified with both its current value and a one quarter lag.

Using Standard and Poor's composite index as a measure of stock prices, M1 as a measure of money, and employing quarterly data for the period 1954:4–1969:4 for USA, they reached the following results:

$$\underset{(1.11)}{SP_t = -26.77} + \underset{(4.13)}{0.61 M_t} + \underset{(3.16)}{3.14 \dot{M}_t} + \underset{(1.46)}{1.46 \dot{M}_{t-1}} + 0.87 u_{t-1} \tag{23}$$

$$R^2=0.968 \qquad D.W.=1.82$$

The money supply variables all have the expected positive sign, and M and M are statistically significant. Also, by this specification is explained as much as 96 per cent of the variations of stock prices by using only the nominal money supply as explanatory variable.

So, from the predicted empirical studies in favor of the monetary portfolio hypothesis we see that the money either directly or indirectly has an influence on the level of stock prices. This influence is not for all the studies of the same level (grade), it differs, but the common conclusion is that money supply affects stock prices.

3.2. Efficient Market Hypothesis studies

Cooper's study

The Cooper study (1972) differs greatly from prior studies of money and stock prices, since it introduces the efficient market model. Specifically, Cooper examined the issue of leads and lags between money and stock prices. Using the framework of equation (22) cited previously, which relates stock prices directly to the money supply, Cooper estimated the following equation:

$$SP_t = \sum_{i=6}^{12} a_i \dot{M}_{t-i} \tag{24}$$

where:

SP_t = percentage change in stock prices adjusted for dividend yields

M = percentage change in money

He referred to the stock price variable as the 'stock yield' since it combines the percentage in the price of a stock with its dividend yields. According to Cooper, stock yields were a better measure of returns on stocks than just the percentage change in stock price.

More particularly, in his work Cooper related the stock yield to the current percentage change in money, to past percentage changes in money for up to 12 months, and to future percentage changes in money for up to 6 months. Using regression analysis, he estimated the relation using monthly data for the period 1947 – 1970 for the USA. The results of his tests showed a weak relationship between stock yields and rates of the money supply. His estimated equation explained only about 7 per cent of the monthly variation in stock yields. Moreover, the money supply variable in the current period was found to be not statistically significant in explaining stock yields, a result which tends to contradict the efficient market hypothesis, since if the market is efficient a synchronous adjustment of stock yields should occur. Cooper, also found only one of the lagged money supply variables and only two of the future money variables to be statistically significant in explaining stock yields.

On the basis of these results, Cooper concluded that it was difficult to assess the significant lead and lag relationships from regression analysis. That is the reason why he proceeded to use the more sophisticated spectral analysis technique, in order to examine the relation of money and stock prices in the frequency domain. These results showed that stock returns led money changes but did not lag money changes. *On this basis, his results offered support for the concept of market efficiency.*

Auerbach's study

Auerbach uses Cooper's approach in order to show if there is any relation between money and stock yields. Two modifications, however, were made in the approach followed. *First*, the data for the variables were examined for evidence of trends and cycles. The examination revealed that both variables contained trend and cycle elements which may have tended to bias the results obtained by Cooper. Thus, the trend and cycle components of each variable were removed. *Second*, to examine the degree of association between the money supply and the stock yield, simple cross correlation tests were performed rather than regression analysis (that Cooper used). The correlation coefficient, which is a measure of the degree to which two variables are related, can vary from +1 to −1. For example, if two variables display little or no association the coefficient would approach zero; if there is perfect positive association the coefficient would be +1; and with perfect negative association it would be −1.

Using simple correlation analysis, therefore, the cross correlation was computed between the current stock yield and the current money variable. Next, cross correlations were calculated between the current stock yield and the money variable in each of 60 prior monthly periods. Finally, to test whether stock yields lead money, the variables were reversed and cross correlations were computed between the current money variable and the stock yield in each of prior monthly periods. These tests were conducted using monthly data for the period 1947 – 1970 for USA.

The results of the tests showed that the stock correlations between the current stock yield and 60 prior values of the money variable were not statistically significant. Only the synchronous cross correlation was statistically significant at a value of 0.18. When the variables were reversed to test whether stock yields lead money, the synchronous cross correlation was equal to 0.18 as expected. Cross correlation between the current money variable and stock yields in each of the previous 2 months also were found to be statistically significant.

So, by these tests we can assert that the rates of change of the money supply are not related to future stock yields. In addition, stock yields are related to synchronous and future rates of change in the money supply. Theoretically, *these findings are consistent with the efficient market hypothesis*, since the evidence here indicates that the public rapidly discounts any useful information about monetary changes into stock prices so that past monetary changes no longer contain information about present or future stock prices.

Pesando's study

Pesando in his work (1974) evaluated the contribution of the Keran, Hamburger-Kochin, and Homa-Jaffee models to the problem of forecasting the level of common stock prices. Specifically, the models were re-estimated using *both* Canadian and American data, and then subjected to a series of tests designed to measure their structural stability and sensitivity to possible specification error.

The structural stability of these models can be determined, partly, by testing their sensitivity to alternate specifications of the expectation proxies. One would have less confidence in the models if relatively straightforward changes in these expectations variables caused a serious deterioration in the overall results. By including a distributed lag on current and past rates of growth of real corporate earnings, rather than on the actual values of these variable, as a proxy of expected dividend growth, Pesando showed that in the case of Keran's and Hamburger-Kochin's models, the structure of the models changed (p. 914). These changes refer not only to the reduction of the standard errors and the D.W. statistics, but also to the changes of the estimated coefficients value and the sign reversals. This sensitivity of the estimated coefficients to alternate specifications raises further doubts concerning the structural stability of the models.

The Keran's and Hamburger-Kochin's models were also estimated with Canadian data in order to obtain independent evidence on their predictive ability. From these estimations (p. 916) was viewed that in the Hamburger-Kochin model, the current price level and the corporate bond rate were incorrectly signed. Also, both models were found to be inferior to their U.S. counterparts according to the usual statistical criteria. When the level of corporate earnings is replaced by its rate of growth, the explanatory power of the models drops sharply and major sign reversals again occur among the estimated coefficients.

From the above we can conclude, that someone cannot help but view with suspicion the ability of the models to explain the behavior of stock prices during the 1956 – 1970 period. As Pesando states, "these results suggest that one should not place undue confidence in the quantitative estimates of the impact of fluctuations in the money supply on common stock prices".

Serletis' study

Serletis in his work (1993) uses more sophisticated techniques with respect to the above researchers in examining the existence of a long-run relationship between money and stock prices in the United States, through cointegration tests. Particularly, by using monthly data for the period 1970:1 – 1988:5 of the Standard and Poor's composite index of stock prices, and eight money supply measures, he investigates through Engle-Granger two-step approach as well as Johansen's Maximum Likelihood approach, the possibility that these two variables have a long-run equilibrium relationship.

He begins his analysis by checking the integration properties of the data using the augmented Dickey-Fuller (ADF) test, in order to test each variable for a unit root in levels, and then repeats this test in first differences for the variables that have a unit root in the level specification. The results of the test indicate that the variables are becoming stationary (i.e., don't have unit roots) in their first differences. This result is necessary in order to check for the existence of cointegration.

Following, he tests the null hypothesis of no cointegration against the alternative of cointegration, using both Engle and Granger two-step procedure and Johansen's method of maximum likelihood estimation of cointegrated systems. From both tests he asserts that does not exist a cointegrating vector between money and stock prices, irrespective of the definition of the money supply. *This result is consistent with the efficient market hypothesis.*

Thus, from the empirical studies supporting the efficient market hypothesis, we may conclude that there is no equilibrium relationship between money and stock prices. The money variable cannot be used for affecting or predicting the value of stock prices. That was shown both by casting in doubt the empirical findings of the monetary portfolio hypothesis and by providing tests that confirm the efficient market hypothesis.

4. The Mathematical Model in Use

In paragraph 2.1. we have presented two mathematical models that showed the relationship between stock prices and money, and were consistent with the monetary portfolio hypothesis. In this paper none of this models will be used to test for the possible relation between money and stock prices. Alternatively, we will introduce a new mathematical model which asserts the same conclusion as the cited ones above, namely that money supply affects stock prices.

For this case, a general equilibrium model that relates stock prices to money supply changes is considered. The model describes an economy inhabited by identical infinitely-lived agents. A representative agent maximizes the present value of expected utility from consumption and real money balances over an infinite time horizon, subject to an intertemporal budget constraint. The preferences of the representative agent are defined over consumption and real money balances, and given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, \frac{M_t}{P_t}) \qquad 0 < \beta < 1 \qquad (25)$$

where:

c_t = real consumption

M_t = nominal money holdings

P_t = price level

β = subjective discount factor

The agent is assumed to maximize equation (25) subject to the following budget constraint:

$$(Q_t + D_t)\, S_{t-1} + M_{t-1} = Q_t\, S_t + P_t\, c_t + M_t \qquad (26)$$

or

$$(Q_t + D_t)\frac{S_{t-1}}{P_t} + \frac{M_{t-1}}{P_t} = Q_t \frac{S_t}{P_t} + c_t + \frac{M_t}{P_t} \qquad (27)$$

where:

Q_t = price of a stock

D_t = dividend per stock received at the beginning of period t

S_t = number of stock holdings in the agents portfolio

By constructing the Hamiltonian[4] for the maximization of equation (25) subject to equation (26), we get the first order conditions involved yielding:

$$Q_t U_1'(c_t, \frac{M_t}{P_t}) = \beta U_1'(c_{t+1}, \frac{M_{t+1}}{P_{t+1}}) \frac{P_t}{P_{t+1}} (Q_{t+1} + D_{t+1}) \qquad (28)$$

$$U_2'(c_t, \frac{M_t}{P_t}) = U_1'(c_t, \frac{M_t}{P_t}) - \beta U_1'(c_{t+1}, \frac{M_{t+1}}{P_{t+1}}) \frac{P_t}{P_{t+1}} \qquad (29)$$

Equation (28) denotes that agents choose consumption at period t such, that at the margin the utility obtained through the purchase price of a stock Q_t equals the discounted utility obtained from consumption, when the stock is sold at period t+1 plus dividends. We also assume that money holdings M_t equal money supply for all t.

In addition, the money supply process is assumed to be described by the law of motion:

$$M_{t+1} = M_t^{\kappa}\, u_t \qquad (30)$$

where:

κ = a parameter which characterizes the monetary economy, and is assumed $0<\kappa<1$

u_t = innovation in money supply (the unexpected money supply)

Equation (29) is also used by Lachler (1985) and Huh (1989), and Lachler assumes a

[4] The analysis of the model is presented in detail in the Appendix.

stable autoregression for the growth rate of the money supply.

To obtain analytical solutions for stock prices, a logarithmic utility function is assumed:

$$U(c_t, \frac{M_t}{P_t}) = \delta \log(c_t) + (1-\delta)\log(\frac{M_t}{P_t}) \qquad \delta > 0 \tag{31}$$

where:

δ = a preference parameter

With (31), equations (28) and (29) turn to be respectively:

$$\frac{Q_t}{c_t} = \beta\,(\frac{P_t}{c_{t+1}P_{t+1}})\,(Q_{t+1} + D_{t+1}) \tag{32}$$

and

$$\frac{(1-\delta)}{M_t} = \delta\,(\frac{1}{c_t} - \beta\,\frac{P_t}{c_{t+1}P_{t+1}}) \tag{33}$$

Using equations (32) and (33), as shown in the Appendix, we can assert the following equation (equation (A24) in Appendix):

$$\log Q_t - \log P_t = \log A + \kappa \log M_{t-1} - \log P_t + \log u_{t-1} \tag{34}$$

from which the fixed or (long-run) point is determined as:

$$\log Q - \log P = \log A + \kappa \log M - \log P \tag{35}$$

or

$$\log(\frac{Q}{P}) = \log A + \kappa \log(\frac{M}{P}) \tag{36}$$

or

$$(q-p) = a + \kappa(m-p) \tag{37}$$

Equation (37) demonstrates that real money supply changes seem to exert an impact on real stock prices. This equation is supportive of the monetary portfolio hypothesis, and is the one that will be used for the examination of the empirical studies section.

5. The Econometric Methodology

Much of classical inference is predicted on the assumption that economic time series are covariance stationary, i.e., the series have finite second moments, and the mean and covariance structure of the data do not change across observations. However, most economic time series of interest exhibit stochastic non-stationarities, thus undermining the foundations of traditional inference. Regressing one trended variable on another, could lead to the erroneous inference of a significant relationship where none exists, a problem referred to as the 'spurious regression problem'. Thus, in order to examine a set of variables to be cointegrated, first we must establish that this variables satisfy the stationarity criterion.

5.1. Integration Analysis

Taking in consideration a stochastic process Y_t, we can state formally that stationarity is satisfied if the following conditions hold, for all values of t:

$$E(Y_t) = \mu \tag{38}$$

$$E[(Y_t - \mu)^2] = x(0) \tag{39}$$

$$E[(Y_t - \mu)(Y_{t-\tau} - \mu)] = x(\tau) \tag{40}$$

Equations (38) and (39) require the process to have a contant mean and variance, while equation (40) states that the covariance between any two values of Y from the series (i.e., autocovariance) depends only on the distance apart in time between those two values. Generally, the mean, variance and autocovariances are independent of time.

It is common to investigate whether a series is stationary by *visual* inspection of the graph of the sample autocovariances against τ, known as the *correlogram*. For a stationary time series, the autocovariances (and of course the correlogram) dies down rapidly. But, correlogram output is not used as a formal test for stationarity in literature.

Formal tests for stationarity are the Dickey-Fuller (DF) and augmented Dickey-Fuller (ADF) tests, which are closely related to the tests for 'unit roots'. The main idea of these tests is to estimate one of the following Dickey-Fuller regressions, defined as:

$$Y_t = \rho Y_{t-1} + u_t \tag{41}$$

$$Y_t = a + \rho Y_{t-1} + u_t \tag{42}$$

$$Y_t = a + \beta t + \rho Y_{t-1} + u_t \tag{43}$$

$$\Delta Y_t = a_0 + a_1 t + \rho Y_{t-1} + \sum_{i=1}^{m} \beta_1 \Delta Y_{t-i} + u_t \tag{44}$$

where the first three equations apply to the non-augmented Dickey-Fuller test and the last equation denotes the augmented Dickey-Fuller test.

Let's consider one of them, i.e., equation (41), and analyze its reasoning[5]. In equation (41), we regard the process Y as having begun at some point in the distant past, where ρ is a real number and u_t is a sequence of independent normal zero-mean random variables with variance σ^2. The series Y_t is stationary if $|\rho|<1$. If $|\rho|=1$, the series is not stationary; the variance of Y_t is then $t\sigma^2$ and is thus increasing with time. Model (41) with $|\rho|=1$ is termed as a random walk. If $|\rho|>1$, the time series is again not stationary, and the variance of the series grows exponentianlly over time. Generally, in testing for unit roots, we are essentially testing the null $\rho=1$ against the one-tailed alternative $\rho<1$.

Considering the case where the null is true and so $\rho=1$, then it is said that model (41) has a *unit root*. Furthermore, the first difference, ΔY_t, will be stationary under the null, as then

$$Y_t - Y_{t-1} = u_t \tag{45}$$

with u_t being stationary by assumption. In this case ($\rho=1$) the series is said to be 'integrated of order one', namely $Y_t \sim I(1)$.

When we say that a series is 'integrated of order one', we adopt the following reasoning. A series that is tending to grow over time cannot be stationary, but the *changes* in that series might be. To take a mechanical example, if an object has a fixed average position around which it moves, always returning after some interval to this position like a randomly perturbed weight at the end of a spring, then its displacement

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[5] An analytical presentation of the reasoning of all regressions (41) - (44) can be found in Appendix A in Roger Perman, "Cointegration: An Introduction to the Literature", *Journal of Economic Studies* , Vol. 18(3), 1991, pp.3-30.

may be a stationary series. An object that has no such fixed position may nevertheless have a velocity or acceleration, that is stationary. For example, if the object is moving ever further from its point of origin, but with velocity fluctuating around some fixed positive mean according to a fixed distribution function, then the velocity of the object is a stationary series.

So, a series is said to be integrated of order 1, I(1), if, although it is itself non-stationary, the changes in this series form a stationary series. It is said to be integrated of order 2, I(2), if, although the changes are non-stationary, *the changes in the changes* form a stationary series. In other words, if the series must be differenced exactly k times to achieve stationarity, then the series is I(k), so that a stationary series is I(0).

Now, returning to equations (41) to (44) we can state that in equation (41) the null hypothesis of a unit root is H_0: $\rho=1$, and is tested against the stationary alternative. In equation (42), the null hypothesis of a unit root can be tested either with or without a drift, i.e., H_0^1: $\rho=1$ and H_0^2: $\alpha=0$, $\rho=1$ against the stationary alternatives. Lastly, in equations (43) and (44), we can test the null hypothesis of a unit root in three ways, namely H_0^1: $\rho=1$, H_0^2: $\beta=0$, $\rho=1$ and H_0^3: $\alpha=0$, $\beta=0$, $\rho=1$ against the stationary alternatives.

Besides the power of the DF – ADF tests, it has been suggested that their framework does not provide a fully adequate set of tests for the existence of unit roots. Taken from this, Phillips and Perron (1988) have proposed a further set of statistics which in the cases of uncertainty existence regarding the dynamic structure of the time series in question, and the non-white noise of the random component, their tests can be superior. In particular, the power of DF – ADF tests is likely to be low for series where moving-average terms are present or where the disturbances are heterogeneously distributed; the Phillips and Perron adjustments are likely to raise the power of the tests in these circumstances.

5.2 Cointegration and Error Correction Mechanism Analysis

An *equilibrium state* is defined as one in which there is no inherent tendency to change. A disequilibrium state is any situation that is not an equilibrium and hence characterizes a state that contains the seeds of its own destruction. An equilibrium state may or may not have the property of either local or global stability; thus, it may or may not be true that the system tends to return to the equilibrium state when it is perturbed. However, we generally consider only stable equilibria, since unstable equilibria will not persist given that there are stochastic shocks to the economy. That is, equilibria are states to which the system is attracted, other things being equal. It may also be possible in some circumstances to view the forces tending to push the system back into equilibrium as depending upon the magnitude of the deviation from equilibrium at a given point in time.

An equilibrium relationship is expressed through a function $f(x_1,x_2,\ldots,x_n) = 0$, which describes the relationships that hold among the n variables x_1 to x_n, when the system is in equilibrium. The phrase 'long-run equilibrium' is also used to denote the equilibrium relationship to which a system converges over time. Over finite periods of time, the long–run or equilibrium relationships may fail to hold, but they will eventually hold to any degree of accuracy if the equilibrium is stable, and if the system does not experience further shocks from outside. Expressed differently, a long-run equilibrium relationship entails a systematic co-movement among economic variables, which an economic system exemplifies precisely in the long run.

From the above it can be determined that a way to specify an equilibrium relationship among a set of variables, is to show that their 'disequilibium errors' u_t tend to fluctuate around their mean value or show some systematic tendency to become small over time. Equivalently, a minimal condition for equilibrium is that the variables in the equilibrium relationship should not drift too for apart. In that case, an equilibrium relationship between the variables implies that these series are *cointegrated.* The reverse is also true, namely if evidence implies that a set of series are cointegrated, then there exists an equilibrium relationship between these series.

The basic idea of cointegration is that if, in the long-run, two or more series move closely together, even though the series themselves are trended, the difference between them is constant. We may regard these series as defining a long-run equilibrium relationship and, as the difference between them is stationary, the error term in a regression will have well-defined first and second moments. The term *equilibrium* has many meanings in economics, and its use in the cointegration literature is rather different from most definitions of equilibrium. Within the cointegration literature, all that is meant by equilibrium is that it is an *observed relationship* which has, on average, been maintained by a set of variables for a long period. Cointergration may be formally defined as:

> The components of the vector X_t, are said to be cointergated of order d, b [denoted $X_t \sim CI(d,b)$] if:
>
> (i) all components of X_t are I(d)
>
> and
>
> (ii) there exists a vector α ($\neq 0$) such that $Z_t = \alpha' X_t \sim I(d-b)$, $b>0$.

Thus, if a set of I(d) variables yields a linear combination that has a lower order of integration ($d-b<d$, for $b>0$), then the coefficient vector α of this linear combination, which induces cointegration between the series is known as the *cointegrating vector*.

From the definition of cointegration, can be deduced that the statistical concept of equilibrium centres on that of a *stationary process*. That is, if we want to examine the existence of cointegration among a set of variables, we must first establish that the series of the variables are stationary, and particularly stationary of the same degree. Only then cointegration has a meaning. So, in the case that we have two (or more) variables, which are integrated of *different* orders, then these two (or more) series cannot possibly be cointegrated. This is an intuitively clear result; it would be very strange to propose a relationship between an I(0) series x_t and an I(1) series y_t. The I(0) series would have a constant mean while the mean of the I(1) series would tend to drift over time. Thus, the 'error' ($y_t-\alpha x_t$) between them would be expected to become infinitely large over time.

Returning to the definition of contegration, if vector X_t has only two components then we consider the context of a single equation specification, in which an equilibrium or long-run relationship will be unique, if it is exists, hence there exists at most one cointegrating vector α. If vector X_t has N components, where $N>2$, then there may be more than one cointegrating vector α. That is, there may be more than one linear combination that leads to cointegration between the relevant variables. Generally, it will be assumed that there are exactly r linearly independent cointegrating vectors, with

$r \leq N-1$, which are gathered together into the Nxr array α. By construction the rank of α will be r, which will be called the 'cointegrating rank' of X_t.

Now, let's consider the case where the vector X_t includes the pair of series x_t, y_t, each of which is I(1). It is generally true that any linear combination of these series is also I(1). However, if there exists a constant α, such that

$$z_t = x_t - \alpha y_t \tag{46}$$

is I(0), then x_t, y_t will be said to be cointegrated, with α being as known the cointegrating vector, and if it exists it will be unique. In the case where $\alpha=1$, the vague idea that x_t and y_t cannot drift too far apart has been translated into the more precise statement that 'their difference will be I(0)', namely $z_t \sim I(0)$.

The next step in fitting equation (46), is to formulate the dynamics imposing the constraint that they be cointegrated. This is most simply accomplished with the Error Correction Mechanism (ECM), which, in brief, constitutes one case of a systematic disequilibrium adjustment process through which the series of interest (x_t, y_t) are prevented from 'drifting too far apart'. For our case of two variables x_t and y_t, the equations can be written as:

$$\Delta x_t = a_0 + \sum_{i=1}^{m} \beta_i \Delta x_{t-i} + \sum_{i=1}^{n} \gamma_i \Delta y_{t-i} + \delta ECT_{t-1} + u_t \tag{47}$$

$$\Delta y_t = \alpha_0 + \sum_{i=1}^{q} b_i \Delta y_{t-i} + \sum_{i=1}^{r} c_i \Delta x_{t-i} + d\, ECT_{t-1} + e_t \tag{48}$$

where:

ECT = error correction term derived from the long-run relationship, that is

$ECT_{t-1} = x_{t-1} - \alpha y_{t-1}$

Δx_t, Δy_t = first differences of variables x_t and y_t

u_t, e_t = error terms (white noise)

As can be seen, for a two variable system a typical error correction model would relate the change in our variable to past equilibrium errors, as well as to past changes in both variables. The idea of this model is simply that a proportion of the disequilibrium from one period is corrected in the next period. For example, the change in price in one period may depend upon the degree of excess demand in the previous period. Such schemes can be derived as optimal behavior with some types of adjustment costs or incomplete information. So, we may say that the ECM is a meaningful short-run adjustment equation to estimate as all terms are I(0).

The existence (or not) of cointegration among a set of variables can be examined by formal tests. These tests will be presented in the following.

The Engle – Granger Two–step Procedure

Engle and Granger (1987) proposed a two-step estimator for models involving cointegrated variables. In the first step, the parameters of the cointegrating equation are estimated with OLS. The fitted residuals from this regression can be used to test for cointegration. Specifically, if the fitted residuals are an I(0) procedure, then the series in question are cointegrated. In the second step, this estimated residuals are used in the error correction model. Alternatively, we can use the estimated coefficient $\hat{a}$ of equation (46) from the first step and insert that in place of α in the error correction term $(x_t - \alpha y_t)$ in equations (47) and (48), as the two will be identical.

From their work Engle and Granger, asserted that the two step estimator of a single equation of an error correction system with one cointegrating vector, obtained by taking the estimated $\hat{a}$ of a from the static regression in place of the true value for estimation of the error correction form at a second stage, will have the same limiting distribution as the maximum-likelihood estimator using the true value of a. They also demonstrated that the OLS standard errors obtained at the second stage are consistent estimates of the true standard errors.

Stock (1987), shows that the order of convergence of these first stage OLS estimates is greater compared with the one in the standard case. This faster convergence in the non-stationary case is sometimes referred to as 'super-consistency'. This fast rate of convergence of the estimator of the cointegrating parameter vector means that the estimators of the short-run parameters are asymptotically independent of the cointegrating vector. Another advantage of this procedure, is that at the first stage it is possible to test that the vector of variables properly cointegrates. Thus, we can be sure that the full error correction model is not a spurious regression.

Johansen's Maximum Likelihood Approach

Following Johansen (1988) and Johansen and Juselius (1990), consider the following vector autoregressive (VAR) model

$$X_t = \Pi_1 X_{t-1} + \Pi_2 X_{t-2} + \ldots + \Pi_k X_{t-k} + \varepsilon_t \qquad t = 1,\ldots,T \tag{49}$$

where X_t is a column vector of *m* endogenous variables. The stochastic terms $\varepsilon_1,\ldots,\varepsilon_T$ are drawn from an m-dimensional *identically and independently* normally distributed covariance matrix Λ. Since most economic time series are non-stationary, VAR models such as (49) are generally estimated in their first difference forms. First differencing of the series satisfies an important requirement in time series analysis, that is the variables of concern are stationary. However, since first differencing removes much of the valuable information about the equilibrium relationships between the variables applying least squares regressions to first differenced variables is not a satisfactory alternative to estimating economic models with non-stationary variables.

Following Johansen, and Johansen and Juselius, we rewrite equation (49) in its first-difference form as

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \ldots + \Gamma_{k-1} \Delta X_{t-k-1} - \Pi X_{t-k} + \varepsilon_t \tag{50}$$

where

$$\Gamma_i = -I + \Pi_1 + \Pi_2 + \ldots + \Pi_i \qquad i = 1,\ldots,k-1 \tag{51}$$

and

$$\Pi = I - \Pi - \ldots - \Pi_k \tag{52}$$

Equation (50) differs from a standard first-difference version of a VAR model only by the presence of ΠX_{t-k} term in it. It is this term that contains information about the long-run equilibrium relationship between the variables in X_t. If the rank of the Π matrix r is $0<r<m$, then there are two matrices $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ each with dimension mxr such that $\boldsymbol{\alpha\beta}' = \boldsymbol{\Pi}$. r represents the number of cointegrating relationships among the variables in X_t. The matrix $\boldsymbol{\beta}$ contains the elements of r cointegrating vectors and has the property that the elements of $\boldsymbol{\beta}'\mathbf{X}_t$ are stationary. $\boldsymbol{\alpha}$ is the matrix of error correction parameters that measure the speed of adjustments in ΔX_t.

Johansen, and Johansen and Juselius demonstrate that the $\boldsymbol{\beta}$ matrix, which contains the cointegrating vectors, can be estimated as the eigenvector associated with the r largest eigenvalues of the following equation:

$$\left| \lambda S_{kk} - \frac{S_{k0} S_{0k}}{S_{00}} \right| = 0 \qquad (53)$$

where $\mathbf{S_{00}}$ contains residuals from a least square regression of $\mathbf{\Delta X_t}$ on $\mathbf{\Delta X_{t-1}}, \ldots, \mathbf{\Delta X_{t-k+1}}$, $\mathbf{S_{kk}}$ is the residual matrix from the least square regression of $\mathbf{X_{t-1}}$ on $\mathbf{\Delta X_{t-k+1}}$, and $\mathbf{S_{0k}}$ is the cross product matrix. These eigenvalues can be used to construct a long likelihood ratio (LR) test statistic, trace test, which is used to test the null hypothesis that there are at most r cointegrating vectors in model (50). The trace test statistic is:

$$-2 \ln Q = -T \sum_{i=r+1}^{m} \ln(1 - \lambda i) \qquad (54)$$

Where $\lambda_{r+1}, \ldots, \lambda_m$ are $m\text{-}r$ smallest eigenvalues. Johansen and Juselius also provide another LR statistic known as the maximum eigenvalues test which is more powerful than the trace test. The maximum eigenvalue test is calculated as:

$$\lambda \max = -2 \ln Q r|r+1 = -T \ln(1 - \lambda r+1) \qquad (55)$$

With the maximum eigenvalue test, the null hypothesis that there are *r-1* cointegrating vectors is tested against the alternative that there are only r cointegrating vectors.

The maximum likelihood approach as stated above, gives consistent maximum likelihood estimates of the whole cointegrating matrix, and produces a likelihood-ratio statistic for the maximum number of distinct equilibrium vectors in the matrix. Thus, it is possible to identify the whole set of cointegrating relationships using this method, a thing that the Engle-Grange two-step procedure cannot succeed.

Another advantage offered by the maximum likelihood estimator is that the Likelihood Ratio test statistic has an exact known distribution, which is a function of just one parameter. Test statistics in the Engle-Granger approach cannot be compared with critical values from known distributions, as the distribution is a function of the whole data-generation process. Furthermore, given these distributional properties of the Maximum Likelihood estimator, specification tests can be carried out on the cointegrating vectors. This facility is not (directly) available in the two step framework.

Besides the differences and the advantages (disadvantages) that the two approaches for cointegration testing may have, they are both tested for the same null hypothesis. The null hypothesis is that of non-cointegration, against the alternative of cointegration of the series in question. In the EG procedure, the null hypothesis of no cointegration is rejected if the OLS residuals are an I(0) procedure. In the Johansen's approach, is rejected if there exist at least one cointegrated vector ($r \geq 1$), in which the coefficients' signs and sizes are correct according to economic theory.

The actual test for a cointegrated vector proceeds in the following way (for $d>0$). *Firstly*, we investigate the temporal characteristic of every variable in the statistic 'long-run' equilibrium equation of interest. *Secondly*, we test for cointegrated vectors. *Finally*, we formulate and estimate a general Error Correction Mechanism, and we determine the ECM's adequacy as a conditional characterization of the data generating process.

6. Data and the Empirical Analysis

At this section of the paper we will estimate empirically the final equation of section 4, namely equation (37) which relates money supply to stock prices. This equation will be tested for the case of five countries, that is USA, Australia, France, Italy and Switzerland, which differ in the size of their economies and more specifically differ in the capitalization and the transaction volume of their exchange markets. If, after the examination of these countries, is asserted that equation (37) is empirically verified, then we may state that the monetary portfolio hypothesis holds. Otherwise, the alternative one, namely the efficient market hypothesis will be operative.

6.1 Data

Equation (37) is estimated with monthly data over the period 1983:1 – 1998:12. The variables that are used are the stock prices (Q) from the Sidney Stock Exchange Market, the New York Stock Exchange Market, the Paris Stock Exchange Market, the Milan Stock Exchange Market and Zurich Stock Exchange Market. Money (M) is measured as (M1) the narrow money component, and prices (P) are measured as the composite price index (CPI) for all items. Data were obtained from various sources of the OECD Main Economic Indicators tape. Commodity price data were obtained in order to convert nominal stock prices into real terms to make the empirical analysis consistent to the asset pricing model employed; that is, real stock prices are used, since they are believed to be the most important variable to investors, in particular for investment horizons spanning a long time period. All the results were generated using the Microfit 4.0 for Windows econometrics program.

6.2 Integration Properties of the Data

To analyze the univariate trend properties of the data, as presented in section 5.1, the Dickey-Fuller (DF) and augmented Dickey-Fuller (ADF) tests were used to test each variable, for every country, for a unit root in logarithms and then repeat this test in first differences for the variables that have a unit root in the logarithm specification. Both the DF and ADF statistics are presented in Table 1. The first column in Table 1 refers to the logarithm specification, and investigates the possibility that the series might have a unit root. The terms in parentheses are the ADF test statistics. It can be deduced from the results, that in no case is there significant evidence against the unit root hypothesis. The next column presents the results of both DF and ADF tests for a second unit root, i.e., for a unit root in the first-differenced series. As can be seen, the results are in favor of stationarity in the first differences for the series, and so all of them are best characterized as I(1) procedures, i.e., having a stochastic trend.

Table 1. DF and ADF test statistics for integration

	Variable	Logarithm	First Difference
Australia	q−p	−2.88 (−3.37)	−11.08* (−10.19)
	m−p	−1.55 (−1.75)	−11.24* (−9.67)
USA	q−p	−1.44 (−2.32)	−10.04* (−9.27)
	m−p	−0.11 (−0.89)	−6.99* (−5.44)
France	q−p	−2.81 (−3.01)	−12.04* (−9.48)
	m−p	−1.10 (−1.32)	−12.23* (−12.43)
Italy	q−p	−1.37 (−1.81)	−10.24* (−8.82)
	m−p	−1.51 (−2.00)	−10.25* (−11.16)
Switzerland	q−p	−0.96 (−1.45)	−11.10* (−8.77)
	m−p	−1.42 (−1.98)	−8.62* (−10.20)

Notes: Sample period, monthly data: 1983:1 – 1998:12.
All the variables are in logarithms.
All regressions include an intercept and a linear trend.
All test statistics are based on regressions with twelve lags.
Under the null hypothesis the 1, 5 and 10% critical values of the DF and ADF statistics are (for 250 observations) −3.99, -3.43 and −3.13, respectively (Fuller,1976, Table 8.5.2). So, test statistics are significant at the *1% level.

The same conclusions can be reached if we, furthermore, plot the logarithms of the series and the first difference of them, as can be seen in Figures 1 – 10. From these is obvious that the logarithms do not satisfy the criterion of stationarity, whereas the first differences of them do.

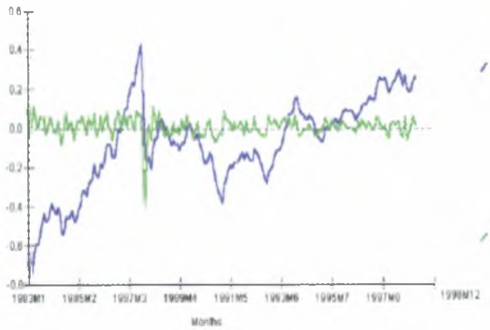

Figure 1. Logarithm and first difference of Australian stock prices

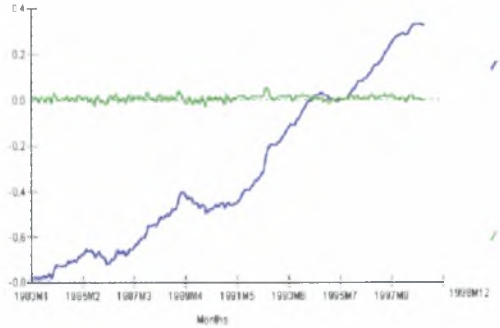

Figure 2. Logarithm and first difference of Australian money supply

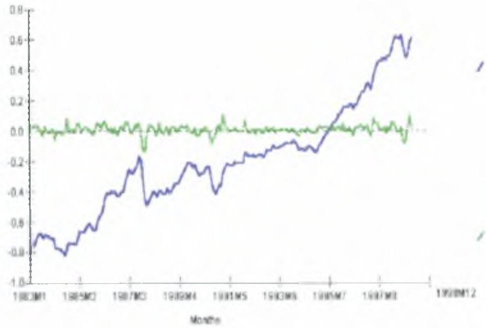

Figure 3. Logarithm and first difference of USA stock prices

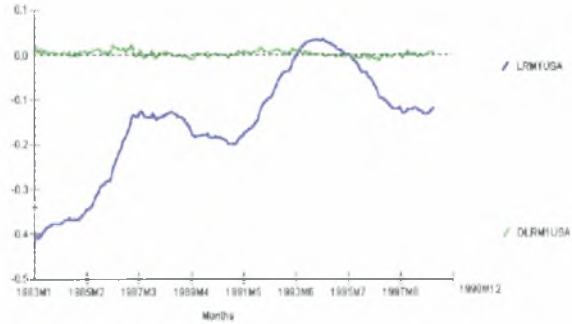

Figure 4. Logarithm and first difference of USA money supply

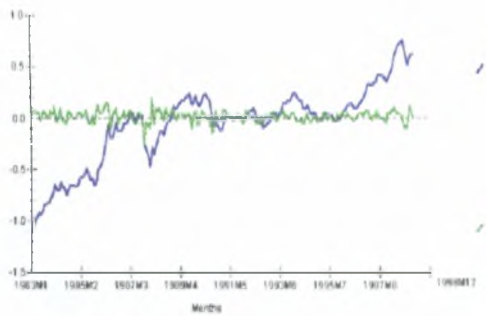

Figure 5. Logarithm and first difference of French stock prices

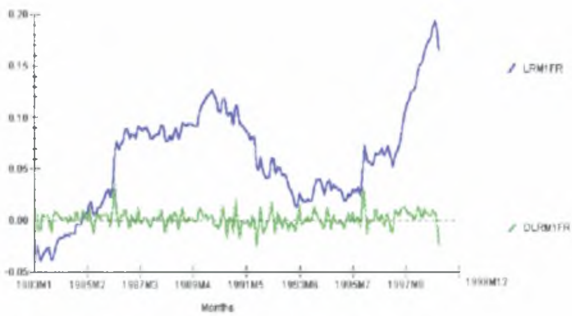

Figure 6. Logarithm and first difference of French money supply

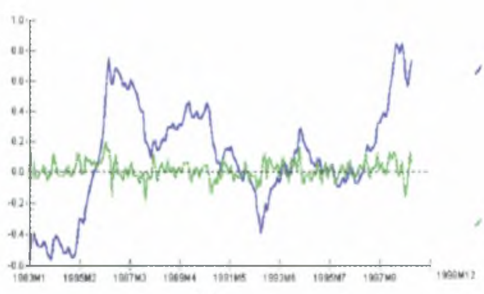

Figure 7. Logarithm and first difference of Italian stock prices

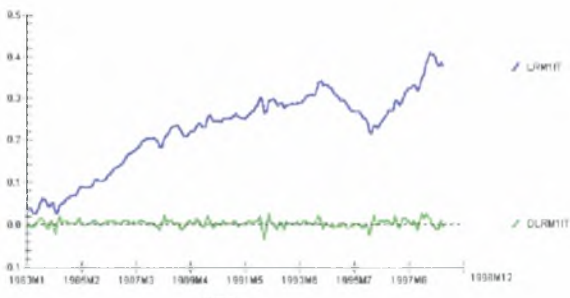

Figure 8. Logarithm and first difference of Italian money supply

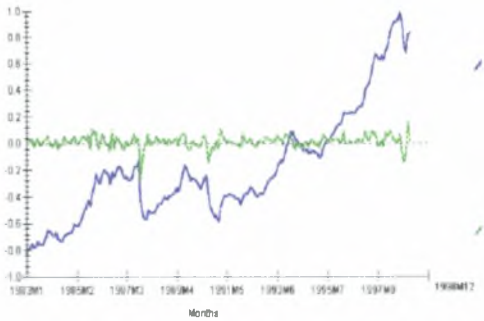

Figure 9. Logarithm and first difference of Swiss stock prices

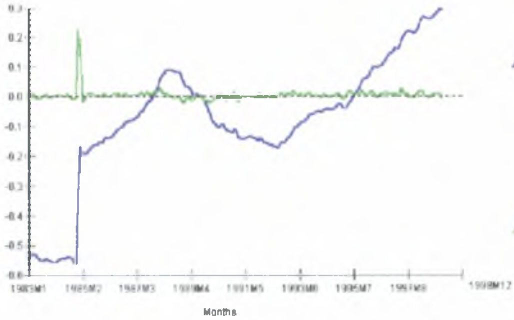

Figure 10. Logarithm and first difference of Swiss money supply

6.3. Cointegration Properties of Data

Since a stochastic trend has been confirmed for each of the series, meaning that the observed time-series possess trends which can be removed by differencing once, the question is whether the long-run movements of money and stock prices are determined by some common driving fundamentals, or whether each series reacts to its own particular set of fundamentals. Or else, whether there exists cointegration between stock prices and money as in equation (37).

The null hypothesis of no cointegration (against the alternative of cointegration) is tested using both the Engle and Granger two-step procedure as well as Johansen's method of maximum likelihood estimation of cointegrated systems.

The Engle-Granger two-step procedure – as already stated in section 5.2 – involves regressing money on stock prices, through equation (37), to obtain the OLS regression residuals. A test of the null hypothesis of no cointegration is then based on testing for a unit root in the regression residuals using the ADF test. A finding of I(0) implies cointegration. Estimating equation (37) over the period 1983:1 – 1998:12, for the five countries of interest, the following results were obtained:

Australia

$$(q-p)=0.06 + 0.47\,(m-p) \qquad (56)$$
$$(3.75)\quad(13.66)$$
$$R^2=0.495,\ DW=0.093$$

USA $(q-p)=0.10 + 2.01\,(m-p)$ (57)

$$(3.29)\quad(12.67)$$
$$R^2=0.458,\ DW=0.016$$

France $(q-p)= -0.42 + 5.92\,(m-p)$ (58)

$$(-15.54)\quad(16.87)$$
$$R^2=0.599,\ DW=0.087$$

Italy $(q-p)= -0.31 + 1.88\,(m-p)$ (59)

$$(-5.91)\quad(8.48)$$
$$R^2=0.274,\ DW=0.044$$

Switzerland $(q-p)= -0.05 + 1.61\,(m-p)$ (60)

$$(-3.01)\quad(19.10)$$
$$R^2=0.657,\ DW=0.049$$

Using the residuals of these regressions for an ADF test of stationarity, we obtain Table 2, as follows:

Table 2. ADF test statistics for the OLS residuals

Variable	Value
Residuals (Australia)	−3.04*
Residuals (USA)	0.33
Residuals (France)	−2.28
Residuals (Italy)	−1.69
Residuals (Switzerland)	−1.87

Notes: Sample period, monthly data: 1983:1 – 1998:12.
All the test statistics are based on regressions with twelve lags.
Critical value at 5% is −2.87 (Fuller, 1976, Table 8.5.2).

From Table 2, we can assert that there exists a long-run equilibrium relationship between money and stock prices only for one of the five countries examined, Australia. This is valid, since only for this country the residuals of the OLS regression are stationary, that is I(0). For the rest of the countries, the null hypothesis of no cointegration holds.

In order to be sure that these results are absolutely correct, we also use the Johansen's maximum likelihood approach to verify them. This approach, which is also described in section 5.2, to the estimation of the number of linearly independent cointegrating vectors for a vector autoregressive process, X_t, of order ρ involves (i) regressing ΔX_t on $\Delta X_{t-1}, \ldots, \Delta X_{t-p+1}$, (ii) regressing X_{t-p} on the same set of regressors, and (iii) performing a canonical correlation analysis on the residuals of those two regressions.

But before obtaining the number of linearly independent cointegrating vectors, we must select the order of the Vector Autoregressive (VAR) model, that is the number of lags in the involved VAR system. The test statistic that we use for this object is the Akaike Information Criterion (AIC). Using this test, the order of the Vector Autoregressive model that was selected for each country is depicted in Table 3, as follows:

Table 3. Selection of the VAR models order

Country	Order of VAR
Australia	4
USA	4
France	4
Italy	4
Switzerland	4

So, we can see that the number of lags in the Vector Autoregressive system of each country is the same and equal to four. Now, we can test for the null hypothesis of no cointegration (against the alternative of cointegration) using Johansen's likelihood ratio test. The relevant statistics on this test are the maximum-eigenvalue test statistic and the trace statistic. In Table 4 that follows, we present the results of the cointegration tests for the five countries examined.

Table 4. Johansen's Maximum Likelihood Cointegration Tests

List of variables included in the cointegrating vector: (q-p) (m-p) intercept

	r	n-r	m.λ.	95%	Tr.	95%
Australia	r=0	r=1	16.0567	15.8700	22.5809	20.1800
(VAR=4)	r≤1	r=2	6.5242	9.1600	6.5242	9.1600
USA	r=0	r=1	8.1666	15.8700	11.0967	20.1800
(VAR=4)	r≤1	r=2	2.9301	9.1600	2.9301	9.1600
France	r=0	r=1	10.1601	15.8700	14.5110	20.1800
(VAR=4)	r≤1	r=2	4.3509	9.1600	4.3509	9.1600
Italy	r=0	r=1	5.6290	15.8700	10.1361	20.1800
(VAR=4)	r≤1	r=2	4.5071	9.1600	4.5071	9.1600
Switzerland	r=0	r=1	9.8514	15.8700	13.2028	20.1800
(VAR=4)	r≤1	r=2	3.3513	9.1600	3.3513	9.1600

Notes: r=number of cointegrating vectors; n-r=number of common trends.
m.λ.=maximum eigenvalue test, and Tr.=trace statistic.

With this approach in the trace test, the null that there are at most r cointegrating vectors is tested against a general alternative, while in the maximum eigenvalue test, the null hypothesis of r cointegrating vectors is tested against the alternative of $r+1$ cointegrating vectors.

According to the results of Table 4, both the maximum eigenvalue test and trace test statistics imply that one possible cointegrating vector exists for Australia, while for the other four countries none cointegrating vector exists. This indicates that a cointegration relationship between money and stock prices exists only for the case of Australia. Thus, in Table 4 the results of the trace and maximum eigenvalue tests accord well with those of the Engle-Granger test, that a cointegrating vector (long-run equilibrium relationship) between stock prices and money exists only for Australia.

Normalizing the cointegrating vector on the real stock prices for Australia, yields the following equation:

$$(q-p) = 0.26 + 0.47(m-p) \quad (61)$$

on the basis of which we can support the hypothesis that there is a positive long-term relationship between (q-p) and (m-p). This result indicates that in the long-run period, an increase of money supply by 1% increases stock prices of the Sidney Exchange Market by 0,47%.

Equation (61) equals equation (56), that is both Engle-Granger and Johansen's procedures give the same results. The only difference is on the value of the constant term, which in equation (61) is a little bit greater than that of equation (56) by about 0.20. They also both show, that there is no cointegrating relationship for the rest of the countries. Thus, both approaches acknowledge the existence of a long-run equilibrium relationship between money supply and stock prices for Australia, and most importantly they assert the same degree of influence between them.

Having established the presence of a cointegrating relationship between stock prices and money, the associated Error Correction Mechanism, which describes the short-run dynamics, is employed. The ECM relates the change in one variable to past changes in both variables and to past equilibrium errors. The ECM for both procedures applied (Engle-Granger and Johansen's), has the following form:

$$\Delta(q-p) = a + \sum_{i=1}^{m} \beta_i \Delta(q-p)_{t-i} + \sum_{i=1}^{n} \gamma_i \Delta(m-p)_{t-i} + \delta ECT_{t-i} + u_t \quad (62)$$

where the ECT is the error correction term which can be derived either from the residuals of the long-run relationship (61) of Johansen's procedure, or from the (almost) same equation (56) of Engle-Granger procedure. The results are the same. The usefulness of the ECM comes from the fact that most of the times the money – stock prices relationship is out of equilibrium, and it usually takes some time to be corrected, that is to come back to equilibrium. The ECT term represents exactly this deviation. The sign of this term is expected to be negative and statistically significant. The value of this Error Correction Term (δ) reflects the speed with which the stock market approaches long-run equilibrium.

The estimation procedure, yielded:

$$
\begin{aligned}
\Delta(q\text{-}p) = {} & \underset{(4.07)}{0.2836}\, \Delta(q\text{-}p)_{t-1} - \underset{(-2.47)}{0.1755}\, \Delta(q\text{-}p)_{t-2} + \underset{(2.49)}{0.1736}\, \Delta(q\text{-}p)_{t-3} \\
& - \underset{(-2.31)}{0.6460}\, \Delta(m\text{-}p)_{t-1} - \underset{(-1.75)}{0.4809}\, \Delta(m\text{-}p)_{t-2} - \underset{(-4.15)}{0.0572}\, ECT_{t-1} \qquad (63)
\end{aligned}
$$

$$R^2=0.181,\ DW=1.897,\ F(5,\ 186)=8.223$$

Numbers in parentheses denote t-statistics, and are all significant at the 5% level, except variable $\Delta(m\text{-}p)_{t-2}$ which is significant at the 10% level. The ECT term in equation (63) has the correct sign and it is significant, indicating that stock prices adjust to restore long-run equilibrium after a short-run disturbance. The value of the coefficient of this term denotes that approximately 6% of the deviation from long-run equilibrium is corrected in the current period. So, we may assume that the Error Correction Mechanism results verify the findings of the cointegration relationship.

Generally, we may state that the results from the empirical analysis are not in favor of just one of the two alternative hypotheses tested. Results indicate that both the *Monetary Portfolio Hypothesis* and the *Efficient Market Hypothesis* hold when examined for the real world. Specifically, the Monetary Portfolio Hypothesis is verified for the case of Australia, while the Efficient Market Hypothesis holds for the cases of USA, France, Italy and Switzerland. These countries were selected on the basis of difference of their economy sizes and the capitalization value of their stock markets.

7. Conclusion

This paper empirically addressed the issue of the influence of money supply to stock prices. In doing so, we began by presenting the alternative hypotheses regarding this matter, namely the Monetary Portfolio Hypothesis and the Efficient Market Hypothesis. The former is in favor of the issue of interest, that is supports the existence of a relationship between money and stock prices. Also two mathematical models, supportive of this hypothesis were described (Keran (1971), and Homa and Jaffee(1971)). The latter hypothesis is against that relation and states that stock prices always fully reflect available information, thus not allowing money to affect stock prices and investors to induce excess profits.

A number of past studies, referring to both hypotheses, were also presented in order to have a broader picture of the issue in question. The next step was to develop in detail the asset pricing model which was tested empirically for the five involved countries. Following, we discussed the econometric methodology to be adopted. In particular, the integration properties of the data were first analyzed and then this information was used to estimate models and carry out statistical hypothesis tests. The univariate test results provide evidence against the presence of a unit root in all of the variables taken in first differences. The application of cointegration tests (Engle-Granger (1987) and Johansen (1990)), suggested the existence of a cointegrating relationship only for one country, Australia. The rest of the countries did no exhibit a long-run relationship between stock prices and money. Also, an Error Correction Mechanism was developed to describe the short-run dynamics of the model for Australia. Its results were accord with the earlier findings of cointegration technique. So, we may conclude that this paper showed the simultaneous operation of both refutive hypotheses.

Generally, we may state some reasons for regarding the concept of cointegration as central to econometric modeling with integrated variables, as well as to the examination of long-run relationships among those variables.

First, economic theory suggests possible equilibrium relationships between variables, but tends to inform us very little concerning the adjustment process at work. If a postulated equilibrium relationship exists, then the variable specified in that relationship should be cointegrated. Testing for cointegration is, therefore, a test for the existence of the equilibrium relationship postulated, and hence of whether the model is well defined.

Second, if we fail to find a cointegrating vector for a given set of variables, we may investigate whether a broader set of series is cointegrated. Thus, the technique serves as a form of mis-specification test, or equivalently as a guide to variable selection.

Finally, a cointegrating vector gives us *directly* highly consistent estimates of long-run equilibrium vectors. These estimates have good properties without the need to make any prior assumptions about the dynamics in the data-generating mechanism.

Cointegration analysis may also be viewed as a simplifying device in a model design. The estimation of long-run equilibrium properties of models may, thus, be analyzed *abstracting from* the model's short-term dynamic structure. The theory underlying cointegration analysis justifies the omission of short-run dynamics in the estimation of long-run parameters.

APPENDIX

The Hamiltonian that arises from the maximization of equation (25) subject to equation (26) is, as follows:

$$H = E_0 \sum [\beta^t U(c_t, \frac{M_t}{P_t}) + \gamma_t \{(Q_t + D_t)\frac{S_{t-1}}{P_t} + \frac{M_{t-1}}{P_t} - \frac{Q_t S_t}{P_t} - c_t - \frac{M_t}{P_t}\}] \qquad (A1)$$

where:

control variables = c_t, M_t, S_t [5]

state variables = M_{t-1}, S_{t-1}, Q_t, P_t, D_t

The first order conditions for the control variables are:

$$\frac{\partial H}{\partial c_t} = \beta^t U_1'(c_t, \frac{M_t}{P_t}) - \gamma_t = 0$$

or

$$\gamma_t = \beta^t U_1'(c_t, \frac{M_t}{P_t}) \qquad (A2)$$

Equation (A2) with a time lead, becomes:

$$\gamma_{t+1} = \beta^{t+1} U_1'(c_{t+1}, \frac{M_{t+1}}{P_{t+1}}) \qquad (A3)$$

For the second control variable, we have:

$$\frac{\partial H}{\partial M_t} = \beta^t \frac{U_2'(c_t, \frac{M_t}{P_t})}{P_t} - \frac{\gamma_t}{P_t} + \frac{\gamma_{t+1}}{P_{t+1}} = 0$$

or

$$\gamma_t = \beta^t U_2'(c_t, \frac{M_t}{P_t}) + \frac{\gamma_{t+1} P_t}{P_{t+1}} \qquad (A4)$$

From equation (A2) and by the use of (A4), we have:

$$\gamma_t = \beta^t U_1'(c_t, \frac{M_t}{P_t})$$

or

[5] The variable M_t is included in control variables, because we are in a market clearance model, where $M^s = M^d = M$.

$$\beta^{t} U_{2}'(c_t, \frac{M_t}{P_t}) + \frac{\gamma_{t+1} P_{t+1}}{P_{t+1}} = \beta^{t} U_{1}'(c_t, \frac{M_t}{P_t})$$

or

$$\beta^{t} U_{2}'(c_t, \frac{M_t}{P_t}) + \frac{\beta^{t+1} U_{1}'(c_{t+1}, \frac{M_{t+1}}{P_{t+1}}) P_t}{P_{t+1}} = \beta^{t} U_{1}'(c_t, \frac{M_t}{P_t})$$

or

$$U_{2}'(c_t, \frac{M_t}{P_t}) + \frac{\beta U_{1}'(c_{t+1}, \frac{M_{t+1}}{P_{t+1}}) P_t}{P_{t+1}} = U_{1}'(c_t, \frac{M_t}{P_t})$$

or

$$\frac{U_{1}'(c_t, \frac{M_t}{P_t})}{P_t} = \frac{U_{2}'(c_t, \frac{M_t}{P_t})}{P_t} + \frac{\beta U_{1}'(c_{t+1}, \frac{M_{t+1}}{P_{t+1}})}{P_{t+1}} \qquad (A5)$$

Solving equation (A5) for U_2', we get:

$$U_{2}'(c_t, \frac{M_t}{P_t}) = U_{1}'(c_t, \frac{M_t}{P_t}) - \beta U_{1}'(c_{t+1}, \frac{M_{t+1}}{P_{t+1}}) \frac{P_t}{P_{t+1}} \qquad (A6)\,[or(29)]$$

Equation's (A5) meaning, is that the agent reduces his consumption in period t because he thinks that holding money will increase his utility, and in order to keep constant utility function – i.e., smoothing out his consumption – this reduce of consumption in period t must equal his utility by holding more nominal balances in period t plus his discounted utility of increasing his consumption in period t+1. In essence the last term of equation (A5), is the discounting marginal utility of consuming more goods at period t+1 by using the money balances saved in period t.

Finally, for the third control variable, we have:

$$\frac{\partial H}{\partial S_t} = -\frac{\gamma_t Q_t}{P_t} + \frac{\gamma_{t+1}(Q_{t+1} + D_{t+1})}{P_{t+1}} = 0$$

or

$$\frac{\gamma_t Q_t}{P_t} = \frac{\gamma_{t+1}(Q_{t+1} + D_{t+1})}{P_{t+1}} \qquad (A7)$$

Combining equation (A7) with equations (A2) and (A3), yields:

$$\frac{\beta^{t} U_1'(c_t, \frac{M_t}{P_t}) Q_t}{P_t} = \frac{\beta^{t+1} U_1'(c_{t+1}, \frac{M_{t+1}}{P_{t+1}})(Q_{t+1} + D_{t+1})}{P_{t+1}}$$

or

$$\frac{U_1'(c_t, \frac{M_t}{P_t}) Q_t}{P_t} = \frac{\beta U_1'(c_{t+1}, \frac{M_{t+1}}{P_{t+1}})(Q_{t+1} + D_{t+1})}{P_{t+1}}$$

or

$$Q_t U_1'(c_t, \frac{M_t}{P_t}) = \beta U_1'(c_{t+1}, \frac{M_{t+1}}{P_{t+1}}) \frac{P_t}{P_{t+1}} (Q_{t+1} + D_{t+1}) \qquad (A8)\,[or(28)]$$

Using the assumed logarithmic utility function equation (31), namely:

$$U(c_t, \frac{M_t}{P_t}) = \delta \log(c_t) + (1-\delta)\log(\frac{M_t}{P_t}) \qquad (31)$$

then we get:

$$U_1'(c_t, \frac{M_t}{P_t}) = \frac{\delta}{c_t} \qquad (A9)$$

and

$$U_1'(c_{t+1}, \frac{M_{t+1}}{P_{t+1}}) = \frac{\delta}{c_{t+1}} \qquad (A10)$$

and

$$U_2'(c_t, \frac{M_t}{P_t}) = \frac{1-\delta}{\frac{M_t}{P_t}} \frac{1}{P_t} = \frac{1-\delta}{P_t} \qquad (A11)$$

By the use of (A9) and (A10) equation (28), turns out to be:

$$Q_t \frac{\delta}{c_t} = \beta \frac{\delta}{c_{t+1}} \frac{P_t}{P_{t+1}} (Q_{t+1} + D_{t+1}) \qquad (A12)[or(32)]$$

By the use of (A9), (A10) and (A11), equation (29) turns out to be:

$$\frac{1-\delta}{M_t} = \frac{\delta}{c_t} - \beta \frac{\delta}{c_{t+1}} \frac{P_t}{P_{t+1}}$$

or

$$\frac{1-\delta}{M_t} = \delta\left(\frac{1}{c_t} - \beta\frac{P_t}{c_{t+1}P_{t+1}}\right) \qquad (A13)[or(33)]$$

The steady state solution of (32) is:

$$\frac{Q}{c} = \beta\frac{P}{cP}(Q+D)$$

or

$$Q = \beta(Q+D)$$

or

$$Q = \frac{\beta}{(1-\beta)}D \qquad (A14)$$

which in logarithmic terms is:

$$\log Q = \log\left(\frac{\beta}{1-\beta}\right) + \log D \qquad (A15)$$

The steady state solution of (33) is:

$$\frac{1-\delta}{M} = \delta\left(\frac{1}{c} - \beta\frac{P}{cP}\right)$$

or

$$\frac{1-\delta}{M} = \frac{\delta(1-\beta)}{c}$$

or

$$c = \frac{\delta(1-\beta)}{1-\delta}M \qquad (A16)$$

Assuming that in equilibrium $c_t = D_t$, equation (A16) becomes:

$$D = \frac{\delta(1-\beta)}{1-\delta}M \qquad (A17)$$

which in logarithmic terms, is:

$$\log D = \log\left[\frac{\delta(1-\beta)}{1-\delta}\right] + \log M \qquad (A18)$$

By combining equations (A15) and (A18), we get:

$$\log Q = \log(\frac{\beta}{1-\beta}) + \log[\frac{\delta(1-\beta)}{1-\delta}] + \log M \qquad (A19)$$

or

$$\log Q = \log(\frac{\beta}{1-\beta}) + \log[\frac{\delta(1-\beta)}{1-\delta}] + \log M + \log P - \log P \qquad (A20)$$

The monetary rule from equation (30) is determined as:

$$M_{t+1} = M_t^{\kappa} u_t \qquad (30)$$

which in logarithmic terms is:

$$\log M_{t+1} = \kappa \log M_t + \log u_t \qquad (A21)$$

and by taking a time lag, we have:

$$\log M_t = \kappa \log M_{t-1} + \log u_{t-1} \qquad (A22)$$

By combining equation (A20) and (A22), we get:

$$\log Q_t = \log A + \kappa \log M_{t-1} + \log u_{t-1} + \log P_t - \log P_t \qquad (A23)$$

or

$$\log Q_t - \log P_t = \log A + \kappa \log M_{t-1} - \log P_t + \log u_{t-1} \qquad (A24)$$

where:

$$A = [\frac{\beta}{1-\beta}][\frac{\delta(1-\beta)}{1-\delta}]$$

The long-run point of (A24), is:

$$\log Q - \log P = \log A + \kappa \log M - \log P \qquad (A25)$$

or

$$\log(\frac{Q}{P}) = \log A + \kappa \log(\frac{M}{P}) \qquad (A26)[or(36)]$$

or

$$(q-p) = a + \kappa(m-p) \qquad (A27)[or(37)]$$

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