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COMMODITY PRICE VARIABILITY:
ITS NATURE AND CAUSES

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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This report was approved by the OECD Council in March 1993.

Preface

In March 1993, the OECD Council approved the release of this report. Reforms in agricultural policy proposed by OECD Ministers in 1987 and elaborated in subsequent Ministerial meetings aim to place greater reliance on market rather than institutionally-set prices. In this context, price variability may likely be an important issue. This report analyses the short-term behaviour of international commodity prices.

COMMODITY PRICE VARIABILITY: ITS NATURE AND CAUSES

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OVERVIEW

Reforms in agricultural policy proposed by OECD Ministers in 1987 and elaborated in subsequent Ministerial meetings aim to place greater reliance on market rather than institutionally-set prices. As a result of reforms, producers of agricultural products will be obliged to refer to prices determined in, or influenced by, international commodity exchanges in making their decisions. One of the arguments for greater reliance on market-determined prices is that these will provide more accurate signals of fundamental market conditions and thus will generate an efficient allocation of resources. In this context, price variability may likely be an important issue. To the extent that market prices will increasingly guide decisions, price variability, particularly in the short to medium term, merits examination.

This paper takes as its starting point the theories of competitive storage and efficient markets to explain the behaviour of commodity prices. It focuses on short-term price fluctuations, that is week to week and month to month changes. It examines the distribution and dynamics of prices for a variety of commodities and compares these results to those predicted by the theory. It then explores, through a variety of empirical approaches, whether fluctuations in commodity prices can be explained by an important set of market fundamentals, taken to be a set of macroeconomic factors.

Summary of results

A statistical analysis of price variability for selected commodities over weekly and monthly intervals suggests that there are no substantial differences between major OECD commodities (except perhaps sugar) and non-OECD agricultural commodities, such as cocoa and coffee, or even between agricultural and non-agricultural commodities, such as copper.

The analysis suggests that, in general, price behaviour may be characterised as follows:

i) Prices display a higher frequency of large fluctuations than expected under the theoretical normal probability distribution, thus conforming to the model of speculative price behaviour. This could explain the reason for concern by policy makers about price variability, particularly given the frequency with which "above average" sized fluctuations occur.

ii) Price behaviour is characterised by episodes of high or low variability; large fluctuations tend to be followed by large fluctuations, and small fluctuations by small fluctuations. This characteristic of price variability might generate concern among policy makers, but it should be noted that it is <u>not</u> a characteristic unique to agricultural commodities; it also applies to non-agricultural commodities as well as to other goods traded in auction markets, such as foreign currencies and share prices.

iii) The effects of price "shocks" (unanticipated price changes) appear to persist for moderately long periods; though declining over time, they never totally dissipate. Commodity price fluctuations are found to contain a moderate size permanent or ’random walk’ component. This finding appears to be at odds with the predictions of competitive storage theory where shocks have only transitory effects.

Commodity price behaviour, in the short run, appears to conflict with the standard assumptions of efficient markets which form the basis of competitive storage theory. Monthly prices do not appear to reflect market fundamentals in as much as changes in macroeconomic factors do not determine price changes. In addition, both weekly and monthly price changes tend to display significant excess volatility. There is also some evidence that excess returns are positively correlated at time horizons of one year. More precisely, the analysis of commodity prices and their relationship to underlying market fundamentals yields the following conclusions:

i) Changes in prices of dissimilar commodities are correlated at both weekly and monthly intervals. This does not support the often-expressed view that the variability of agricultural commodities is unique because of the potential effects of weather and disease on prices. Rather, it suggests that other common factors may be more significant in influencing the short-run behaviour of prices.

ii) While macroeconomic variables are usually taken as the set of common factors, they do not explain a significant portion of commodity price variability. Price changes for a diverse set of commodities are thus significantly correlated even after the effects of macroeconomic factors are removed. As a price change in a given commodity may be in part "explained" by other commodity price changes, this tends to support the hypothesis that other unidentified common factors are responsible for the co-movement of commodity prices.

iii) Unanticipated macroeconomic variability does not appear to have a significant effect on commodity price volatility. In fact, most of the variance in nominal or real commodity prices can be attributed to own price movements. Similar results have been obtained by those examining stock market price fluctuations; market fundamentals apparently do not provide a satisfactory explanation for the changes in those prices.

iv) Some commodity prices, whether measured at weekly or monthly intervals, tend to display excess volatility measured relative to changes in interest rates. Similar results have been obtained for speculative goods, such as securities, exchange rates, housing, and other collectibles. This result casts doubt on the efficiency of these markets, as defined by the theory of efficient markets.

Conclusions

The principal conclusion of this study is that commodity prices, while displaying some of the characteristics which would be expected under the theories of competitive storage and efficient markets, also display aspects which conflict with these theories. Over the short run at least, macroeconomic factors appear to explain only a limited portion of the variability in prices. Short-run dynamic behaviour may be dominated more by the nature of the institutions within which prices are formed, the trading rules which these involve, or the strategies of individual traders, than purely by market fundamentals.

With a move to greater market orientation, producers will increasingly be faced with making decisions on the basis of market prices, rather than the administered prices associated with government agricultural policies. In this economic environment producers will in all likelihood have to deal with greater price risk. In this case, there will be a need to examine what measures might be employed by producers to deal with price variability in making their production and marketing decisions. Various mechanisms, such as futures or options trading, insurance or contracting might be appropriate in this context.

INTRODUCTION

"Noise is what makes our observations imperfect. It keeps us from knowing what if anything we can do to make things better." [Black (1986)]

Commodity prices, like stock market prices, are generally considered to be volatile, although the causes of this price volatility are not well understood. Commodity prices, formed through competitive trading in exchange markets, are assumed to respond quickly to changing information on 'market fundamentals' [Frankel and Hardouvelis (1985); Obstfeld (1986); Stamoulis and Rausser (1987)]. These 'market fundamentals' are the determinants of supply and demand, such as weather, technology, economic policies, income, interest rates, exchange rates, inflation, and other factors. Underlying this view of market behaviour is the assumption that commodity traders have 'rational expectations' and thus incorporate available information concerning 'fundamentals' in their decisions . If prices accurately reflect changes in fundamentals, markets will be efficient in processing available information and provide accurate signals to guide decisions on production, consumption, and storage.

Despite this view of the efficiency of price formation in competitive commodity exchanges, the volatility of prices has been cited as a reason for employing various policy measures to provide a degree of domestic price stability. Price stabilisation, typically implemented in conjunction with price support, has been widely used in OECD countries. The growing recognition of the need for policy reform in order to reduce the costs of such support, and the need to move towards a market-oriented agriculture, implies that the role of governments in determining prices will necessarily diminish. With greater reliance on market-determined prices, the issue of price volatility may be of increased importance, particularly for producers. Consequently, the accuracy of the signals provided by the prices formed through trading in commodity exchanges is an important issue. To the extent that changes in prices reflect factors other than market fundamentals, producers may face excess variability; that is, variability greater than that generated by rationally formed prices in efficient markets[1].

Though the nature of variability and its causes are complex, an understanding of the behaviour of commodity prices is necessary to any policy-oriented discussion of the issues involved. The present paper is intended to contribute to such a discussion by focusing on the observed behaviour of prices in major commodity exchanges. The paper examines the characteristics of short-run commodity price movements and explores a number of potential sources of variability. The question of the relationship between income variability and price fluctuations is not addressed as it necessarily requires an analysis of the agents' decision-making process which is beyond the scope of the present document.

The paper is organised as follows: the first section contains a brief review of the essential elements of commodity price formation in the context of efficient markets; Section II presents a statistical analysis of commodity price behaviour, while Section III contains an empirical analysis of the relationship between volatility in commodity prices and market fundamentals. Section IV summarises the main results and their policy implications.

I. THE THEORY OF EFFICIENT MARKETS

This section discusses in a highly simplified manner the theoretical underpinnings of commodity price formation and identifies its implications for the behaviour of prices. The competitive storage model is usually used as a basis for explaining commodity price determination. This model relies on the existence of ideally functioning markets and embodies the assumptions underlying the efficient markets hypothesis under which prices provide accurate signals for the allocation of resources.

A. Implications of the theory for price formation

The competitive storage model takes a simple view of the functioning of competitive markets: an equilibrium in price and quantities supplied and demanded, including storage, is reached with all participants maximising expected profits and holding rational expectations[2]. Storage introduces a dynamic element in the price formation mechanism; prices reflect a two-period process, where the demand for storage by risk neutral profit maximising agents is the result of the following conditions: if the expected price, that is its present discounted value at time t+1, is equal to or greater than the price at time t including storage costs and waste, then storage is positive, whereas if the discounted expected price is less than the current price, including waste and storage, then storage is zero. Storage can not be negative; one can not store what does not exist. Given rational expectations, optimal storage is determined and also the current price. In the theory, it is assumed that market participants make their decisions on all available information under an accurate assessment of the relevant economic system, including its supply and demand parameters.

An important aspect of the competitive storage model is its assumption that the market is efficient, implying that equilibrium prices fully reflect all available information. Under the efficient markets hypothesis, equilibrium prices embody all relevant information on market fundamentals. Market participants, operating under rational expectations, are assumed not to waste information and to understand fully its implications for price formation. Prices will then provide an accurate valuation of the good. An efficient market will imply that there are no systematic or forecastable excess returns or profits to be made from market participation [Fama (1970, 1976); LeRoy (1989)]. This implies that the returns from storing a unit of the commodity can not be systematically above the expected equilibrium return. There are no excess profits to be made, given publicly available information. Changes in prices should be capable of being explained by the arrival of new information to the market, which is immediately reflected by prices as expectations adjust. Thus the efficient markets hypothesis also provides a theoretical explanation for both the determination and dynamics of prices. Social welfare is maximised where markets are efficient and storage is at optimal levels. Thus, from a policy perspective, the efficiency of markets is important.

B. Implications for price behaviour

If we examine the behaviour of real prices under the competitive storage model and the theory of efficient markets, we would expect to observe the following:

i) Real prices are stationary, that is when shocked they will return to their equilibrium value. Prices may be characterised by periodic "spikes" as a result of low stock levels, but as storage reduces fluctuations it generates long periods of price stability[3]. With storage, the distribution of real prices should be positively skewed, with the long tail of the distribution towards high prices. This implies that the effect of storage is asymmetric: storage can be increased to support prices, while only an infinite amount of storage can avoid a "stockout" and extremely high prices. The price distributions are also likely to display kurtosis, or a greater probability of extreme prices compared to the normal. The exact form of the distribution will however depend on key market parameters as well as on the nature of the stochastic process underlying supply and demand.

ii) Although storage naturally introduces a degree of correlation in prices, in the long run real prices will gravitate towards their equilibrium value (mean). This implies that shocks to the system will not be permanent, but only transitory.

iii) The variance of price changes is non constant and there is often an excess of large and small price changes. This high frequency of small price changes is due to the stabilising effect of storage, while the high frequency of large price increases reflects periods of low stocks or even stock-outs.

To characterise the price formation process, the efficient markets hypothesis provides additional testable propositions:

i) If prices are rationally formed, that is with forward looking expectations based on knowledge of the relevant economic system and all available information[4], they should not deviate significantly or systematically from those predicted on the basis of market fundamentals. Commodity prices should reflect availabilities as well as demand conditions. The efficiency of the market would be questionable if one consistently observed simultaneous increases in excess supplies and prices for a given commodity, or if price movements were unrelated to the determinants of supply and demand. Empirically, one should find a statistically significant relationship between changes in prices and changes in the factors affecting supply and demand.

ii) Given publicly available information, there should be no trading strategy under which traders can systematically earn excess profits. Market efficiency would be questionable if "excess returns" were found to be related systematically through time (serially correlated)[5]. Since prices are assumed to reflect market information instantaneously, returns from holding a commodity should not be correlated over time unless traders reacted to news with a lag, or trading behaviour were based on factors other than market valuations.

iii) The market efficiency hypothesis should exclude excess volatility in prices, that is variability greater than that which can be explained by changes in market fundamentals.

The analysis of variability is frequently fraught with conceptual and statistical problems. It is nevertheless important to try to determine whether price changes are consistent with market fundamentals, whether they display excess volatility, or whether there exist systematic excess returns, since these elements could cast doubt on the efficiency of price formation in commodity exchanges. With this background, the remainder of the paper attempts to examine empirically the characteristics of price behaviour and their relationship to the efficient market hypothesis.

II. STATISTICAL ANALYSIS OF COMMODITY PRICE VARIABILITY

This section summarises the results of a statistical analysis of price variability measured over both weekly and monthly periods, using nominal and deflated daily spot prices. Part A provides a description of the data, Part B presents a set of descriptive statistics, and Part C explores the characteristics of price dynamics.

A. Definitions and sources of data

The commodities examined are among those frequently referenced in international discussions. Both major OECD and selected non-OECD commodities are included, representing diverse commodity types, that is food, fibre, beverages and metals. This is to permit significant differences, if any, in the price dynamics of such commodities to be identified. The data used in the analysis are the settlement or spot prices for commodities traded in major commodity exchanges, such as the Chicago Mercantile Exchange and the London Metal Exchange (see Appendix 1 for a complete list). The commodities covered are wheat, maize, cotton, soyabeans, cocoa, coffee, sugar and copper. The prices used here are often considered as representative "international" prices for the commodities concerned, and are widely employed as reference prices for public and private purposes[6].

Price series are taken from the database of the Commodity Research Bureau and from the London Metal Exchange, and cover the 1970-1990 period, except for sugar and cocoa which begin in 1979 and 1980 respectively. The macroeconomic variables used in Section III of the paper are the UK Pound, Deutsche Mark, and Japanese Yen to the US dollar exchange rate as well as the Standard and Poor's composite share price index, sampled on Wednesdays as for commodities. The US Treasury Bill 1 month return (proxy for the interest rate), the Index of Industrial Production for the 7 major OECD countries and US Producer Prices, are based on end of month prices. Detailed definitions and data sources are contained in Appendix 1.

Daily prices are sampled weekly and monthly to avoid the statistical problems often arising from the averaging of data, as well as statistical "noise" from sampling across all days[7]. The Wednesday price is taken as the weekly price, whereas the monthly price is the price on the last Wednesday of the month. Such prices correspond more closely to theoretical requirements, and are those which are most likely to be used by traders in decision making[8].

Analysis of price variability may be undertaken using either nominal or deflated prices. Where the theory specifically suggests the use of 'real' prices, nominal values are deflated by the US Producer Price Index. Since this index is only available on a monthly basis, weekly prices are analysed only in nominal terms.

B. Descriptive statistics

The distribution of prices in levels (actual values) and first differences (period-to-period changes) provides information on the range of observed prices, and permits the calculation of measures which characterise the distribution (mean, skewness and kurtosis). Tables 1 and 2 contain basic descriptive statistics for both nominal and deflated prices (indexed 1985=1), as well as two summary measures of price dispersion. As commodities are subject to a non-negative storage constraint, there is a probability of 'stockouts' and thus periodic price spikes. As indicated above, this would generate positively skewed distributions for real prices, with a higher proportion of extreme values compared to the theoretically normal probability distribution. Deflated prices, measured monthly, display positive skewness, except for cocoa where it is negative. In nominal terms, both monthly and weekly prices of most commodities are characterised by significant skewness; the exceptions being the monthly prices of wheat, maize, cotton and cocoa. However, price changes for only about one-half of the commodities display significant skewness.

Price changes, both in nominal and deflated terms, display significant kurtosis except for cocoa in nominal prices. This is a common characteristic of speculative prices in general, including share prices, foreign exchange and bonds. It implies that a higher proportion of large and small price changes are observed compared to the normal probability distribution. For commodities, this is probably due to the fact that storage can not be negative, thus large price changes occur when stocks decline to very low levels, while the remainder of the time price changes are quite small as storage stabilises price movements. This would increase the frequency of large and small changes. Statistical tests confirm that commodity price changes tend not to be normally distributed; there is a higher frequency of large as well as small price changes than would be expected under the theoretical normal probability distribution. All in all, these general characteristics of the distributions of price changes correspond fairly well to those expected for real prices of a storable good: positive skewness, kurtosis and non-normality.

C. Commodity price dynamics

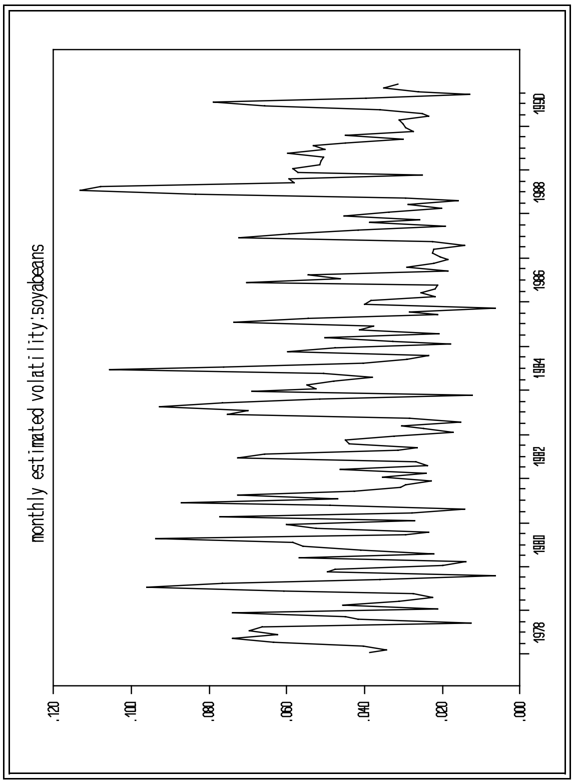
It is standard practice to describe and compare price variability through the use of summary measures such as the coefficient of variation or the standard deviation of the percentage change in price, as shown in Tables 1 and 2. These measures suggest that price variability differs little among commodities, except for sugar where it is approximately twice as large as for other commodities. Although summary measures provide some information on the nature of price variability, they ignore the dynamic properties of prices. As the sequencing of price fluctuations through time may be of importance, we analyse briefly the main characteristics of their movement over time in this section.

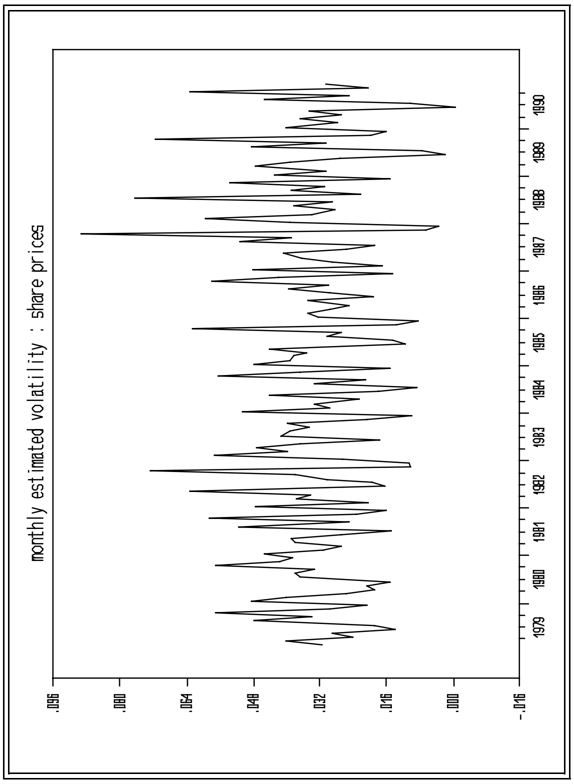
A graphical description of prices and their volatility estimates of selected commodities is provided on the following pages. Volatility is measured as the estimated conditional standard error from an autoregressive model with monthly intercepts. The method of estimation of this measure is described in footnote 13. The use of these intercepts accounts for differences in variability over time. Table 3 summarises the results of the autoregressions used to predict commodity price volatility.

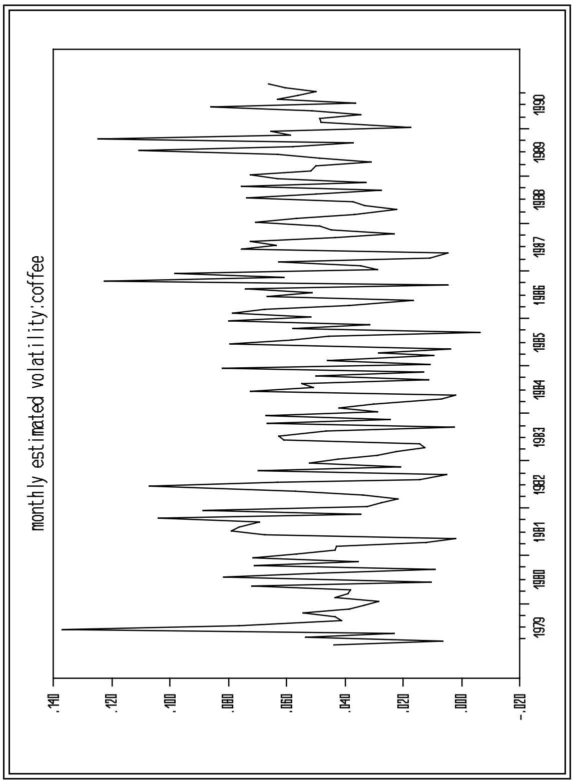
The tendency for price changes to display kurtosis is frequently associated with the clustering of price changes (indicated by the ARCH test statistic in Tables 4 and 5). This implies that today's variability is correlated with yesterday's variability, an observation which is potentially important. Thus, large changes in prices tend to be followed by large changes and small changes tend to be followed by small changes, although such changes are not necessarily in the same direction.

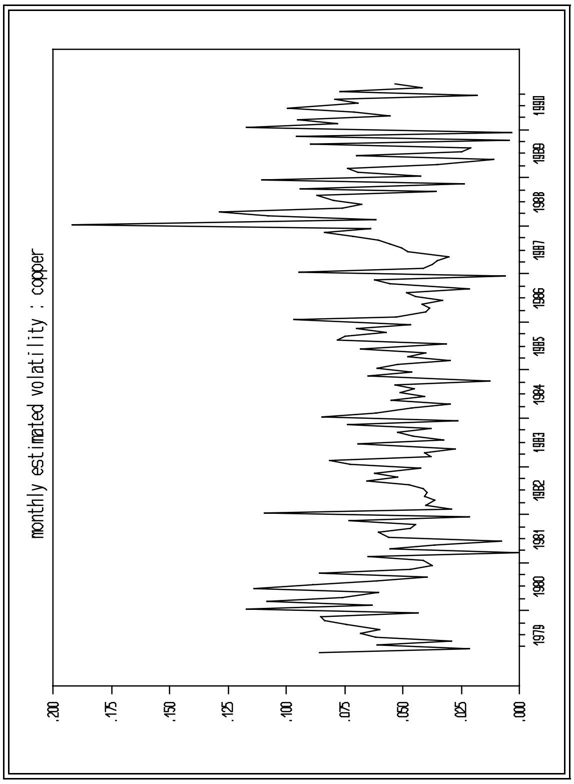
At the weekly frequency, all commodity prices are characterised by highly significant clustering of price changes. At the monthly frequency, this characteristic diminishes, but remains significant for a number of commodities [see Diebold (1987)]. Why do commodity prices tend to show episodes of relative stability or relative volatility? Are these episodes created by the physical constraint imposed by storage? Low stock levels may induce not only higher price levels but also larger variability due to the tighter supply and demand balances. Bouts of variability could also be associated with increased uncertainty about future prices or the arrival of particular types of information (e.g. on weather or general economic conditions) at the market. Alternatively, they may be the result of specific types of trading behaviour.

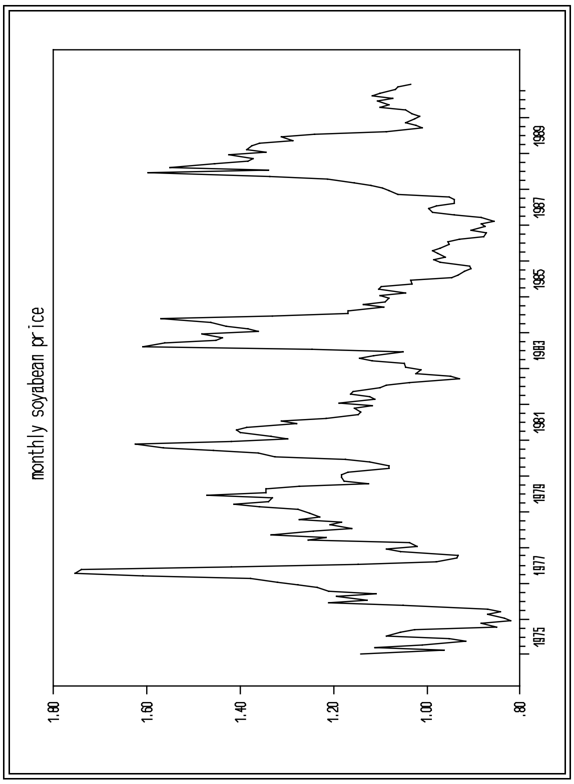
To explore further the relationship among price changes over time, we examine how important a given price shock, that is an unanticipated change in price or "forecast error", is likely to be on the future evolution of price. In other words, we measure the size of the "permanent component" of a given price change. We find that, in general, commodity prices display strong and positive correlations for fairly long periods. Thus, prices above or below the mean have a tendency to be followed by like observations above or below the mean. In the limit this would lead to explosive behaviour, but in reality prices are not explosive nor do they rapidly return to a mean path once they are diverted from this path. Commodity prices appear to behave as if they were a random walk, and our analysis frequently yields autoregressive coefficients not significantly different from one (Tables 6, 7 and 8)[9]. This result implies that the effects of "shocks" (unanticipated changes in prices) persist over time giving prices a 'random walk' characteristic[10]. This is not consistent with the predictions of competitive storage theory which assumes that storage would

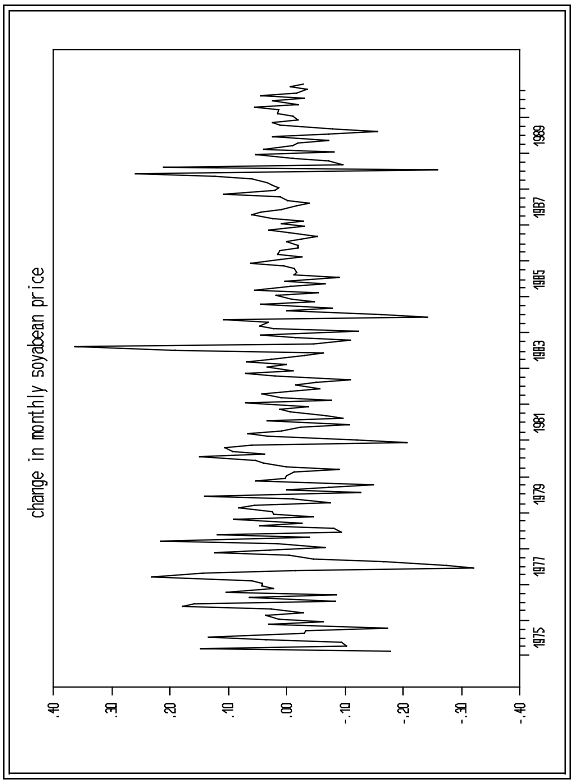

monthly estimated volatility:soyabeans
.120 .100 .080 .060 .040 .020 .000
1978 1980 1982 1984 1986 1988 1990

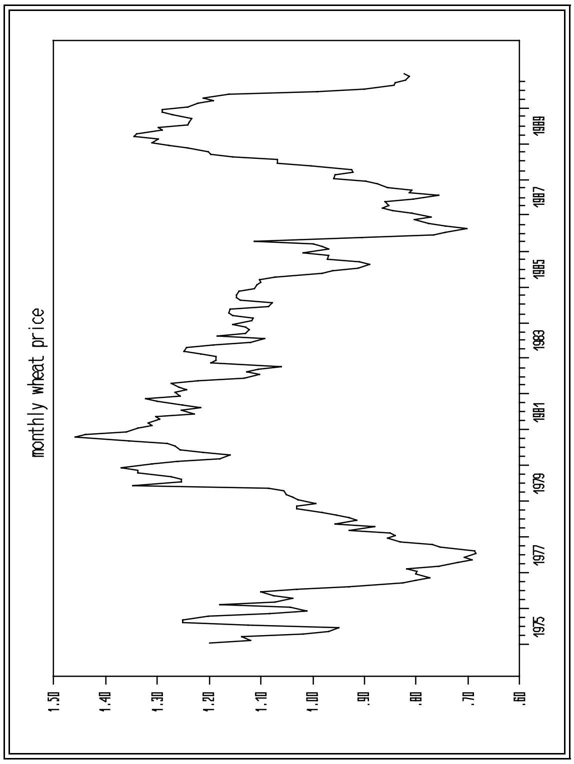

monthly estimated volatility : share prices
.096 .080 .064 .048 .032 .016 .000 -.016
1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990

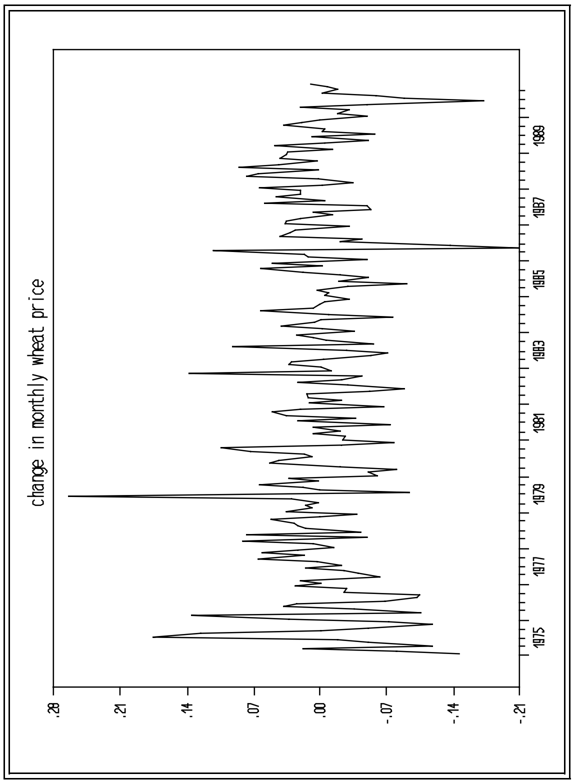

monthly estimated volatility:coffee
.140 .120 .100 .080 .060 .040 .020 .000 -.020
1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990

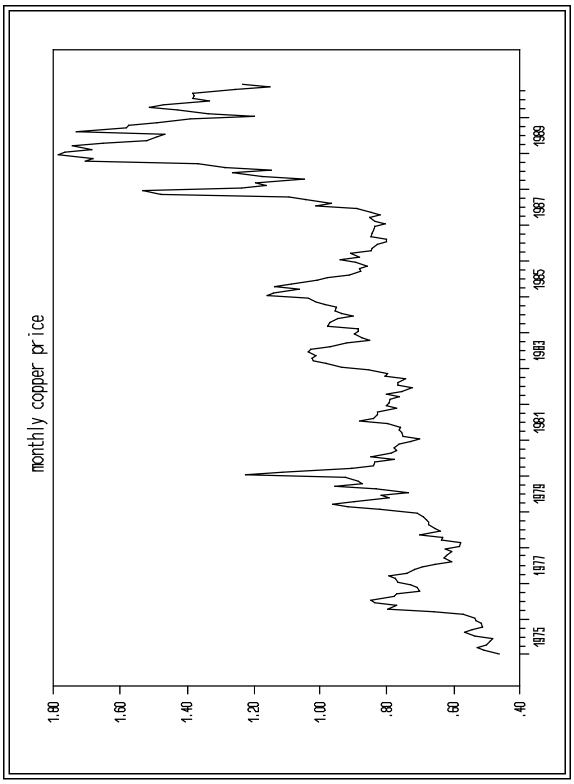

monthly estimated volatility : copper
.200 .175 .150 .125 .100 .075 .050 .025 .000
1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990

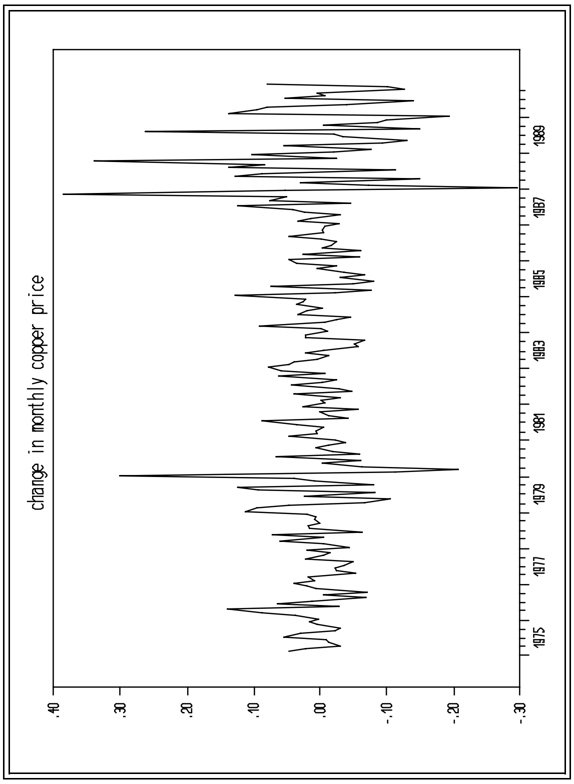

monthly soyabean price
1.80
1.60
1.40
1.20
1.00
.80
1975
1977
1979
1981
1983
1985
1987
1989

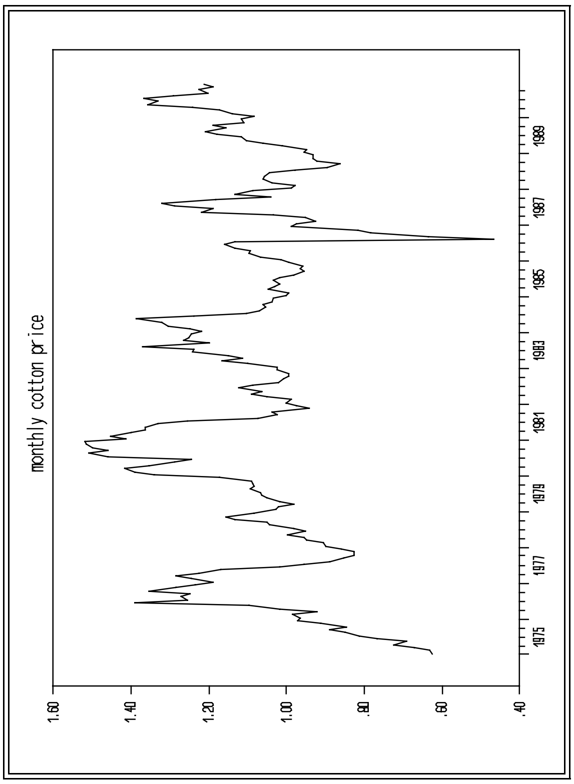

change in monthly soyabean price
.40
.30
.20
.10
.00
-.10
-.20
-.30
-.40
1975
1977
1979
1981
1983
1985
1987
1989

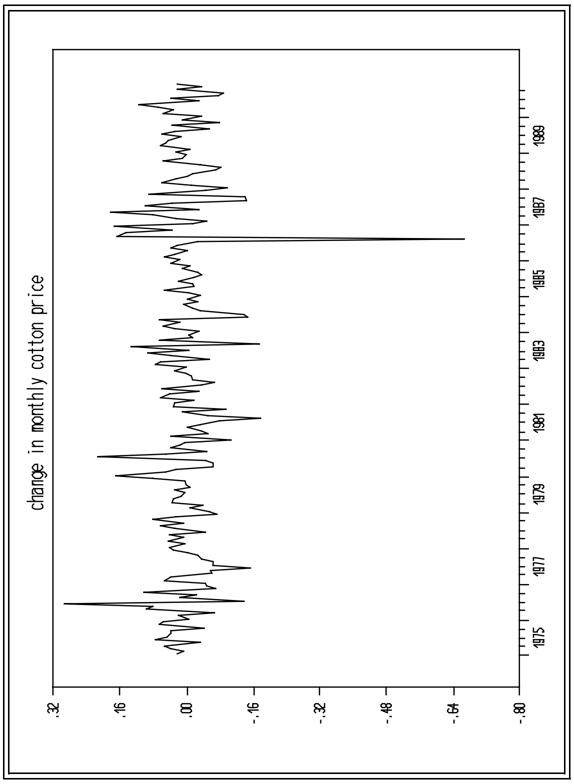

monthly wheat price
1.50
1.40
1.30
1.20
1.10
1.00
.90
.80
.70
.60
1975
1977
1979
1981
1983
1985
1987
1989


change in monthly wheat price
.28
.21
.14
.07
.00
-.07
-.14
-.21
1975
1977
1979
1981
1983
1985
1987
1989


monthly copper price
1.80
1.60
1.40
1.20
1.00
.80
.60
.40
1975
1977
1979
1981
1983
1985
1987
1989


change in monthly copper price
.40
.30
.20
.10
.00
-.10
-.20
-.30
1975
1977
1979
1981
1983
1985
1987
1989


monthly cotton price
1.60
1.40
1.20
1.00
.80
.60
.40
1975
1977
1979
1981
1983
1985
1987
1989


change in monthly cotton price
.32
.16
.00
-.16
-.32
-.48
-.64
-.80
1975
1977
1979
1981
1983
1985
1987
1989

smooth the effects of such shocks and that prices always return to their equilibrium[11]. It should be noted, however, that the results of this analysis are subject to a number of methodological caveats [Shiller and Perron (1985); Perron (1989); Cochrane (1988); and Lo and McKinlay (1988)].

Persistence estimates for weekly and monthly nominal prices are presented in Tables 9 and 10. They measure the extent to which a shock at time t affects prices k periods ahead, or the extent to which a shock k periods ago affects the current price. Values of 1 indicate that the shock is essentially permanent, while values of 0 indicate that it is completely transitory. Values falling between 0 and 1 point to some combination of permanent and temporary components. For monthly prices, persistence over a 24 month horizon is about 1 for wheat, maize, coffee, and sugar, and about .5 for the remaining commodities. After three years, the effect of a shock is still close to one for the former set of commodities, but after 5 years only about 1/2 the effect of the shock remains for wheat and maize, and only 1/4 for soyabeans, cotton and cocoa. For sugar and coffee it nevertheless remains close to 1, even after 5 years, indicating a large permanent component. For weekly prices, persistence at a 52 week interval is greater than 1 for wheat, maize, cotton, and sugar, and slightly below for soyabeans. After 104 weeks, or 2 years, only the effects of the shocks to wheat, maize and sugar still appear to be close to 1. After 5 years the permanent component is about one half of the original shock for wheat and maize, while for the remaining commodities it declines to between 25 and 35 per cent. Similar results are found to apply for deflated commodity prices. Shocks tend to dissipate, though not completely, thus indicating the existence of a permanent component of moderate size. Persistence of price shocks might be expected over a period of up to two years. This is likely due to the fact that storage introduces a two-period process in price determination. Given the usual biological cycle for crops of one year, persistence estimates close to one are not unexpected. However, the fact that the effects of shocks persist for some length of time before being dissipated could be an important element in policy discussions[12].

The characteristics of price movements revealed above are of particular significance for possible price or income stabilisation policies. The analysis suggests that for the commodities examined: i) there is strong evidence that prices and price changes are not normally distributed, due to significant kurtosis and skewness; ii) no consistent differences in this characteristic are apparent among commodity types, that is temperate crops, fibres, tropical products, or metals; iii) there is evidence of time dependent variation; and iv) the effects of shocks do not quickly dissipate, but tend to linger, giving rise to a permanent component in the effect of a shock.

III. COMMODITY PRICE DYNAMICS AND MARKET FUNDAMENTALS

The similarity in the characteristics of the distributions and dynamic properties of international prices for food, feed, fibre, and raw materials is pronounced. These characteristics have also been found for speculative prices, including those for stocks and bonds, foreign exchange, land and collectibles [Diebold (1987); Cutler, Poterba and Summers (1990)]. To explore further the relationship among prices, the correlation (co-movement) of price changes through time was examined following the method used by Pindyck and Rotemberg (1990). We find, as they did, significant correlation among price changes for commodities having little substitution or complementarity in either production or consumption. The results of these tests for monthly and weekly prices are presented in Tables 11A and 11B. In additional work, annual (1900-1989) and quarterly (1961-1990) price changes were also found to be highly correlated, as shown in Table A2.3 in Appendix 2. The finding of significant correlation in the case of weekly prices is particularly interesting given the likelihood of 'noise' which is likely to be present in observations of greater frequency.

For commodities which are either close substitutes or complements in production or consumption strong co-movement might be expected. However, the set of commodities analysed here is heterogenous, being inherently different in both production and consumption characteristics. This raises the issue of whether such movements could be attributable to the effect of a set of market fundamentals common to all commodities. The leading candidates are macroeconomic factors, such as economic growth rates and inflation, which are associated in particular with the demand side of commodities. A number of analysts, in seeking to explain the commodity price boom of the early to mid 1970s and the decline in prices during the early 1980s, have pointed to such factors as the main determinants of commodity price co-movements [Chu and Morrison (1983); Bond, Vlaustin and Crowley (1982, 1983); Pindyck and Rotemberg (1990)].

A. Model-based tests of the impact of macroeconomic factors

To examine whether variability in macroeconomic factors may influence commodity price volatility, two approaches are employed. The first relies on the use of a standard commodity model to describe the price formation process. The second is based on an approach which does not impose any specific theoretical structure on the price formation process.

In the first approach, we use a reduced form price equation derived from a standard commodity model to examine how much of the variability in commodity prices can be explained by variability in a set of macroeconomic factors (Table 12). Details of the model and estimating equation are found in Appendix 3. Estimation is based on monthly data, since weekly observations for much of the required data are not available. Macroeconomic variables, such as output, inflation, exchange rates and interest rates are generally assumed to affect commodity prices primarily through their effect on demand, including storage. If commodities are considered as part of an investment portfolio, then the prices of alternative investments, for example shares or government bonds, may also be important. Thus the variables selected as relevant for the determination of commodity price movements are: the British pound, Japanese yen and German mark to US dollar exchange rates, expressed as a simple arithmetic average, Standard and Poor's composite share price index (S&P), the United States Treasury bill monthly return as a proxy for the interest rate, the US producer price index (PPI) as a measure of inflation, and the Index of Industrial Production for the 7 major OECD economies (IP7) as an indicator of economic activity.

The results of the estimation (with all variables in first differences of logs except for interest rates which are in simple first differences) indicate that, on the whole, these macroeconomic variables account for little of the short-run variation in commodity prices. This is indicated by the adjusted R squared statistic and the low frequency of statistically significant explanatory variables. Most variables, however, are of the correct sign. Interest rates are statistically significant for cotton and soyabeans, while inflation is significant for cotton and maize. Copper, cotton and soyabean prices appear to be affected by variations in industrial production in the major OECD economies. Even when the explanatory effect of the macroeconomic variables is taken into account, the residual variation in prices of wheat, soyabeans, copper, cotton and coffee continues to display significant correlation across commodities. Such 'excess co-movement' has also been found by Pindyck and Rotemberg (1990) using somewhat different data.

In a second approach to this issue, we first estimate the volatility of commodity prices and macroeconomic variables individually (as described in Section II, Part C) and then use these estimates to test whether macroeconomic variables can be said to 'cause' price variability in the sense of Granger-causality. These tests, based on multivariate vector autoregressive models, determine whether knowledge of macroeconomic variability can improve our forecast of commodity price variability. This involves the use of lagged variability of the macroeconomic variables in predicting the current variability of prices[13]. The analysis is carried out in both nominal and deflated terms. Where nominal values of the macroeconomic and commodity price variability are used, inflation is included as a separate variable; where deflated prices are used, commodity prices, share prices and interest rates are deflated by the US producer price index. The results obtained are summarised in Tables 13 and 14. The F-test statistic in those tables indicates whether or not a given macroeconomic variable is a significant factor in predicting commodity price variability.

These results, as for those obtained from the reduced form estimation, suggest that macroeconomic variables do not contribute significantly to observed commodity price variability, although not all the variables are statistically insignificant in all equations. Inflation appears to have an effect on wheat, cotton, copper and coffee, while exchange rates are significant for cotton in the nominal case. The variability of share prices appears to be associated with maize price variability and variability in interest rates with that in coffee and wheat prices[14]. Where the tests are undertaken using deflated values, share prices are significant for maize, soyabeans and coffee, and exchange rates for soyabeans. However, the lack of strong and consistent association between the macroeconomic variables and prices seems to suggest that short-run fluctuations in the macroeconomy are not of major significance in commodity price volatility.

B. Further empirical tests of the impact of macroeconomic factors

Although the method used above permits an examination of the causality between two variables, it may be the case that a given variable does not influence price volatility directly, but only indirectly. For example, interest rates may affect exchange rates, which in turn affect commodity prices. In addition, contemporaneous correlations among several such variables may be present. To evaluate the existence of such indirect effects, we examine the dynamic response of commodity prices to a shock in a given macroeconomic variable. The analysis evaluates the dynamic response of price over 24 months to a one standard deviation shock in each of the macroeconomic variables. Again the results indicate that macroeconomic variability does not appear to have a strong impact on the short-run variation in commodity prices, even when indirect effects are taken into account.

Further insight into the strength of this relationship is provided by the decomposition of variance of the forecast errors of commodity prices. This procedure attributes to each of the macroeconomic variables, as well as to the commodity price itself, a share of the forecast error variance of the commodity price. These results are shown in Table 15. For a period of up to 3 months, the contribution of macroeconomic variables to commodity price variability remains very limited and even after six months about 2/3 of the forecast error variance is attributable to own price innovations. For example, in the case of wheat, after six months about 6 per cent of the variance of the forecast error is due to innovations in industrial production, share prices, interest rates and exchange rates, and approximately 15 per cent to inflation innovations, while for coffee, share prices, exchange rates, inflation and interest rate innovations each only account for between 3 and 7 per cent of variation in forecast errors. In the case of soyabeans, only interest rate innovations account for over 10 per cent of the variation in forecast error. Similar results are found for all commodities when the analysis is carried out using deflated values, which again leads us to conclude that the contribution of macroeconomic variability to commodity price variability is quite limited in the short run.

In a final approach, the relationship between macroeconomic and commodity price variability was examined through regression analysis using the previously estimated measures of commodity and macroeconomic volatility. Commodity price volatility is estimated as a function of the estimated volatility of industrial production, inflation, exchange, and interest rates as well as share prices; where deflated values are employed, the inflation rate variable is excluded. In almost all cases, little explanatory power is attributed to the macroeconomic variables, although there are some coefficients which are statistically significant. For instance, in equations with inflation included as a separate variable, the interest rate is significant over 80 per cent of the time, and the share price variable for about 50 per cent of the time. The remaining variables are not significant (Table 16)[15]. The use of deflated estimates of price and macroeconomic variability does not substantially alter the conclusions reached (Table 17).

When past price variability is taken into account, the explanatory capacity of the equations is improved for about half of the commodities examined. In certain cases, the inclusion of the price volatility of other commodities appeared to be a significant factor, for instance coffee price volatility was significant for price volatility of soyabeans, corn, and cotton, while wheat was significant for copper. In addition, the amount of commodity price variability "explained" by the variability of other commodity prices exceeds that explained by macroeconomic factors. If the volatility of other commodities is highly significant in the determination of volatility of any one commodity, this would tend to indicate that volatility of commodity prices remains linked by a common factor or set of factors, although no strong association can be found linking price variability and the leading explanatory candidate: changes in macroeconomic factors.

C. Results from other studies

The results discussed above are broadly consistent with those obtained in a number of recent studies that have attempted to test whether commodity markets are efficient in the terms of the competitive storage model [Deaton and Laroque (1990, 1991); Roll (1984); Pindyck and Rotemberg (1990); and Mathis and Reichlin (1991)]. All these studies call into question aspects of the underlying hypothesis of efficient markets. Roll (1984) examines the informational efficiency of markets by providing a systematic analysis of the movements in orange juice futures prices due to weather fluctuations. Although the weather is a most obvious and significant factor in output variability, fluctuations in weather conditions explain little of the variation in futures prices, as is also the case for macroeconomic variables, and a variety of other plausible factors explored. Pindyck and Rotemberg (1990) also question the competitive storage model for commodity price formation. As has been found in this study, they conclude that price changes for dissimilar commodities are correlated, and remain so even after the effects of macro-economic variables have been explicitly taken into account. They suggest this could imply that qualitative factors, such speculative bubbles (or even sunspots!) could influence price formation.

Finally, it is particularly interesting to note that an empirical analysis of commodity price movements over the 1900 to 1988 period based directly on the competitive storage model produced ambiguous results [Deaton and Laroque (1990, 1991)]. The authors note that even with respect to long run price movements: "it is still far from clear that the competitive storage model gives a fully adequate account of the data. There are many stochastic processes that satisfy the derived autoregression, but can not be generated from the commodity price model."(1990, p.30).

The results of the empirical analysis in this paper and that undertaken by others suggest that competitive storage theory does not adequately account for observed commodity price variability. It is difficult to find a strong relationship between an important set of factors (macroeconomic factors) which might be thought of as fundamentals in commodity markets. Similar results have been found when trying to explain variability in share prices as well as in exchange rates [LeRoy and Porter (1984); Shiller (1981, 1984, 1990); Fama and French (1988)]. We must conclude that our empirical analysis does not support a strong association between price variability and changes in market fundamentals, at least when measured over the short run.

If markets are efficient, prices or returns should neither display excess volatility nor should any excess returns be correlated over time. In the final empirical part of this study, we briefly explore these two propositions.

D. Excess variability of prices and excess returns

Given the difficulties in identifying a causal relationship between macroeconomic variables and price movements, we attempt to explore in an indicative fashion other aspects of price variability, notably excess variability and excess returns. If prices are formed in efficient markets, price movements should reflect only new information on market fundamentals. Consequently, volatility in excess of that attributable to such information should not be observed. Within this perspective, we ask whether expected returns to commodities are 'excessively volatile' compared to the expected rational returns based on market fundamentals.

To test this proposition, we use a simple approach: we regress the excess returns of commodities on a constant and the nominal interest rate. The excess return is defined as the return to holding the commodity from t to t+1 less the nominal interest rate. We assume this to be the expected rational return, whereas the nominal rate of interest is the expected gross market return.

If there is no excess volatility, nominal interest rates have no effect on excess returns. Thus a negative coefficient on the interest rate would imply excess variability and a positive coefficient would imply the contrary[16]. The results of this test are presented in Tables 18 and 19. They indicate that commodity price returns, for a number of cases, can be considered excessively variable. The interest rate variable, although negative in all cases, is statistically significant in only about one half of the cases: sugar, cotton and soyabeans. It is noteworthy that significant excess volatility was found for a number of commodities. The results, although not totally conclusive, are similar to those found when testing for excess volatility in exchange rates and share prices [Froot (1987); Shiller and Campbell (1988)].

The final proposition examined is that of excess returns. Market efficiency implies that returns from holding commodities are not predictable from past history since excess profits are bid away in the market. However, if returns are correlated, then it is possible to forecast a part of the price variability from past movements in returns over a given period of time. This would imply that not all agents, or traders, necessarily hold forward looking rational expectations. In the present analysis, as in that conducted for other types of speculative assets elsewhere, excess returns are measured by the difference between the one period return and the nominal interest rate.

The results obtained show significant positive autocorrelation of excess returns in the short run, while over the longer run they exhibit negative serial correlation. Thus the average autocorrelation coefficient for the first 12 month period, as well as the one month autocorrelation coefficient, are generally positive (Table 20)[17]. Over time horizons greater than one year, average autocorrelation coefficients on the whole become negative, although for some commodities they again become positive at longer term horizons, that is two years or more. What is important about this finding is that it tends to contradict the predictions of traditional asset pricing models in which returns are independent and not serially correlated, and thus unpredictable. If excess returns are correlated in the short run, returns over time are not independent. These results tentatively imply that such returns are partially forecastable, and could also indicate that factors other than market fundamentals are determining short-run price movements [Poterba and Summers (1988)]. Further precision in data selection and analysis, particularly for commodities characterised as a two-period process, is, however, necessary before any definite conclusions can be reached.

These results are similar to those found for speculative assets such as bonds and securities, exchange rates, and other assets [Cutler, Poterba and Summers (1990); DeBondt and Thaler (1985); Fama and French (1988); Froot (1987)]. The relatively significant autocorrelation in returns in the short run is an aspect of speculative price dynamics which appears to characterise a large number of storable commodities. Data on stock and bond returns in 13 countries, returns to holding of major currencies as well, as real estate collectibles and gold and silver, were found to be positively and significantly correlated over the short run, and slightly negatively correlated in the longer run [Cutler, Poterba and Summers (1990)]. These findings also suggest that returns are somewhat predictable, a result that conflicts with the traditional view of efficient markets.

E. Implications of the results

The results obtained from tests are indicative of a possible failure of commodity markets to be informationally efficient. Our analysis, confirming that obtained by others for foreign exchange and stock markets, finds that the contribution of market fundamentals to explaining price volatility appears to be limited. This is the case even where statistical procedures are employed to account for the time dependent variability of speculative and economic factors. Nonetheless, we are left without a definitive answer to the original question posed in this study: what are the causes or sources of short-term price movements?

If commodity price movements can not be primarily attributed to changes in market fundamentals, the explanation of price volatility may lie in the behavioural characteristics of traders, or the nature of the institutional framework (including that of the commodity exchanges) in which they operate. For example, Shiller (1984, 1986) attributes certain observed dynamics of speculative market behaviour to the influence of social dynamic factors, which include among others "fashions or fads". Others have suggested that markets containing heterogeneous traders operating under a variety of trading strategies could explain observed price behaviour [Cutler, Poterba and Summers (1990); Delong et al. (1990); Jackson and Peck (1991); Summers (1986); Kyle (1985)]. For example, these authors find that when markets include traders who base their decisions on past returns rather than on forward-looking expectations, this could generate the observed short run serial correlation in prices and returns. More recently it has been shown that the presence of "buy low and sell high" and "buy high and sell higher" feedback traders in addition to rational traders can generate observed price variability in markets, in particular short-run positive and longer-run negative correlation in returns. Although these perspectives differ from those of the traditional competitive storage model and the theory of efficient markets, they can not be excluded, a priori, although they may imply a more behavioural and institutional view of commodity price formation.

IV. CONCLUSIONS

The empirical analysis of price volatility undertaken here indicates that, by and large, the short-run behaviour of commodity prices is not only fairly similar across commodities, but also resembles in many respects the behaviour of the more general class of speculative assets, including stocks and foreign exchange. The distributions of real prices conform fairly well to those expected from the standard competitive storage model, characterised by significant positive skewness and kurtosis. With respect to price changes, distributions are characterised by non-normality due mainly to the presence of kurtosis or 'fat tailed distributions'. Again this is a common characteristic of speculative price changes.

The analysis of the dynamic behaviour of prices, however, gave rise to several results which seem to contradict the traditional competitive storage model which is thought to explain commodity price formation. For instance, the effects of a "price shock" do not appear to be uniquely transitory, but rather to have a substantial permanent component. While the effect of the shock does decline over time, it does not completely dissipate. In addition, there is significant time dependent variability evident in commodity price movements. Large and small price changes give evidence of clustering, a characteristic frequently observed in other speculative markets such as stock prices, foreign exchange and other collectibles.

From a policy perspective, it may not be sufficient to describe or underline the differences and similarities of commodity prices among themselves or with other speculative assets. It would be more useful to be able to determine the possible causes of the observed variability. According to the standard classical theory of commodity price formation, variability should be linked to changes in market fundamentals, that is the determinants of supply and demand. However, the evidence provided by this analysis, and supported by that of others, tends not to find strong support for this hypothesis. Short-run commodity price movements do not seem to be strongly related to changes in the macroeconomy for example[18]. While empirical questions are always open to further analysis, to improvements in data, and to improved techniques, this conclusion does seem to be relatively robust. Our analysis, and that of others, finds that, in the short run, prices do not appear to convey substantial information on market fundamentals. In fact, the underlying efficient markets hypothesis is called into question not only because of the lack of significant relationship with market fundamentals, but also through observed excess volatility and the correlation in excess returns. These features raise questions about the efficiency of international commodity markets as short-run processors of information on market fundamentals.

The presence of heterogenous traders operating with a variety of trading strategies may be the cause of the excess volatility in returns or the short-run positive serial correlation of prices. Technical innovations in the mechanics of trading, such as computerisation, as well as institutional innovations, such as continuous trading hours, may have contributed to an increased use of mechanical trading rules as well as the participation of traders who tend to introduce 'noise' into the market. These developments could have given rise to some of the characteristics found here.

These results should not be interpreted to mean that since markets may not be ideally efficient, particularly in the short run, institutionally-set prices would do a better job of conveying relevant information to market participants. Nor should they be interpreted to imply that policy makers should intervene directly to limit price variability. There may, however, be a need to examine the structure of the institutions of price formation, such as commodity exchanges, and the way these function. There may also be a need to evaluate what mechanisms might be available to those who make resource allocation decisions, particularly producers, to deal with the possible uncertainty created by fluctuations in commodity prices.

The results of this study should stimulate further reflection on alternative, private or public, methods for dealing with commodity price variability. It may be useful to consider alternative private arrangements that do not require the government to bear the price change risk in commodity markets. At the institutional level it is possible that regulatory measures may improve the efficiency of markets. Given the entrepreneurial nature of much primary production it is probably not possible, nor even desirable, to eliminate all the effects of price dynamics. Futures markets, in particular, have long been used to manage price risk by producers and traders. It may be useful to consider the expanded use of futures and options contracts to permit agents themselves to deal with price change risk. Alternative financial instruments, such as commodity indexed bonds or insurance schemes of various types, may also be considered as substitutes for direct government intervention in price formation to reduce risk.

NOTES

1. In the following, "efficiency" refers to the informational efficiency of prices.

2. The element of optimal storage was introduced by Gustafson (1958). Storage levels, constrained to be non-negative, are those resulting from risk-neutral firms seeking to maximize their discounted expected profit. Later, the theory incorporated the rational expectations hypothesis [Muth (1961)]. It is now assumed that agents form their expectations knowing the relevant economic model and utilizing all available information in the market. This model of commodity price formation was further elaborated by Samuelson (1971, 1972); Kohn (1978); Newbery and Stiglitz (1981); Scheinkman and Schectman (1983); Salant (1984); Hart and Kreps (1986); Wright and Williams (1982); Williams and Wright (1991); and Deaton and Laroque (1990, 1991).

3. Commodity prices have been theoretically characterised as following a renewal process; that is, there is a probability of a periodic stock out which generates extreme price increases. However, with the new harvest, the storage-consumption decision is again possible, beginning with production $X_T > 0$, Storage ≥ 0 or 0, and consumption > 0.

4. We limit the discussion to information which is publicly available. The issue of asymmetric information sets or insider information is also important, but cannot be addressed adequately from a theoretical or empirical perspective in the present paper. For a general introductory discussion of these issues, see Pesaran (1987); Grossman (1981); and Grossman and Stiglitz (1980).

5. This does not imply that if prices do not follow a random walk (i.e. contain an element of mean reversion), there are possibilities for excess profits [Danthine (1977); Williams and Wright (1991)].

6. It should be stressed that they are not necessarily "international trade" prices, i.e. those at which the bulk of international transactions take place. Such prices may reflect quality differences as well as the information available to participants and their bargaining power.

7. The choice of spot prices rather than the commonly used averaged export/import prices is made to avoid the problem of aggregation over time as well as to avoid the inclusion of movements of other variables such as freight costs or insurance in the analysis of price movements. Spot prices should also be more consistent with the theory of competitive storage.

8. Although futures markets also exist for these commodities, and there are undoubtedly important relationships between the two sets of prices, the analysis is restricted to the movement of spot prices.

9. None of the test statistics reject the hypothesis of an autoregressive coefficient of one at the 5 per cent level or above. Similar results were obtained in analysing quarterly prices over the period 1960-1990, and annual prices for 1900-1989. These results are summarised in Appendix 2, Tables 1 and 2.

The failure to reject the unit root hypothesis implies non-stationarity of the series, however it should be recalled that this is an asymptotic property of the series with roots on the unit circle. The analysis implies that shocks or innovations to the series may exist for very long periods of time before reverting to some long-run equilibrium value. From a technical perspective, this implies that differencing rather than detrending is usually a more appropriate procedure. In the limit, differencing may introduce a non-stationarity in the moving average portion which is less deleterious to the estimation results than ignoring non-stationarity in the autoregressive process.

10. A shock is defined as the unanticipated change in price, ϵ , in the following relation:

$$x_t = x_{t-1} + \epsilon$$

11. Over short horizons it is difficult to distinguish between the long-run equilibrium mean price and a permanent shock. Since prices are not generally explosive, it is unlikely that they are pure random walks. However, the effects of shocks do appear to persist for some time [Cochrane (1988); Lo and McKinlay (1988); Perron (1987, 1989); Shiller and Perron (1985); Fama and French (1988)].

12. It should be noted that the power of the test statistic declines with the length of difference interval compared to the number of observations. In the case of monthly observations using 5 year differences there are 4 two non-overlapping observations, and using a 10 year difference only 2 non-overlapping observations. From a statistical perspective it is best to have observations on very long time periods. Using the relatively limited time spans may distort the measures. This persistence measure has also been found to underestimate the permanent component of price disturbances [Campbell and Mankiw (1987)].

13. The estimating equation now includes the lagged unconditional standard errors of macroeconomic variables in addition to own commodity standard errors in order to test for 'causality' in a Granger sense.

Commodity price variability is estimated following suggestions by Schwert (1989), and Davidian and Carroll (1987).

i) A 12th order autoregression for returns is first estimated including dummy variables D_{jT} to allow for different monthly returns:

$$R_T = \sum_{j=1}^{12} \alpha_j D_{jT} + \sum_{i=1}^{12} B_i R_{T-i} + \epsilon_T$$

ii) A 12th order autoregression for the absolute values of errors from i) for different monthly standard deviations:

$$|\hat{\epsilon}_T| = \sum_{j=1}^{12} \gamma_j D_{jT} + \sum_{i=1}^{12} p_i |\hat{\epsilon}_{T-1}| + \upsilon_T$$

A weighted least squares procedure is used with two and three iterations between i) and ii). The use of dummy variables d_{jT} allows conditional mean returns to vary over time (i) and allows different weights for lagged absolute unexpected returns (ii).

The estimated values are then multiplied by $\sqrt{\frac{\pi}{2}}$ for consistency with a normal distribution.

14. Because of the large number of coefficients that need to be estimated in the 12 lags for each of the variables, this necessarily taxes heavily the number of available observations. One might suspect that this in itself could be a factor giving rise to the generally low level of significance of macroeconomic variables in the determination of macroeconomic variability, thus several alternative versions of the models were examined. To lessen the workload on the data set and the models, the number of lags could be reduced or a Bayesian approach could be employed in estimation.

As we preferred to permit the data to determine the possibility of significant contributions of macroeconomic variables even at fairly long lags, the models were re-estimated using a Bayesian approach and specifying a harmonic decay for the coefficients. No significant difference in results were found with this modification. We also re-estimated the models, setting both exchange rates and stock price indices as exogenous and testing for block exogeneity. In neither case was there any change in the significance of the remaining macroeconomic variables. In addition we tested the possible contribution of only financial type variables, that is interest rates and share prices on commodity price variability with both monthly and weekly data.

15. It should, however, be noted that interest rate variability is the most significant factor determining commodity price variability and can be interpreted as representing the opportunity cost associated with storage. Nevertheless, the overall effect of the macroeconomic variables on commodity price variability remains quite weak.

16. The constant term in this relationship represents the average risk premium, if the risk premium is zero, the joint null hypothesis would be that both coefficients are zero.

17. In addition, if one subtracts 1/12th of the first month's autocorrelation from the average annual autocorrelation (1-12 months), the autocorrelation remains significantly positive for all commodities.

18. Tests for a long-run equilibrium relationship between macroeconomic factors and commodity prices using quarterly data over the 1960-1990 period did not give evidence of co-integration; that is, there appears to be no long-run equilibrium relationship between them.

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Table 1. **Descriptive statistics**

Weekly commodity prices (1975:1:7-1990:12:26)

	Mean	**Coefficient of Variation (1)**	**Kurtosis (2)**	**Skewness (3)**
Wheat	1.1	0.32	-0.98**	-0.29**
Maize	1.07	0.20	0.09	-0.16*
Soya	1.21	0.17	0.15	0.68**
Cotton	1.05	0.17	0.53**	-0.19*
Coffee	0.78	0.36	2.21**	0.36**
Copper(4)	1.02	0.31	0.61**	1.03**
Sugar(4)	2.03	0.54	4.07**	1.94**
Cocoa(4)	0.86	0.20	-0.36	-0.47**

1. Ratio of standard deviation to the mean.
2. Kurtosis indicates a higher frequency of observations well above or below the mean compared to the normal distribution. It generates distributions characterised by the presence of fat tails often accompanied by peakedness.
3. Skewness is the degree to which the observed distribution differs from a symmetric one.
4. Series begin in 1975 for copper; 1979 for sugar; and 1980 for cocoa.

*, ** = Significant at the 5 and 1 per cent level respectively.

Table 1 (cont.). **Descriptive statistics**

Monthly commodity prices (1975:1-1990:12)				
	Mean	**Coefficient of Variation (1)**	**Kurtosis (2)**	**Skewness (3)**
Wheat	1.11	0.18	-0.99*	-0.25
Maize	0.97	0.20	-0.05	-0.11
Soya	1.05	0.27	0.62	-0.08**
Cotton	1.05	0.17	0.43	-0.09
Coffee	1.02	0.36	2.47**	0.36*
Copper(4)	0.93	0.31	0.67**	1.06**
Sugar(4)	4.06	0.66	4.0**	1.91**
Cocoa(4)	0.86	0.20	-0.32	-0.35

Deflated monthly commodity prices (1975:1-1990:12)				
	Mean	**Coefficient of Variation (1)**	**Kurtosis (2)**	**Skewness (3)**
Wheat	1.31	0.26	0.28	0.66**
Maize	1.16	0.33	-0.22	0.52**
Soya	1.33	0.29	0.69*	0.89**
Cotton	1.25	0.26	0.78*	0.93**
Coffee	1.24	0.48	3.95**	1.68**
Copper(4)	1.04	0.20	0.41	1.02**
Sugar(4)	4.27	0.48	4.5**	2.14**
Cocoa(4)	0.87	0.23	-0.35	-0.59**

1. Ratio of standard deviation to the mean.
2. Kurtosis indicates a higher frequency of observations well above or below the mean compared to the normal distribution. It generates distributions characterised by the presence of fat tails often accompanied by peakedness.
3. Skewness is the degree to which the observed distribution differs from a symmetric one.
4. Series begin in 1975 for copper; 1979 for sugar; and 1980 for cocoa.

*, ** = Significant at the 5 and 1 per cent level respectively.

Table 2. **Descriptive statistics**

Weekly commodity prices (Δ) (1975:1:7-1990:12:26)

	Mean	**Variance**	**S.D. of %Δ(1)**	**Kurtosis (2)**	**Skewness (3)**
Wheat	-0.63E-03	0.93E-03	0.28E-01	2.24**	-0.18*
Maize	-0.49E-03	0.11E-02	0.32E-01	7.4**	0.18*
Soya	-0.38E-03	0.22E-02	0.35E-01	3.67**	-0.44**
Cotton	0.71E-03	0.13E-02	0.41E-01	147.1**	-7.87**
Coffee	0.63E-04	0.34E-02	0.12	81.54*	1.26*
Copper(4)	0.99E-03	0.20E-02	0.36E-01	8.98**	0.63**
Sugar(4)	0.59E-03	0.31E-02	0.64E-01	9.41**	0.11
Cocoa(4)	-0.78E-03	0.11E-02	0.38E-01	1.73**	0.29**

1. Standard deviation of the percentage change in price.
2. Kurtosis indicates a higher frequency of observations well above or below the mean compared to the normal distribution. It generates distributions characterised by the presence of fat tails often accompanied by peakedness.
3. Skewness is the degree to which the observed distribution differs from a symmetric one.
4. Series begin in 1975 for copper; 1979 for sugar; and 1980 for cocoa.

*, ** = Significant at the 5 and 1 per cent level respectively.

Table 2 (cont.). **Descriptive statistics**

Monthly commodity prices (Δ) (1975:1-1990:12)

	Mean	**Variance**	**S.D. of %Δ(1)**	**Kurtosis (2)**	**Skewness (3)**
Wheat	-.025E-02	.34E-02	.54E-01	3.26**	.31
Maize	-.17E-02	.37E-02	.68E-01	2.58**	.29
Soya	-.53E-03	.75E-02	.72E-01	2.51**	.05
Cotton	.29E-02	.64E-02	.90E-01	22.4**	-2.54**
Coffee	-.11E-02	.10E-02	.83E-01	7.48**	.33
Copper(4)	.40E-02	.63E-02	.73E-01	5.58**	.92**
Sugar(4)	.17E-02	.55E-01	.14	7.40**	.62**
Cocoa(4)	-.32E-02	.40E-02	.75E-01	.79	.51*

Deflated monthly commodity prices (Δ) (1975:1-1990:12)

	Mean	**Variance**	**S.D. of %Δ(1)**	**Kurtosis (2)**	**Skewness (3)**
Wheat	-.97E-02	.66E-02	.06	4.41**	.37
Maize	-.84E-02	.59E-02	.071	2.07**	-.09
Soya	-.75E-02	.13E-01	.087	3.25**	-.32
Cotton	-.40E-03	.19E-01	.089	15.1**	-1.14**
Coffee	-.48E-02	.88E-02	.076	12.7**	.23
Copper(4)	-.11E-02	.09E-02	.074	3.93**	.73**
Sugar(4)	-.011	.71	.144	9.24**	.71**
Cocoa(4)	.51E-02	.43E-02	.01	1.09**	.51*

1. Standard deviation of the percentage change in price.
2. Kurtosis indicates a higher frequency of observations well above or below the mean compared to the normal distribution. It generates distributions characterised by the presence of fat tails often accompanied by peakedness.
3. Skewness is the degree to which the observed distribution differs from a symmetric one.
4. Series begin in 1975 for copper; 1979 for sugar; and 1980 for cocoa.

*, ** = Significant at the 5 and 1 per cent level respectively.

Table 3. **Summary Statistics for Autoregressive Models for Volatility of Commodity Prices and Macroeconomic Variables[1] (1975-1990)**

	Nominal			Deflated		
Series	$\bar{R}^2$	χ^2 **Monthly Intercepts** $d_1=d_2=d_k$	Q(36)	$\bar{R}^2$	χ^2 **Monthly Intercepts** $d_1=d_2=d_k$	Q(36)
Wheat	.23	37.3*	16.9	.24	38.5*	19.0
Soyabeans	.13	15.9*	35.5	.10	13.7	31.5
Corn	.07	39.4*	20.6	.15	26.4*	29.8
Cotton	.21	23.3*	14.9	.22	30.6*	14.5
Coffee	.13	26.6*	20.2	.07	21.3*	21.2
Copper	.20	14.6	21.2	.21	19.7*	22.4
Stock Prices	.09	43.5*	31.3	.09	43.87*	37.0
Interest Rates	.31	23.2	26.1	.07	29.5*	32.25
Exchange Rates	.09	31.5*	23.4	NA	NA	NA
Producer Price	.15	25.3*	22.8	NA	NA	NA
Industrial Production	.10	20.8*	27.1	NA	NA	NA

* = significant at the 1 per cent level.

1. Volatility is estimated using a 12th order autoregressive process with monthly intercepts. Q(k) is the Ljung-Box statistic for residual auto-correlation, and the χ^2 statistic tests for the equality of monthly intercepts. For method of estimation, see footnote 13.

Table 4. **ARCH Test Statistics - Δln**[1]
Weekly Nominal Commodity Prices (1975:1:1-1990:12:26)

	Wheat	Maize	Soyabeans	Coffee	Cotton[2]	Copper	Sugar	Cocoa
ARCH (1)	70.90	144.64	87.15	201.83	0.37E-02	28.24	4.51	0.86E-01
ARCH (2)	98.69	187.57	110.09	269.07	0.74E-02	32.12	5.53	0.38
ARCH (3)	118.75	189.96	116.69	301.28	0.85E-02	37.28	12.48	0.33
ARCH (4)	123.70	207.76	124.41	320.48	0.11E-01	41.79	20.94	22.07
ARCH (6)	127.11	225.85	130.64	341.12	0.19	45.67	21.99	23.86
ARCH (8)	129.61	224.11	130.41	351.83	0.36	47.10	24.25	25.08
ARCH (12)	132.07	228.05	132.50	360.98	0.37	52.86	27.07	27.36

1. Test statistics are distributed as $\chi^2(n)$ and are significant at the 1 per cent level for wheat, maize, soyabeans, coffee, copper for all n, and for sugar for $n \geq 3$, and cocoa for $n \geq 4$.

2. Over the periods 1970:1:7-1987:6:1 and 1987:1:5-1990:12:26, Arch test statistics were significant at the 1 per cent level.

Table 5. **ARCH Test Statistics - Δln**[1]
Monthly Nominal Commodity Prices (1975:1-1990:12)

	Wheat	**Maize**	**Soyabeans**	**Coffee**	**Cotton**[2]	**Copper**	**Sugar**	**Cocoa**
ARCH (1)	12.80***	5.26**	22.92***	4.49***	2.29	.17***	1.27	.01
ARCH (2)	14.67***	6.09**	22.63***	5.31*	2.43	13.56***	1.80	4.72
ARCH (3)	14.87***	5.90	20.87***	6.73*	2.46	13.53***	1.86	4.70
ARCH (4)	15.33***	6.13	20.60***	7.73***	2.64	13.47***	1.87	5.15
ARCH (6)	16.10***	6.89	23.75***	7.63	2.70	16.92***	1.79	5.59
ARCH (8)	17.25**	7.83	27.38***	12.53**	2.69	17.78***	7.15	7.93
ARCH (12)	17.74	9.28	32.78***	13.45	2.76	20.31***	8.00	8.94

1. Test statistics are distributed as $\chi^2(n)$.

   *** = 1 per cent level of significance;
   ** = 5 per cent level of significance;
   * = 10 per cent level of significance.

2. Over the periods 1970:1-1987:6 and 1987:1-1990:12, Arch test statistics were significant at the 1 per cent level.

Table 6. **Tests of Autoregressive Roots**[1] Weekly Commodity Prices (1970:1:7-1990:12:26)				
	α	$\mathbf{t}_{\hat{\alpha}}$	**Trend**	$\mathbf{t}_t$
Wheat	.994	-1.98	-.11E-05	-.33
Maize	.992	-2.28	-.73E-06	-.21
Soyabeans	.986	-2.94	.17E-05	.37
Cotton	.986	-3.22*	.65E-05	1.44
Coffee	.990	-1.47	-.16E-05	-.16
Copper	.973	-3.39*	.26E-04	2.59**
Sugar	.992	-1.55	-.46E-05	-.29
Cocoa	.98	-2.18	-.22E-04	-1.65

α = autoregressive coefficient; null hypothesis is $|\alpha| = 1$.

The null hypothesis is the presence of the unit root in the series' autoregressive representation with a trend embedded in the test equation. When the test statistic, as presented above, is significant, we can reject the null hypothesis of a unit root in favour of a trend stationary series.

** = significant at the 5 per cent level;
* = significant at the 10 per cent level.

[significance test values from Dickey-Fuller (1979) and Fuller (1976)].

Tests, including possible structural change in 1973, did not alter the conclusions of the test [Perron (1989)].

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1. The estimating equation for the test is:

$$\ln y_t = \mu + \gamma t + \alpha \ln y_{t-1} + \sum_{j=2}^{k} \alpha_j (\ln y_{t-j+1} - \ln y_{t-j}) + e_t$$

Table 7. **Tests of Autoregressive Roots**[1] Monthly Commodity Prices (1970:1-1990:12)				
	α	$\mathbf{t}_{\hat{\alpha}}$	**Trend**	$\mathbf{t}_{\mathbf{t}}$
Wheat	.97	-2.10	-.17E-04	-.25
Maize	.963	-2.34	-.99E-05	-.15
Soyabeans	.93	-3.26*	.51E-04	.60
Cotton	.93	-3.11	.13E-03	1.32
Coffee	.98	-1.73	.13E-04	.17
Copper	.91	-3.18*	.38E-03	2.50**
Sugar	.94	-1.68	-.37E-03	-1.61**
Cocoa	.986	-.30	-.43E-03	-1.79*

α = autoregressive coefficient; null hypothesis is $|\alpha| = 1$.

The null hypothesis is the presence of the unit root in the series' autoregressive representation with a trend embedded in the test equation. When the test statistic, as presented above, is significant, we can reject the null hypothesis of a unit root in favour of a trend stationary series.

** = significant at the 5 per cent level;
* = significant at the 10 per cent level.

[significance test values from Dickey-Fuller (1979) and Fuller (1976)].

Tests, including possible structural change in 1973, did not alter the conclusions of the test [Perron (1989)].

---

1. The estimating equation for the test is:

$$\ln y_t = \mu + \gamma t + \alpha \ln y_{t-1} + \sum_{j=2}^{k} \alpha_j (\ln y_{t-j+1} - \ln y_{t-j}) + e_t$$

Table 8. **Tests of Autoregressive Roots**[1]
Monthly Deflated Commodity Prices (1970:1-1990:12)

	α	**$t_{\hat{\alpha}}$**	**Trend**	**t_t**
Wheat	.96	-2.48	-.18E-03	2.4
Maize	.94	-2.75	.28E-03	2.4**
Soyabeans	.92	-3.57**	-.32E-03	-3.0**
Cotton	.92	-3.5**	-.23E-03	-2.4**
Coffee	.975	-1.91	-.92E-04	1.28
Copper	.93	-2.8	.52E-04	.52
Sugar	.959	-1.8	.69E-04	.19
Cocoa	.94	-1.59	-.46E-03	-1.6

α = autoregressive coefficient; null hypothesis is $|\alpha| = 1$.

The null hypothesis is the presence of the unit root in the series' autoregressive representation with a trend embedded in the test equation. When the test statistic, as presented above, is significant, we can reject the null hypothesis of a unit root in favour of a trend stationary series.

** = significant at the 5 per cent level

[significance test values from Dickey-Fuller (1979) and Fuller (1976)].

Tests, including possible structural change in 1973, did not alter the conclusions of the test [Perron (1989)].

1. The estimating equation for the test is:

$$\ln y_t = \mu + \gamma t + \alpha \ln y_{t-1} + \sum_{j=2}^{k} \alpha_j (\ln y_{t-j+1} - \ln y_{t-j}) + e_t$$

Table 9. **Persistence estimates**[1] Weekly commodity prices (1970:1-1990:12)							
no. of weeks	**5**	**9**	**26**	**52**	**104**	**260**	**360**
Wheat	1.15 (0.09)	1.30 (0.14)	1.37 (0.24)	1.30 (0.33)	1.51 (0.54)	0.59 (0.33)	0.41 (0.27)
Maize	1.17 (0.09)	1.25 (0.13)	1.26 (0.22)	1.22 (0.30)	1.23 (0.44)	0.48 (0.27)	0.39 (0.26)
Soyabeans	1.06 (0.08)	1.05 (0.11)	1.07 (0.19)	0.86 (0.21)	0.61 (0.22)	0.25 (0.14)	0.26 (0.17)
Cotton	1.26 (0.10)	1.30 (0.14)	1.26 (0.22)	1.19 (0.30)	0.63 (0.22)	0.35 (0.20)	0.26 (0.17)
Coffee	0.32 (0.03)	0.27 (0.03)	0.24 (0.04)	0.23 (0.06)	0.17 (0.06)	0.16 (0.09)	0.13 (0.09)
Copper	0.95 (0.11)	0.99 (0.15)	0.84 (0.21)	0.68 (0.25)	0.47 (0.24)	0.12 (0.10)	0.13 (0.12)
no. of weeks	**3**	**5**	**9**	**26**	**52**	**104**	**156**
Sugar	1.14 (0.09)	1.24 (0.13)	1.32 (0.19)	1.37 (0.33)	1.40 (0.48)	1.18 (0.57)	0.35 (0.66)
Cocoa	0.95 (0.08)	0.91 (0.10)	0.88 (0.13)	0.69 (0.17)	0.58 (0.21)	0.41 (0.21)	0.35 (0.22)

1. Cochrane's method of k-differences is used to measure the persistence of innovations in the series [Cochrane (1988)].

   Standard errors in parentheses.

   For K = 360, there are 3 non-overlapping samples. Max K should not exceed 1/3 N.

Table 10. **Persistence estimates**[1]
Monthly commodity prices (1970:1-1990:12)

no. of months	**2**	**4**	**12**	**24**	**36**	**50**	**60**
Wheat	1.20 (0.12)	1.19 (0.17)	1.21	1.42	1.32	0.85 (0.44)	0.54 (0.30)
Maize	1.15 (0.12)	1.25 (0.18)	1.20	1.22	1.01	0.69 (0.36)	0.47 (0.27)
Soyabeans	1.08 (0.11)	1.16 (0.17)	0.87	0.63	0.51	0.30 (0.15)	0.25 (0.14)
Cotton	1.00 (0.10)	0.98 (0.14)	0.93	0.50	0.37	0.29 (0.15)	0.28 (0.16)
Coffee	1.25 (0.13)	1.51 (0.22)	1.61	1.26	1.19	1.31 (0.68)	1.30 (0.73)
Copper	1.60 (0.11)	1.00 (0.15)	0.74	0.51	0.28	0.18 (0.19E-01)	0.13 (0.74E-01)
Sugar	1.10 (0.11)	1.11 (0.16)	1.20	0.99	0.95	1.11 (0.57)	0.99 (0.56)
Cocoa	0.98 (0.10)	0.85 (0.12)	0.67	0.49	0.42	0.36 (0.19)	0.32 (0.18)

1. Cochrane's method of k-differences is used to measure the persistence of innovations in the series [Cochrane (1988)].

   Standard errors in parentheses.

   For K = 60, there are 4 non-overlapping samples. Max K should not exceed 1/3 N.

Table 11A. **Correlations of monthly changes in commodity prices: 1970-1990**
(first difference of logs)

	Wheat	**Coffee**	**Cotton**	**Copper**	**Soyabeans**
Wheat	1.0				
Coffee	.15	1.0			
Cotton	.10	-.02	1.0		
Copper	.14	.13	.14	1.0	
Soyabeans	.35	.22	.22	.21	1.0
$\chi^2(10)$ = 67*					

Table 11B. **Correlations of weekly changes in commodity prices: 1970-1990**
(first difference of logs)

	Wheat	**Coffee**	**Cotton**	**Copper**	**Soyabeans**
Wheat	1.0				
Coffee	-.03	1.0			
Cotton	.02	.02	1.0		
Copper	.07	.08	.08	1.0	
Soyabeans	.43	.08	.07	.18	1.0
$\chi^2(10)$ = 248.6*					

* = Significant at the 1 per cent level.

Table 12. **Regressions of reduced form price equations**
1975:1 - 1990:12
Coefficients and standard errors are a linear combination of 6 order lags of the macroeconomic variables except own price

	CNS	**IP7**	**PPI**	**Interest rate**	**Mex**	**S&P**	**Price (-1)**	$\bar{R}^2$	**ARCH(1)**	**ARCH(2)**	**Q(6)**	**Q(36)**
Wheat	-.009 (.009)	.47 (1.17)	1.49 (1.38)	-11.2 (20.5)	-.21 (.30)	-.15 (-.28)	.21*** (.08)	.02	4.05**	5.99**	7.3	39.5
Maize	-.019* (.01)	1.65 (1.39)	2.81* (1.65)	-34.8 (24.6)	-.25 (.34)	.23 (.32)	.23*** (.08)	.10	3.4**	4.08	8.1	25.2
Soyabeans	-.018 (.011)	2.52* (1.55)	1.74 (1.79)	-62.6** (27.2)	-.52 (.39)	.43 (.35)	.10 (.09)	.05	7.4***	7.33**	13.6*	25.5
Cotton	-.03** (.004)	3.73** (1.95)	5.66*** (2.33)	-84.5*** (34.4)	.20 (.49)	.68 (.46)	-.12 (.08)	0	1.01	1.84	10.1	28.9
Coffee	.005 (.013)	1.6 (1.94)	-1.45 (2.13)	18.2 (32.2)	.16 (.44)	-.48 (.41)	.21*** (.08)	.02	8.5***	10.08***	9.1	35.2
Copper	-.013 (.012)	2.95* (1.65)	1.19 (1.89)	-37.0 (27.3)	.003 (.38)	.69 (.36)	.08 (.08)	.04	3.38*	6.43**	7.96	40.3
Sugar	-.32 (.02)	3.15 (3.6)	4.10 (4.8)	-26.9 (67.4)	-.72 (.96)	1.12 (.81)	.13 (.10)	.01	1.54	2.49	8.3	26.9
Cocoa	-.013 (.02)	2.73 (3.18)	.63 (3.95)	-24.2 (41.2)	-.05 (.61)	.15 (.46)	.008 (.11)	0	2.2	4.8*	10.3	25.3

All variables are in first differences of logs. ARCH(1) and ARCH(2) test of autoregressive conditional heteroscedasticity at 2nd and 4th lags.
Q(6) Ljung Box test of autocorrelated residuals.
***,**,* = significant at the 1, 5 and 10 per cent levels respectively.
Variable definitions CNS: constant; IP7: Industrial production - 7 largest OECD; PPI: Producer Price Index - US; MEX: Average exchange rate: US$, Yen, UK Sterling, German Mark; S&P: Standard & Poor's Composite Share Index.

Table 13. **F-tests from autoregressive models for commodity and macroeconomic volatility** (1978-1990)

A six variable 12th order vector autoregressive (VAR) model is estimated for each commodity (CPr), and industrial production OECD 7 (IP7), US producer price index (PPI), T-Bill interest rate (Interest), mean exchange rate, US$ to £, yen and DM (MEX), and Standard & Poor's composite stock price index (S&P).

Dependent variable	CPr	IP7	PPI	Interest rate	Mex	S&P	$\bar{R}^2$	d.f.	Q(36)
Wheat	1.17	1.35	2.46***	3.49***	1.44	.64	.49	72	16.9
Maize	.92	.50	.40	.54	.51	2.20**	.08	72	37.4
Soyabeans	1.45	.31	.77	.91	1.16	1.57	.21	72	29.9
Cotton	2.56***	.29	2.53***	.51	1.67*	.63	.26	72	27.4
Coffee	.99	1.38	2.17**	2.41***	1.39	1.54	.20	71	23.9
Copper	2.39	.69	1.66*	1.15	1.53	1.56	.26	59	36.1

Note: the analysis was not undertaken for sugar and cocoa due to lack of sufficient observations.

* = significant at the 1 per cent level;
** = significant at the 5 per cent level;
*** = significant at the 10 per cent level.

Table 14. **F-tests from autoregressive models for commodity and macroeconomic volatility** (deflated) (1978-1990)

A six variable 12th order vector autoregressive (VAR) model is estimated for each commodity (CPr), and industrial production OECD 7 (IP7), US producer price index (PPI), T-Bill interest rate (Interest), mean exchange rate, US$ to £, yen and DM (MEX), and Standard & Poor's composite stock price index (S&P).

Dependent variable	CPr	IP7	Interest rate	Mex	S&P	$\bar{R}^2$	d.f.	Q(33)
Wheat	.87	1.50	1.20	.58	.51	.32	60	19.7
Maize	1.34	1.24	.49	.86	2.22*	.21	60	22.9
Soyabeans	1.24	1.04	1.03	2.29*	2.08**	.35	60	18.0
Cotton	2.02**	0.25	1.51	.94	.38	.22	60	21.0
Coffee	.84	.40	.88	.57	2.8*	.16	60	30.1
Copper	2.87*	.86	1.03	1.43	1.31	.23	60	27.6

Note: the analysis was not undertaken for sugar and cocoa due to lack of sufficient observations.

*   = significant at the 1 per cent level;
** = significant at the 5 per cent level;
*** = significant at the 10 per cent level.

Table 15. **Decomposition of Variance**
Proportion of forecast error k-months ahead by each innovation, expressed as percentage[1]

k	Standard error	IP7	INT	PPI	MEX	SP	Wheat
Wheat (nominal)							
1	.016	.03	3.77	1.31	.67	.23	93.98
3	.017	3.48	5.46	3.68	6.31	1.79	79.2
6	.021	5.93	5.02	16.3	6.78	7.65	58.25
12	.024	7.59	4.97	27.12	7.68	6.04	46.6
24	.025	9.31	4.88	26.35	8.53	9.61	41.3
Soyabeans							
1	.022	.24	4.91	2.73	.015	.0006	92.1
3	.025	1.91	14.11	2.94	.95	5.19	74.9
6	.028	2.11	12.19	5.68	3.72	8.67	67.6
12	.033	3.5	10.0	10.0	13.9	11.9	50.6
24	.037	6.5	9.3	11.7	14.4	12.5	45.7
Coffee							
1	.031	6.27	.10	7.22	4.78	2.18	79.4
3	.033	8.06	.43	7.53	6.19	2.80	74.9
6	.036	7.6	.47	12.25	11.8	4.19	63.6
12	.041	11.44	1.23	12.7	14.8	7.14	52.6
24	.048	14.54	1.87	14.2	15.0	8.77	45.6

1. The MAR is based on systems estimates using variables estimated from a WLS procedure as explained in footnote 13.

Table 16. **Regressions of commodity price and macroeconomic volatility (1978:2-1990:12)**
VCommodity = α_1 VIP7 + α_2 VPI + α_3 VSP + α_4 VRT + α_5 VMEX + CNS

	$\bar{R}^2$	CNS	VIP7	VPI	VMEX	VSP	VRT
Wheat	.05	-.74 (.78)	.40 (.13)	-.007 (.07)	.26*** (.06)	-.08 (.09)	-.0005*** (.00017)
Maize	.04	-3.86*** (.50)	-.21 (.07)	-.00003 (.00007)	.018 (.06)	.16** (.08)	-.0014*** (.0001)
Soyabeans	.02	-4.7*** (.38)	-.11 (.08)	-.13** (.06)	.092* (.055)	-.11* (.06)	-.0004*** (.00012)
Coffee	.01	-5.75*** (1.8)	-.32 (.25)	.037 (.083)	-.004 (.09)	-.26*** (.09)	.0008*** (.00019)
Copper	.09	-2.43* (1.35)	-.005 (.05)	.15 (.12)	-.06 (.06)	-.034 (.09)	-.0047*** (.0002)
Cotton	.00	-3.3*** (1.17)	-.06 (.12)	.07 (.09)	-.07 (.11)	.08 (.10)	-.0001 (.0002)

VIP7: Volatility of industrial production; **VMEX**: Volatility of exchange rate; **VPI**: Volatility of producer prices, US;
VRT: Volatility of interest rate; **VSP**: Volatility of Standard & Poor's Index.
*,**,*** indicate significance at the 10, 5 and 1 per cent level respectively.
The use of estimated variables requires correction of the variance-covariance matrix. Standard errors are corrected by Hansen's methods using 12 lags and a dampening coefficient of .7. Standard errors in parentheses refer to corrected standard errors.

Table 17. **Regressions of commodity price and macroeconomic volatility (1978:2-1990:12)[deflated]**

VCommodity = α_1 VIP7 + α_2 VPI + α_3 VSP + α_4 VRT + α_5 VMEX + CNS

	$\bar{R}^2$	CNS	VIP7	VPI	VMEX	VSP	VRT
Wheat	.04	-1.37*** (.50)	.33*** (.11)	NA	.18** (.07)	-.10* (.054)	-.0008*** (.0012)
Maize	.00	-4.34*** (.64)	-.118 (.09)	NA	-.00091 (.09)	.17*** (.06)	-.0007 (.00008)
Soyabeans	.02	-2.83*** (.40)	.07 (.08)	NA	.126** (.05)	-.12*** (.047)	-.0009*** (.0001)
Coffee	.08	-6.42*** (1.90)	-.47*** (.13)	NA	-.033 (.06)	-.16 (.05)	.001*** (.00008)
Copper	.00	-4.34 (.99)	-.15 (.12)	NA	-.14 (.11)	-.009 (.06)	-.0015*** (.002)
Cotton	.01	-4.55*** (1.12)	-.033 (.15)	NA	-.32*** (.13)	-.033 (.07)	.0005*** (.0001)

VIP7: Volatility of industrial production; **VMEX**: Volatility of exchange rate; **VPI**: Volatility of producer prices, US;
VRT: Volatility of interest rate; **VSP**: Volatility of Standard & Poor's Index.
*,**,*** indicate significance at the 10, 5 and 1 per cent level respectively.

The use of estimated variables requires correction of the variance-covariance matrix. Standard errors are corrected by Hansen's methods using 12 lags and a dampening coefficient of .7. Standard errors in parentheses refer to corrected standard errors.

Table 18. **Excess volatility of expected returns**
(monthly commodity prices)

	β	**t-test** β **= 0**	**F-test** α **= 0** β **= 0**	χ^2 **test** α **= 0** β **= 0**	**D.F.**	**DW**
Wheat	-1.41	-.79 (-.91)	2.99**	8.7***	189	1.60
Maize	-3.25	-1.47a (-1.67)*	2.66*	9.95***	189	1.65
Soyabeans	-5.05	-2.15** (-2.30)**	3.34**	10.04***	189	1.76
Cotton	-4.34	-1.50a (-1.57)a	1.29	6.48**	189	2.13
Coffee	-2.05	-.76 (-.75)	.78	1.96	189	1.54
Copper	-3.01	-1.26 (-1.20)	.84	1.66	188	1.85
Sugar	-9.11	-1.97** (-2.08)**	2.08	4.72*	133	1.86
Cocoa	-1.66	-.54 (-.45)	1.32	2.41	119	1.99

Note: Standard errors are computed using the GMM, allowing for conditional heteroscedasticity used in the calculation of t-tests (t-tests of unrestricted estimation).

a significant at the 15 per cent level;
* significant at the 10 per cent level;
** significant at the 5 per cent level;
*** significant at the 1 per cent level.

Table 19. **Excess volatility of expected returns**
(weekly commodity prices)

	β	**t-test** $\beta = 0$	**F-test** $\alpha = 0$ $\beta = 0$	χ^2 **test** $\alpha = 0$ $\beta = 0$	**D.F.**	**DW**
Wheat	-.49	-.28 (-.26)	3.85**	8.33***	808	2.05
Maize	-1.83	-.88 (-.95)	2.96**	8.28***	808	1.86
Soyabeans	-3.98	-1.69* (-1.74)*	3.3**	8.25***	806	2.0
Cotton	-3.61	-1.38 (-1.43)a	.98	5.21*	808	1.95
Coffee	-2.04	-.24 (-.47)	.11	.23	790	2.8
Copper	-2.59	-1.08 (-1.18)	.70	1.61	810	2.2
Sugar	-11.2	-2.2** (-2.0)**	2.57*	4.17	563	2.0
Cocoa	-2.81	-.84 (-.87)	1.46	2.36	512	1.89

Note: Standard errors are computed using the GMM, allowing for conditional heteroscedasticity used in the calculation of t-tests (t-tests of unrestricted estimation).

a significant at the 15 per cent level;
* significant at the 10 per cent level;
** significant at the 5 per cent level;
*** significant at the 1 per cent level.

Table 20. **Autocorrelation - excess returns[1] relative to short-term Treasury bills**						
	Months averaged in autocorrelations					
	1	*1-12*	*13-24*	*25-36*	*37-48*	*49-60*
Soya	.12	-.11 (-.10)[2]	-.4	.14	-.17	.31
Cotton	-.059	-.28 (-.29)	-.07	-.05	.13	.18
Wheat	.19	.29 (.27)	-.23	-.22	-.13	0
Maize	.18	.10 (.086)	-.41	.01	-.3	.5
Coffee	.23	.10 (.081)	-.72	.68	-.46	.17
Copper	.07	-.08 (-.08)	-.17	-.17	0	.098
Sugar	.10	.05 (.048)	.03	.50	-.04	NA
Cocoa	.03	-.30 (-.30)	.16	-.13	.18	NA

1. Excess returns are defined as

$$ExR_i = \log(Pi_t/Pi_{t-1}) - \log(1 + i_{US(t-1)})$$

where i_{US} = US Treasury bill 1 month return.

2. Figures in parentheses are the average 1-12 month autocorrelation of excess returns less 1/12th of the coefficient of the first month.

APPENDIX 1

Data Definitions and Sources

Commodity price data are taken from the Knight Ridder database on Global Finance and Commodity Markets, except for copper.

1. **Wheat**: No.2, hard winter, Kansas City.

2. **Corn**: No.2, yellow, Central Illinois.

3. **Soyabeans**: No.1, yellow, Chicago.

4. **Cotton**: average market, 1 - 1/16.

5. **Coffee**: Brazilian, New York.

6. **Copper**: London Metal Exchange, World Metal Statistics, British Bureau of Non-ferrous Metal Statistics.

7. **Sugar**: world, raw, New York.

8. **Cocoa**: Ivory Coast, New York.

All data were sampled on Wednesday closing prices.

Macroeconomic Data

1. **Exchange rates**: £, DM and Yen to US dollar, OECD, Economics Department.

2. **Share prices**: Standard and Poor's Composite Stock Price Index.

All the data for 1 and 2 are sampled on Wednesdays.

3. **Interest rates**: US Treasury Bill, 1 month return, Ibbotson Associates 1992 Yearbook.

4. **Producer Price Index**: United States, OECD Main Economic Indicators (monthly).

5. **Industrial Production Index**: seven major OECD countries, OECD Main Economic Indicators (monthly).

APPENDIX 2

Table A2.1 **Tests of Autoregressive Roots**[1]
Deflated Annual Commodity Prices 1900-1988

	k=2	k=3	k=4	k=6
Wheat	-3.5^{*}	-3.8^{**}	-2.8	-2.3
Maize	-3.7^{*}	-3.6^{*}	-2.6	-2.6
Rice	-2.9	-2.8	-2.5	-2.7
Sugar	-2.9	-3.2	-2.6	-2.7
Wool	-2.8	-3.1	-2.3	-1.9
Cotton	-1.7	-2.0	-1.5	-2.0
Cocoa	-2.2	-2.3	-2.2	-2.4
Coffee	-2.4	-2.5	-2.5	-2.7
Copper	-2.1	-2.1	-1.9	-2.3
Rubber	-2.7	-2.6	-2.4	-1.0
Beef	-2.7	-3.1	-3.0	-2.8

Where k = no. of lagged price differences used in tests of significance for ρ in the estimating equation in footnote 1.

The null hypothesis is the presence of the unit root in the series' autoregressive representation with a trend embedded in the test equation. When the test statistic, as presented above, is significant, we can reject the null hypothesis of a unit root in favour of a trend stationary series.

** = significant at the 1 per cent level;
* = significant at the 5 per cent level.
(significance test values from Dickey-Fuller (1979) and Fuller (1976)).

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1. The estimating equation for the test is:

$$\Delta \ln y_t = \mu + \gamma t + \rho \ln y_{t-1} + \sum_{j=2}^{k} \alpha_j (\ln y_{t-j+1} - \ln y_{t-j}) + e_t$$

Table A2.2 **Tests of Autoregressive Roots**[1]
Deflated Quarterly Commodity Prices 1960:1-1989:4

	k=2	k=3	k=4	k=6
Wheat	-2.3	-2.7	-3.2	-2.4
Maize	-2.5	-2.5	-2.8	-2.4
Rice	-2.5	-2.8	-2.9	-2.6
Sugar	-2.6	-2.9	-2.6	-2.6
Soyabeans	-2.3	-2.4	-2.0	-2.2
Soyabeanmeal	-2.0	2.5	-2.4	-2.03
Beef	-2.3	-2.8	-3.1	-2.0
Cotton	-2.8	-2.8	-1.7	-1.4
Wool	-3.0	-3.9**	-3.4*	-2.7
Cocoa	-1.1	-1.4	-1.3	-1.4
Coffee	-2.0	-2.3	-1.7	-1.4
Copper	-2.8	-2.8	-3.1	-2.6
Rubber	-3.9**	-4.1**	-3.4*	-2.6

Where k = no. of lagged price differences used in tests of significance for ρ in the estimating equation in footnote 1.

The null hypothesis is the presence of the unit root in the series' autoregressive representation with a trend embedded in the test equation. When the test statistic, as presented above, is significant, we can reject the null hypothesis of a unit root in favour of a trend stationary series.

** = significant at the 1 per cent level;
* = significant at the 5 per cent level.
(significance test values from Dickey-Fuller (1979) and Fuller (1976)).

1. The estimating equation for the test is:

$$\Delta \ln y_t = \mu + \gamma t + \rho \ln y_{t-1} + \sum_{j=2}^{k} \alpha_j (\ln y_{t-j+1} - \ln y_{t-j}) + e_t$$

Table A2.3

A. Correlations of Quarterly Changes in Commodity Prices: 1960:1-1990:2
(Non-overlapping observations, first difference of logs)

	Wheat	**Sugar**	**Cotton**	**Copper**	**Beef**	**Rubber**	**Cocoa**
Wheat	1.0						
Sugar	.249	1.0					
Cotton	.094	-.109	1.0				
Beef	.200	-.156	.259	1.0			
Copper	.108	-.056	.145	.258	1.0		
Rubber	.302	.032	.348	.330	.263	1.0	
Cocoa	-.133	.177	.123	-.075	.187	.193	1.0

$\chi^2(21) = 80.63$*

B. Correlations of Annual Changes in Commodity Prices: 1900-1988
(Non-overlapping observations, first difference of logs)

	Wheat	**Sugar**	**Cotton**	**Copper**	**Beef**	**Rubber**	**Cocoa**	**Timber**	**Palm-oil**
Wheat	1.0								
Sugar	.291	1.0							
Cotton	.386	.469	1.0						
Copper	.443	.264	.368	1.0					
Beef	.253	.182	-.015	.303	1.0				
Rubber	.476	.335	.455	.556	.309	1.0			
Cocoa	.400	.388	.247	.372	.238	.279	1.0		
Timber	.612	.383	.534	.579	.430	.645	.531	1.0	
Palm-oil	.342	.256	.507	.542	.142	.439	.498	.674	1.0

$\chi^2(36) = 170.8$*

* = Significant at the 1 per cent level.

APPENDIX 3

A simple, neo-classical commodity model is used to examine the relationship between macro-economic variables and commodity prices. The model employed is adapted from Trivedi (1990). It specifies behavioural equations for production, demand and competitive storage, under the hypothesis of rational expectations. A reduced-form price equation is then derived for estimation purposes.

The following model is assumed to describe a generic commodity market:

$$\textit{Production}:\quad S_t = b_1 P^*_{t/t-1} + \gamma'_1 X_{1t} + \mu_{1t} \tag{1}$$

$$\textit{Consumption}:\quad D_t = -b_2 P_t + \gamma'_2 X_{2t} + \mu_{2t} \tag{2}$$

$$\textit{Inventory}:\quad I_t = b_3 (P^*_{t+1/t} - (1+r) P_t) \tag{3}$$

$$\textit{Market Equilibrium}:\quad I_t = S_t - D_t + I_{t-1} \tag{4}$$

where:

b_i and γ_i are parameters;
p^*_{t+j} = expected price at t+j; j = 0, 1;
X = vector of exogenous variables;
r = interest rate;
μ_i = error term.

It should be noted that under the rational expectations hypothesis b_3 is $\{k * Var(P_{t+1}|\Omega_t)\}$ and is also endogenous. However, due to the important non-linearities which this implies, a simplification as in Muth (1961) is used. The $Var(P_{t+1}|\Omega_t)$ is assumed constant and b_3 is then set at b. By substituting the relevant equations in the market equilibrium condition, we may express price at P_t as follows:

$$P_t = \lambda\, P_{t-1} + \alpha_1\, P*_{t+1/t} + \alpha_2\, P^*_{t/t-1} + Z_t \tag{5}$$

where:

$$\lambda = b(1+r) * F^{-1}$$

$$F = b(1 + r) + b_2$$

$$\alpha_1 = b * F^{-1};\ \alpha_2 = -(b + b_1) * F^{-1}$$

$$Z_t = F^{-1} (\gamma'_2 X_{2t} - \gamma'_1 X_{1t}) + F^{-1} (\mu_{2t} - \mu_{1t})$$

We assume that μ_t is white noise, thus:

$$E(\mu_{it}) = 0 \qquad E(\mu_{it}, \mu_{jt}) = 0 \qquad i \neq j, i = 1,2.$$

The price of a commodity is expressed as a function of the set of all exogenous variables of the structural model, including the expected price one period forward. The expected price variable is however unobservable, thus we must find a representation for the expected price which is observable. The more recent literature tends to assume that in forming price expectations on future prices, agents use all the available information efficiently, including the given structure of the economy.

The solution to (5) depends upon the roots of:

$$\alpha_1 \nu^2 - (1 - \alpha_2 \nu) + \lambda = 0 \tag{6}$$

where the real roots are ν_1, ν_2; $\nu_1 < 1$, and $\nu_2 > 1$ for the 'standard' case.

We follow Pesaran (1987), and Trivedi (1990) to solve for a unique forward reduced form solution to (5) using the method of Martingales, (8) and assume that the processes generating the exogenous variables in (5) are stationary.

Thus (5) is solved for P_T as follows:

$$P_t = \nu_1 P_{t-1} + Z_t - (\Phi_2)\ E(Z_t/\Omega_{t-1}) \tag{7}$$

$$Z_t = (1 - \alpha\nu_1)^{-1} \sum_{i=0}^{\infty} \nu_2^{-i}\ E(Z_{t+i}/\Omega_T) \tag{8}$$

where:

$$\Phi_2 = [(-b_2 - b)/(-b)*\nu_2] \tag{9}$$

In this formulation only forecasts of future values of exogenous variables are needed, in addition to lagged prices. For such purposes a distributed lag function of exogenous variables may be employed and this is the path we follow.

It should be noted that in the present specification of production, the information structure of the price expectation does not correspond to the known technology in agricultural production. A similar criticism has been made of the Trivedi model (1990). Palaskas and Gilbert (1990) argue that embedding a speculative stock demand in a general supply/demand model may be expected to give rise (under rational expectations) to a reduced form representation with the same general structure. Obviously this is not satisfactory procedure, but a more complete specification may be analytically intractable and an alternative specification is not possible given the resources currently available to the Secretariat.