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Efficiency in Commodity Futures Markets

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Abstract

This paper undertakes an econometric investigation into the efficiency of commodity futures markets. Despite a considerable amount of empirical literature, there is no general consensus on whether or not the markets are efficient. The results of this study suggest that for certain commodities expected excess returns to futures speculation are non-zero, however, it is argued that these results do not necessarily imply that markets are inefficient, or that agents do not act rationally. The implications of the study for the cost of using the futures markets for hedging, and for the power of futures prices to forecast future spot prices, are also noted.

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Summary

This paper undertakes an econometric investigation into the efficiency of commodity futures markets. Despite a considerable diversity of views in the empirical literature, there is no general consensus on whether or not the markets are even approximately efficient.

The paper analyzes the operations of the futures markets for a number of commodities over 1976-88 and tests several hypotheses about the efficiency of the markets. The results suggest that for several commodities expected excess returns to futures speculation are non-zero, particularly for forecast horizons of more than three months. The analysis shows, however, that these results do not necessarily imply that markets are inefficient, or that agents do not act rationally.

The paper also notes the implications of the study for the cost of using the futures markets for hedging and for the power of futures prices to forecast future spot prices.

I. Introduction

An important characteristic of the 1970s and 1980s has been the large volatility of primary commodity spot prices. For instance, from 1971 to 1974 prices of food commodities (in SDRs) rose by over 100 percent, but fell by 25 percent from 1974 to 1977. More recently, during 1983-1986 prices of metals and minerals fell by 23 percent, but rose by 54 percent from 1986-1988. This instability in commodity prices has affected the export earnings of a large number of developing countries, which depend for the bulk of their exports on a single, or a handful of commodities. To the extent that many developing countries are net importers of these commodities, their import bills have also fluctuated considerably. The fluctuations have had a serious impact on their income and consumption leading them to seek to find ways of reducing the fluctuations, or at least reducing their impact. At the macro level, the impact on economic management can be reduced, for instance, by the authorities' use of additional official funding as is provided by the IMF's Compensatory and Contingency Financing Facility (CCFF). 1/ At the more disaggregated level, the risks being faced by individual agents or groups of agents can be reduced by using available market instruments. It is in the latter context that hedging via the futures markets can play an important role, but this in turn may have important stabilizing effects in the aggregate.

Commodity futures are, of course, hardly new. The operations of several of the futures markets go back nearly a century. However, the recent sharp expansion in the size of these operations, together with advances in communications, mean that futures markets could make a substantial contribution to improving developing countries' welfare. A critical issue for any developing country contemplating the use of futures markets is the cost of using these markets. The costs are essentially of two kinds: the first one arises from the returns that may be demanded by other investors for assuming the risk of future spot price volatility, that is, the risk premium. The second cost arises from any market failure. If the market is not using publicly available information efficiently, futures prices become biased predictors of future spot prices, entailing additional costs in using the markets. 2/ An evaluation of these two types of costs revolves around the issue of market efficiency. According to the efficient market hypothesis, the expected excess rate of return to speculation in the futures market for commodities should be zero. Since excess returns to futures speculation can be decomposed into the risk premium component and the forecasting error

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1/ The CCFF was established in August 1988 replacing the former Compensatory Financing Facility (CFF). The new facility preserves the basic features of compensatory financing and in addition provides contingency financing from the Fund to help members maintain the momentum of Fund-supported adjustment programs. For an account of the operations of the facility see Pownall and Stuart (1988).

2/ Another cost of operating in the futures market is the transaction cost (which includes brokers' and other commission fees, the cost of maintaining margins, etc).

component, a test of the efficiency hypothesis can provide an indication of the costs due to one or both of these components.

Despite an extensive empirical research on futures markets there is little agreement on the extent to which these markets can be characterized as approximately efficient. The reasons for the lack of consensus include empirical evidence based on a heterogeneity of commodity samples, time periods, and econometric techniques. In any case, there are very few studies which have examined the data for the 1980s, which has been such a highly volatile period. The exercises this paper undertakes focus on the futures prices for seven commodity markets over the period 1976-1988. A number of different econometric tests are utilized to evaluate the degree of efficiency of these markets, and the ability of futures prices to forecast accurately future spot prices.

The rest of the paper is arranged as follows: Section II contains a discussion of the efficient markets hypothesis and of the existing main empirical studies on the validity of the hypothesis in commodity markets. Section III presents some simple descriptive statistics of excess returns in futures markets. Here the paper focuses primarily on the unconditional prediction errors of the futures prices, whilst in Section IV, the regression tests for conditional unbiasedness are undertaken. In Section V the paper evaluates whether there is any evidence that one or several variables consistently predict the excess returns in different markets over different sample periods. The paper focuses in this section on the out-of-sample forecasting accuracy of futures prices relative to alternative time series models. Finally, Section VI concludes the paper by noting the main implications of the empirical results and suggests directions for future research.

II. The Efficiency Hypothesis: Theory and Existing Empirical Studies

The concept of efficiency as applied to commodity future markets is no different from the concept as applied to any other asset market: the market is said to be (informationally) efficient if it utilizes all of the available information in setting the futures prices. The intuitive idea behind this concept of efficiency is that investors process the information that is available to them and take positions in response to that information as well as to their personal situations. The market aggregates all this diverse information and reflects it in the price. 1/

Formally, the market is said to be efficient with respect to some information set, ϕ, if futures prices would be unaffected by revealing that information to all participants. Moreover, efficiency with respect

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1/ Cf. Ross (1987). The use of efficiency in the informational sense is different from the notion of Pareto efficiency whereby an economy is efficient if it is not possible to produce more of any one good or service without lowering the output of some others.

to an information set, ϕ, implies that it is impossible to make economic profits by trading on the basis of ϕ. This notion of efficiency can be made empirically operational by noting that the expected excess returns to speculation in the futures market should be zero. Excess returns ν_{t+n} are defined by

$$\nu_{t+n} = ((f_{t+n}, T) - (f_t, T)) \qquad (1)$$

where (f_{t+n},T) denotes the log of the futures price at time t+n, for any given contract maturing at some time T (T > t+n). Similarly, (f_t,T) denotes futures price at time t, for contract maturing at time T. Since we only compare contracts of the same maturity, in order to simplify the notation, in subsequent discussion we will denote (f_t,T) by f_t, (f_{t+n}, T) by f_{t+n} and so on.

The null hypothesis of efficiency is that on average excess returns are equal to zero. 1/
That is,

$$H_o : E \ (\nu_{t+n}) = 0 \qquad (2)$$

If H_o is rejected it would imply that there is a systematic bias in futures prices over the life of a contract with futures prices at time T being on average higher or lower, than prices at t. 2/

Of course, a rejection of H_o does not necessarily imply that investors behave irrationally or that there are imperfections in the futures markets. This can be seen by noting that the excess returns in equation (1) can be decomposed into two components - a component reflecting forecast error and a component reflecting the risk premium, i.e.

$$\nu_{t+n} = f_{t+n} - f_t = [E(f_{t+n}) - f_t] + [f_{t+n} - E(f_{t+n})] = RP_t + \mu_{t+n}. \qquad (3)$$

The first term on the right $[E\ (f_{t+n}) - f_t]$ is the risk premium RP_t. One way to interpret this term is to regard it as the compensation demanded by risk averse investors for taking over the risk of future price changes. The second term is the forecast error μ_{t+n}. The forecast error would result if investors' expectations of the behavior of futures prices were not borne out, in other words their expectations were not rational.

1/ As we discuss presently this is a necessary but not a sufficient condition for efficiency.

2/ Although the information set at t+n is different from that at t, if markets are efficient, on average there is no presumption that f_{t+n} would exceed, or be less than, f_t.

Clearly if RP_t is non-zero, ν_{t+n} being non-zero, does not imply that μ_{t+n} is non-zero or that markets are not competitive. 1/

The above two components of efficiency in futures markets reflect directly the twin roles of the futures markets. The first, related to the notion of risk premium, is that futures markets act as insurance markets allowing diversification of commodity price risk. The second function is akin to the forecasting role--that is, futures prices provide forecasts of future spot prices. There is an extensive theoretical literature on both these roles. An example of the insurance role is the model by Danthine (1978) in which producers of commodities purchase inputs in a given period in order to deliver output in the following period. Future demand is uncertain and this generates price uncertainty. In this environment, Danthine shows that the role played by the futures price in the producers' decision problem turns out to be exactly analogous to the role of a certain output price. Firms act as if they were hedging the totality of their production on the futures market.

The role of futures prices as predictors of future spot prices was first rigorously analyzed by Samuelson (1965). In that paper he shows that under certain assumptions the sequence of futures prices for a given contract follows a martingale, or in other words, today's futures prices are the best unbiased predictor of tomorrow's futures price. Furthermore, since by arbitrage futures prices and spot prices are equalized at maturity, futures prices are also unbiased predictors of future spot prices.

These two roles of futures markets are closely related. In particular, forecasting accuracy of futures prices is, as Danthine shows, linked to the degree of risk aversion of the participants in the market. For example, if speculators, as opposed to hedgers, are risk neutral, and if agents use all the available information rationally, it can be shown that futures prices will follow a martingale as Samuelson demonstrates. On the other hand, if speculators are risk averse, they will require a premium from hedgers as compensation for taking over risk. As noted above, in such a case of risk aversion, futures prices will not be unbiased predictors of spot prices since they will also include the risk premium.

In Danthine's model, with only one asset market, risk premium is necessarily positive. This does not need to be true in the more general models such as that of Sharpe and Lintner's "Capital Asset Pricing Model" (CAPM) or Lucas' "Intertemporal Asset Pricing Model" (IAPM). 2/ Neither CAPM nor IAPM make any presumption about the sign of the risk premium

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1/ Even more strongly, as will be discussed presently, when $RP_t = 0$ (because investors are risk neutral, or because the sign of risk premium changes over time with its average being zero), $\mu_{t+n} \neq 0$ does not necessarily imply that investors are irrational.

2/ See, for example, Lucas (1978).

although they both assume that investors are risk averse, and prefer assets that help to reduce the risk of their well diversified portfolio (CAPM), or that they prefer assets that help to smooth consumption over time (IAPM). For example, in the latter model, if the expected gain from investing in the futures market covaries positively with investors' consumption, the risk premium will be positive because when the return is high, its marginal value to investors will be small. But if over time the conditional covariance of returns to futures assets and other assets in investors' portfolios is changing and may also change signs, the risk premium will also be changing, and can fluctuate from positive to negative.

Empirically the hypothesis of futures markets efficiency has been examined by a number of economists. Most of them imposed the condition of rational expectations and examined whether excess returns in the futures market reflect a risk premium. Since under rational expectations the average forecasting error would be expected to be zero, non-zero returns would indeed reflect risk premium. For example, Dusak (1973) analyzed the determinants of futures prices in the context of CAPM. In this framework, returns on futures market assets are governed by these assets' contribution to the risk of a large and well diversified portfolio. Dusak tested this model using bimonthly data for three commodities (wheat, corn, and soybeans) for the 1952-1967 period and found that risk premium in these contracts was not significantly different from zero. 1/ More recently, Hazuka (1984) tested a consumption oriented CAPM for several commodities that were classified according to storage characteristic. Only futures contracts with one month to expiration were utilized. Hazuka found that the risk premium involved in the futures contracts was significantly different from zero, although the estimates of the coefficients in the model were different from their theoretical values. 2/

Both Dusak and Hazuka impose the condition that the covariance of the return from holding a long position in the futures contract and the return on market portfolio (CAPM), or the marginal utility of consumption (consumption beta), is constant. To the extent that this is not so, their estimates of risk premia will not be consistent.

The third detailed study of market efficiency is by Jagannathan (1985). Again assuming rational expectations, he analyzes the determinants of risk premium. He examined whether two-month returns to futures speculation for three commodities (corn, wheat, and soybeans) for the 1960-1978 period are consistent with the consumption-beta model of risk premium. This model requires that the relative return to two

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1/ In a more recent study, Bodie and Rosansky (1980) found that if the Dusak sample is extended to a longer period (1950-1976), the unconditional excess returns are significantly positive.

2/ Hazuka examined one month to maturity returns of futures contracts for agricultural commodities including corn, oats, sugar, and wheat, and metals such as copper and silver.

different assets move proportionally to the relative conditional covariances of the return to each asset and the rate of change of consumption. Jagannathan models the time-varying conditional covariance between the rate of change of consumption and the real return to forward speculation by projecting the observed covariances on a set of variables that include U.S. industrial production growth and the U.S. terms of trade. He finds that while the comovements of the estimated ex ante returns to forward speculation and the estimated conditional covariances are broadly consistent with the predictions of the consumption-beta model, on the whole the evidence suggests that this model does not provide an adequate description of returns to futures speculation.

As these studies indicate, and as noted in the Introduction, the empirical evidence on efficiency in the commodity markets is heterogenous at best. Although the most recent evidence seems to suggest, at least for some sample periods, the presence of a time-varying risk premium thereby rejecting the hypothesis of market efficiency, it is not clear whether these statistical rejections imply a robust rejection of the efficiency hypothesis or whether in fact they are exploiting "too fine" prediction errors. One question that none of the papers answer is whether we could substantially improve the forecast of spot prices using some alternative model over the "suboptimal" predictions of futures prices. The rejection of the efficiency hypothesis will be less important if we can show that there are only trivial gains to be had by using more sophisticated models. For this reason, in Section V we evaluate those gains or losses by studying whether alternative models improve in a robust way the out-of-sample forecasting ability of futures prices. As an intermediate step, in Section III and IV we examine the in-sample forecasting ability of futures prices and some alternative models over different sample periods.

III. Tests of Unconditional Unbiasedness

Some preliminary evidence on the forecasting ability of futures prices can be obtained by testing whether the excess returns from holding a futures contract for n periods are on average equal to zero. Excess returns, ν_{t+n}, are defined as before:

$$\nu_{t+n} = f_{t+n} - f_t \tag{1}$$

where f_t (f_{t+n}) denotes the log of the futures price at t(t+n). We test whether futures prices are unbiased forecasts of future spot prices by testing the null hypothesis H_o: $E(\nu_{t+n}) = 0$ for n=1,3,6,9 months. 1/ The

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1/ The reason for calling this a test of 'unconditional' unbiasedness is because it is not dependent on any specific information set based on which expectations are to be taken. For instance, in subsequent analysis, the information set consists only of past prices of the same commodity, or information on macro-variables. Here, all publicly available information is included.

reason why testing the null hypothesis is equivalent to testing whether futures prices are unbiased predictors of spot prices at the maturity of the contract is because futures prices at maturity, f_T, are equal to spot prices, s_T, by arbitrage. 1/ Since futures contracts do not mature each month, by using futures prices from contracts maturing at different times we can increase the sample size very substantially. 2/ Therefore, the unbiasedness test based on excess returns as described in equation (1) has more power than similar tests based on excess returns over maturity spot prices, s_T-f_T.

Table 1 presents the results of this test for seven different commodities for the thirteen-year period 1976-1988. It shows the mean excess return from holding a futures contract for 1, 3, 6, and 9 months (i.e. a forecast horizon of 1, 3, 6, 9 months), and the corresponding t-statistic for the test of the null hypothesis of unbiasedness. In the case of corn, for instance, for a forecast horizon of 1 month, the mean excess return was -0.003 which is not significantly different from zero. Although mean excess returns are positive for some commodities such as cocoa and coffee, they are not statistically different from zero for any of the seven commodities, over any of the four forecast horizons.

The results in Table 1, superficially at least, suggest that the null hypothesis of a zero bias in futures prices cannot be rejected. However, the evidence is also consistent with the presence of a bias that is positive during some years and negative in others, and has a mean zero. Since there is evidence from other asset markets, such as the foreign exchange market, that this is in fact the case, it would be important to check whether there is a time-varying bias in the futures markets. One simple procedure for isolating any such bias would be to divide the sample into subperiods over which it is expected to display differential behavior. The method of obtaining the subsamples is based on the evidence on investor expectations in the foreign exchange market. This evidence suggests, for instance, that investors consistently underpredict the value of an asset when the asset is appreciating (for example, the dollar in the early eighties) and systematically overpredict it when it is depreciating (as was the case after 1985 when the dollar started to depreciate (see Frankel and Froot (1987), and also Kaminsky (1988)). Following this type of evidence, we divided the 1976-1988 period into subperiods according to whether the commodity spot price was increasing or decreasing. As it

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1/ To see the equivalence of the null hypothesis and the proposition that futures prices are unbiased predictors of future spot prices, apply iteratively the unbiasedness hypothesis k periods, and note that the time t information set is a subset of the t+1 information set. This gives:

$$f_t = E_t(f_{t+1}) = E_t[E_{t+1}(f_{t+2})] = E_t(f_{t+2})$$

$$= \ldots E_t(s_{t+k})$$

2/ See Annex for the methodology for combining different futures contracts.

Table 1. Tests of Unconditional Unbiasedness: Complete Sample

Commodity	Forecast Horizon	Excess Returns 1/ $f_{t+i} - f_t$ Mean	"t-statistic"
Food			
Corn	1	-0.003	-1.289
	3	-0.008	-1.372
	6	-0.014	-1.304
	9	-0.020	-1.340
Soybeans	1	-0.001	-0.281
	3	-0.002	-0.241
	6	-0.001	-0.117
	9	-0.000	-0.029
Wheat	1	-0.002	-1.129
	3	-0.006	-1.061
	6	-0.012	-1.069
	9	-0.017	-1.005
Beverages			
Cocoa	1	0.001	0.479
	3	0.002	0.309
	6	0.003	0.150
	9	0.007	0.242
Coffee	1	0.004	1.222
	3	0.013	1.344
	6	0.019	1.000
	9	0.032	1.100
Raw Materials			
Copper	1	0.001	0.317
	3	0.001	0.207
	6	-0.001	-0.117
	9	-0.006	-0.309
Cotton	1	0.001	0.608
	3	0.002	0.326
	6	0.004	0.296
	9	0.008	0.445

Note: The 't' statistics use standard errors corrected for autocorrelation (using methods of moments). The i subscript refers to the forecast horizon (i = 1, 3, 6, 9). The sample is from March 1976 to December 1988.

turned out, the results for futures markets were quite similar to those for other asset markets. For illustrative purposes, Table 2 presents the results for two commodities. Consider first the results for wheat, for which the period March 1976 to December 1988 was divided into four subperiods: March 1976 to December 1976, December 1976 to January 1981, January 1981 to July 1986 and July 1986 to December 1988. During the third subperiod, the excess returns in the futures market were consistently negative for all four forecast horizons, indicating that futures prices overpredicted future spot prices. Conversely, during the last subperiod, excess returns had the opposite sign. In the case of cocoa, (with four different subperiods) during 1976-77, the excess returns were consistently positive whilst over the 1986-1988 period they were negative. For both commodities, the forecasting bias (i.e. the excess returns) is generally significantly different from zero and is substantial in magnitude, reaching as much as 8 percent per year. As in the foreign exchange market, the nature of the bias changes over time and it is on average positively correlated with the sign of the change in the commodity spot price. For example, during the 1981-1986 period the price of wheat declined almost continuously (see figure 1) and realized excess returns during this period were negative (throughout the early 1980s, it was expected that wheat spot prices would begin to increase). During the 1986-1988 period when the price of wheat followed an upward trend, the excess returns in the futures market were consistently positive. In the case of cocoa during the 1986-1988 period, spot prices were expected to rise, but instead showed a downward trend with consistently negative excess returns (figure 2).

Similar results, although not reported, were obtained for the other commodities for different subperiods. For example, during the early 1980s when spot prices in the soybean and the corn markets showed a trend decline, excess returns in the futures market for both commodities were consistently negative. In some cases these excess returns were over 20 percent per year, such as for corn from January 1981 to October 1982, or 16 percent, in the case of soybeans from November 1980 to October 1982. Similar pattern was found in the other markets although the results were less significant.

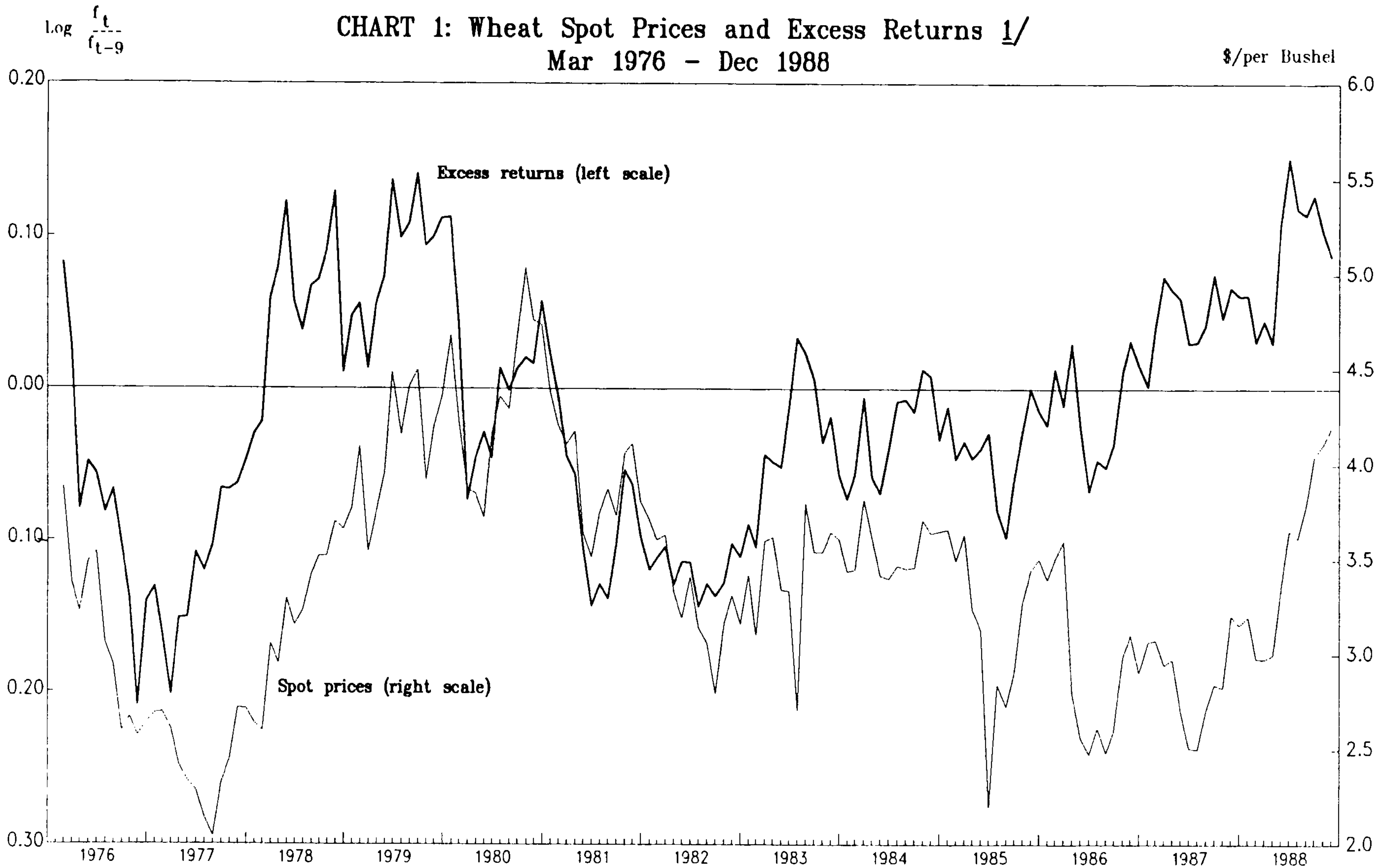
This evidence of excess returns significantly different from zero does not necessarily imply market failure. There are two main reasons for this. The first revolves around the possibility that although expectations are rational ex-ante they may look biased ex-post. An explanation of why this may be the case can be provided by the following example in which investors use all the available information efficiently but still make non-zero forecast errors due to the fact that the information is incomplete. Suppose a country's monetary authority follows a contractionary monetary policy during some years and reverts to an expansionary monetary policy in subsequent years. Other things given, investors will in general observe that nominal prices of commodities will be falling when monetary policy is contractionary and increasing

Table 2. Tests of Unconditional Unbiasedness: Selected Subsamples for Wheat and Cocoa

Commodity	Forecast Horizon	Sample Period	Excess Returns $f_{t+i} - f_t$ Mean	"t-statistic"
Wheat	1	3/76-12/76	-0.020	-1.75
	3		-0.046	-1.86
	6		-0.075	-3.32
	9		-0.067	-2.11
	1	12/76-1/81	0.002	0.44
	3		0.006	0.58
	6		0.004	0.21
	9		0.001	0.04
	1	1/81-7/86	-0.007	-2.63
	3		-0.020	-3.41
	6		-0.039	-3.86
	9		-0.054	-3.95
	1	7/86-12/88	0.005	1.16
	3		0.018	2.44
	6		0.039	3.39
	9		0.048	2.37
Cocoa	1	3/76-3/77	0.044	4.27
	3		0.119	9.81
	6		0.221	9.31
	9		0.292	7.70
	1	3/77-8/82	0.007	-0.53
	3		0.040	-0.51
	6		0.074	-0.51
	9		0.128	-0.06
	1	8/82-1/84	0.010	1.08
	3		0.014	0.87
	6		0.013	0.36
	9		0.000	0.01
	1	1/86-12/88	-0.009	-1.82
	3		-0.029	-2.95
	6		-0.053	-3.75
	9		-0.067	-3.53

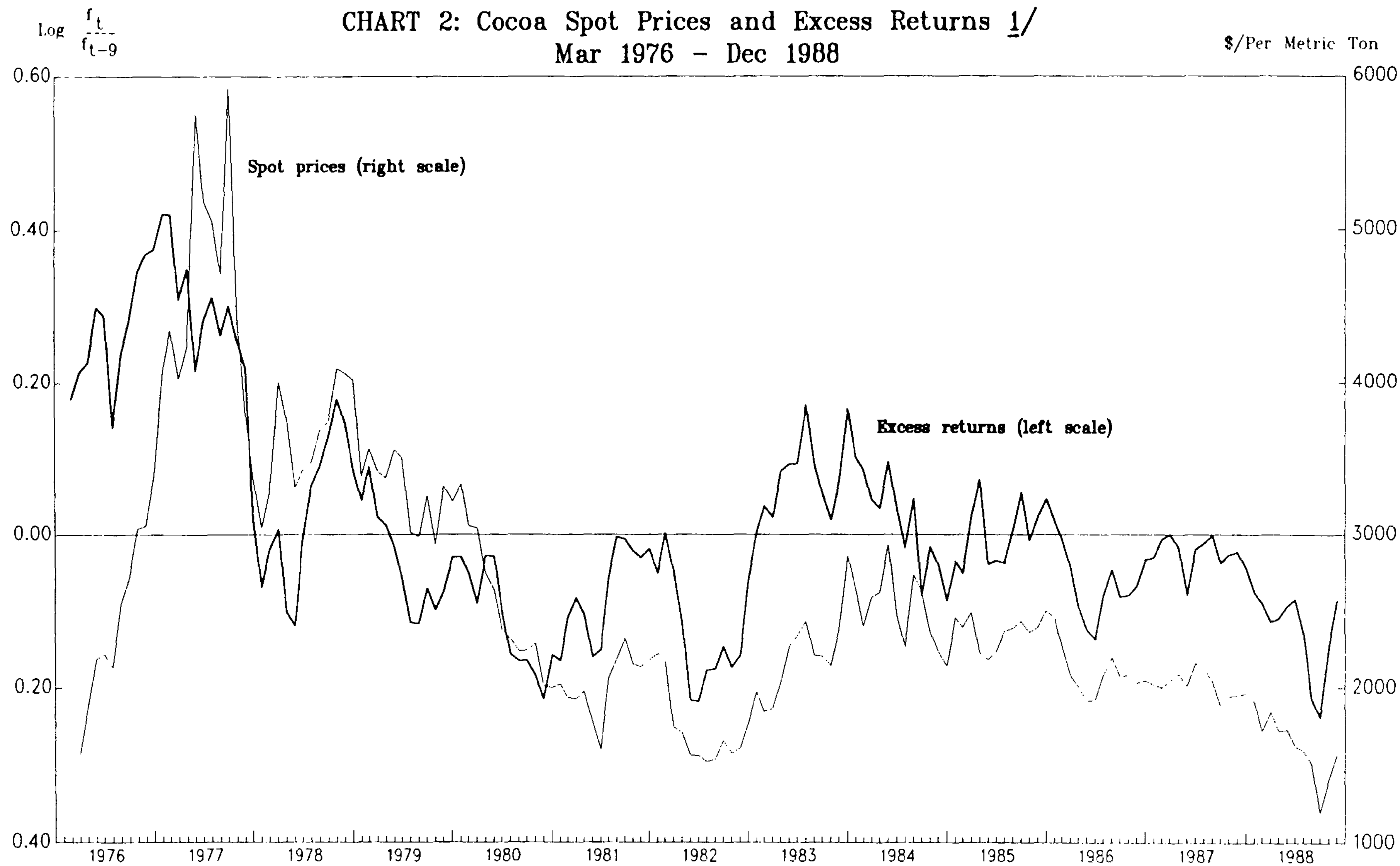
Note: The 't' statistics use standard errors of means corrected for autocorrelation (using method of moments).

CHART 1: Wheat Spot Prices and Excess Returns 1/
Mar 1976 - Dec 1988



1/ Nine months forecast horizon.

CHART 2: Cocoa Spot Prices and Excess Returns 1/
Mar 1976 - Dec 1988



1/ Nine months forecast horizon.

otherwise. Suppose that in these circumstances, the spot price of a given commodity can be written as follows:

$$s_t - s_{t-1} = \delta_i + \epsilon_t \tag{4}$$

where δ_i is positive if the monetary policy is expansionary (δ_e) and negative (δ_c) otherwise, and ϵ_t is a white noise process. 1/ Suppose that investors know that the monetary authority can change its policy from contractionary to expansionary but do not know with certainty when the change will be implemented. Of course, being rational they will use all the information available to predict the time of the change. But, the prediction can only be probabilistic: the best they can do is to estimate the probability that the policy will be changed in a given period. 2/ Suppose that the current policy is contractionary, and denote by p_t the probability of switching to an expansionary policy in period t. In this case the expected decline in the future spot price, using all available information up to period t-1, $E(S_t - S_{t-1})$ will be

$$E_{t-1}(S_t - S_{t-1} = \delta_e p_t + \delta_c(1-p_t) \tag{5}$$

Suppose now that, as it turns out, the change in policy is not implemented for several periods. If we estimate the mean forecast error during this period we will obtain

$$E_{t-1}(S_t - S_{t-1}) = (\delta_c - \delta_e)p_t \tag{6}$$

which is different from zero, even though expectations were completely rational ex-ante. In such a situation, as Frankel and Froot conclude (in the case of the foreign exchange market), "Investors could even be rational, and yet make repeated mistakes of the kind detected here, if the true model of the spot process is evolving over time" (p. 150). In other words, when a given variable follows a process that is changing over time, agents in the process of learning will make mistakes. However, it does not mean that agents are not rational or that it will be possible to make money speculating in a market with such an environment.

Of course, over a long-run period--such as the thirteen-year period for our sample--there are very likely to be periods of both upswing and downswing in prices, or periods of both contractionary or expansionary policies. This would mean that over a large sample period investors'

1/ It can be shown using the Lucas (1980) model that this will be the stochastic process followed by spot prices if money supply follows a random walk process with a changing drift δ_i and output is constant.

2/ This issue can also be analyzed in the standard Bayesian approach. Agents acquire new information in each period and revise prior beliefs continuously. The distribution of the information set, therefore, becomes tighter over time. This approach is consistent with the fact that markets appear to be more efficient over the short-term horizon than over the longer term.

forecasting errors, positive in some periods, negative in others, would tend to balance each other out. In such a situation, on average, the forecasting error will not be significantly different from zero--exactly the result obtained earlier in Table 1 for our full sample.

A second reason for the evidence of non-zero excess returns not implying market failure is the existence of a non-zero time-varying risk premium. Earlier it was shown that the excess returns in the futures markets can be decomposed into a forecast error, μ_{t+n}, and a risk premium, RP_t (equation 3). Conditional on the assumption of a zero forecast error, a non-zero excess return could simply be interpreted as evidence of non-zero risk premium--indicating that investors are risk averse. As noted in Section II, modern theories of asset pricing suggest that the risk premium separating futures prices in a given period from futures prices in subsequent periods will vary through time proportionally to the movements in the covariance of the returns of futures contracts and consumption. Since this conditional covariance may change signs, no bias need be found over a large time interval yet over any given time period the expected excess return may be different from zero.

Although the above tests for efficiency appear fairly clear, they are based on a sample that relies on ex post choice of possible breakpoints. Whilst such a procedure has been followed in the literature, it may not be quite legitimate since by definition the information on breakpoints is not available to investors ex ante. The next Section presents tests of efficiency that overcome this problem.

IV. Weak and Semi-Strong Tests of the Efficiency Hypothesis

The aim of this section is twofold: first, to examine the efficiency of futures markets without the imposition of ex-post sample separation; secondly, in the event that the null hypothesis of efficiency appears not to hold, to find those variables that can consistently predict excess returns and hence improve over the forecast of spot prices made by using futures prices only.

The tests undertaken below are the standard tests used in the finance literature to test the efficient market hypothesis. These tests, proposed by Fama (1970), distinguish two levels of market efficiency: (1) The 'weak form' which asserts that current prices fully reflect the information contained in a historical sequence of prices. Thus investors who rely on past price patterns cannot expect to receive any abnormal returns (this is the random walk hypothesis). (2) The 'semi-strong' form which asserts that current asset prices reflect not only historical price information but also all publicly available information relevant to the futures markets. If markets are efficient in this sense, then no publicly available information (such as that, say, concerning the macroeconomic environment) can yield abnormal returns. 1/

Efficiency tests as applied to the futures market exploit the proposition that if information is used efficiently and there is no risk premium, the excess return from holding a futures contract for n periods (f_{t+n} - f_t) should not be correlated with information up to time t. This is because in such a case the excess return is just the forecasting error, and efficiency requires the forecasting error to be orthogonal to variables in the information set, I_t. 2/ This null hypothesis of market efficiency can be examined by testing the hypothesis that $\beta_0=\beta_m=0$ in the following regression:

$$f_{t+n} - f_t = \beta_0 + \beta_m' x_t + \epsilon_{t+n} \quad (7)$$

where x_t is a vector of variables in the information set I_t, and β_m' is a vector of m coefficients. Since under the null hypothesis, x_t and ϵ_{t+n} are orthogonal, OLS will generate consistent estimates of the coefficients. In our case though, the OLS estimates of the standard errors will not necessarily be consistent for two reasons. First, the errors might not be homoscedastic. The results of the White test (Table 3) suggest that for the majority of commodities the null hypothesis of heteroscedasticity cannot be rejected. Secondly, the errors in equation (7) may not be uncorrelated since the sampling interval does not necessarily equal the forecasting interval. In this case, as Hansen and Hodrick (1980) show, the errors will be moving averages of order (n-1) where n is the forecast horizon. To obtain consistent estimates of the standard errors, we computed the correct asymptotic covariance matrix using the Method of Moments (MOM) estimator proposed by Hansen (1982). Since in small samples the covariance matrix so estimated may not be positive definite we apply the Newey-West (1985) correction to guarantee positive definiteness.

Although any element of the information set I_t could be used in a test of the hypothesis that (f_{t+n} - f_t) is orthogonal to I_t, in order to have a test with sufficient power one would want to use elements which are a priori likely to be important determinants of the excess returns. The elements in I_t that we have selected fall into three categories, with the first category corresponding to the weak form of efficiency and the second and third categories corresponding to the semi-strong form. Thus category (1) includes past excess returns from the same commodity market;

1/ There is a third 'strong' form of efficiency which asserts that all information that is known to any investor, including privately held information, is reflected in market prices. Thus no abnormal excess returns are possible.

2/ Note that in these tests the notion of efficient use of the available information imposes stronger restrictions that the one discussed in the previous section in which investors had incomplete information about the stochastic process followed by the variable in question.

Table 3. White Test for Heteroscedasticity 1/

Commodity	χ^2 (4) 2/	Marginal Significance Level
Food		
Corn	3.367	0.4984
Soybeans	33.712	8.537 E-7
Wheat	1.554	0.8170
Beverages		
Cocoa	6.616	0.1576
Coffee	9.521	0.0493
Raw Materials		
Copper	46.336	2.0966 E-6
Cotton	17.627	0.0015

1/ The dependent variables are the "Excess Returns" to a long futures position in each of the seven commodity markets. The right hand side variables include the lagged dependent variable with one and two lags and the square of the lagged dependent variable, also with one and two lags.

2/ The χ^2 statistic is a test of the restriction that the errors are homoscedastic. The sample is from March 1976 to December 1988.

category (2) past excess returns from the same and other commodity markets; and category (3) past excess returns from the same commodity market as well as some macrovariables such as aggregate consumption, industrial production and the terms of trade that are likely to affect savings or investment, and therefore, rates of return on futures assets.

Table 4 presents the estimates of the "weak" test based on the following equation, which indicates excess returns in a given market as a function of a constant and three lagged excess returns:

$$f_{t+n} - f_t = \beta_0 + \sum_{m=1}^{3} \beta_m (f_{t-m+1} - f_{t-n+1}) + \epsilon_{t+n} \qquad (8)$$

In this Table we present the point estimates of the β's and the corresponding t-statistics, as well as the test of the null hypothesis that expected returns are zero (χ^2 statistic) with the corresponding significance levels. As the results indicate, the strongest evidence against the joint hypothesis of no market failure (i.e. no forecast error) and zero risk premium occurs in the cocoa and the copper markets at 3 and 6 months forecast horizon respectively. In both cases some of the lagged excess returns have marginal significance levels smaller than 10 percent. Although the constants are not significantly different from zero, we reject the null hypothesis that all coefficients for these two commodities are zero at marginal significance levels smaller than 5 percent. For wheat and coffee also, for the nine-month forecast horizon we can reject the null hypothesis at better than 10 percent level of significance. But for other maturities for wheat and coffee, and other commodities there is no strong evidence against the null hypothesis. In other words, for three of the seven commodities, namely corn, soybeans and cotton, the futures markets can be clearly said to be efficient in the 'weak form'. For the other four commodities, however, the null hypothesis of efficiency appears rejected for some of the forecast horizons at the conventional levels of significance.

Of course, the tests in Table 4 only use data from the "own" market. Since, as is generally accepted, these tests may not have enough power, we next discuss in Tables 5 and 6 the results of the "semi-strong" efficiency test. The first of these two tables presents the results of the own forecast error and the six other commodities' lagged forecast errors, as indicated by the following equation:

$$f^j_{t+n} - f^j_t = \beta_0 + \sum_{m=1}^{7} \beta_m (f^m_t - f^m_{t-n}) + \epsilon^j_{t+n} \qquad (9)$$

where the superscript j refers to commodity j.

Table 4. Weak Test of Efficiency: Complete Sample 1/

Commodity	Horizon	β_0 (t-stat)	β_1 (t-stat)	β_2 (t-stat)	β_3 (t-stat)	$\chi^2(4)$ Marginal Significance Level 2/
Food						
Corn	1	-.003 -1.24)	-.010 (-.08)	.051 (.85)	-.050 (-.82)	3.35 (0.5011)
	3	-.008 (-1.42)	-.038 (-.31)	-.041 (-.42)	.001 (.01)	2.31 (0.6789)
	6	-.014 (-1.26)	-.102 (-.64)	-.022 (-.17)	.162 (1.08)	2.93 (0.5696)
	9	-.024 (-1.44)	-.082 (-.40)	-.176 (-1.57)	.173 (.81)	2.99 (0.5595)
Soybeans	1	-.011 (-1.09)	-.620 (-.95)	-.311 (-.92)	-.222 (-1.43)	2.23 (0.6935)
	3	-.012 (-1.15)	.061 (.40)	-.522 (-1.16)	.327 (.92)	2.53 (0.6393)
	6	-0.003 (-0.29)	0.029 (0.27)	-0.037 (-0.24)	0.049 (0.30)	0.32 (0.9885)
	9	-0.005 (-0.32)	-0.087 (-0.41)	-0.141 (-1.00)	0.142 (0.64)	1.31 (0.8597)
Wheat	1	-0.002 (-1.10)	-0.040 (-0.51)	0.001 (0.01)	-0.058 (0.84)	1.94 (0.7468)
	3	-.005 (-.94)	.028 (.28)	.037 (.36)	.052 (.53)	2.45 (0.6536)
	6	-.003 (-.31)	.306 (1.83)	.027 (.22)	.017 (.12)	6.11 (0.1911)
	9	-0.002 (-0.08)	0.009 (0.04)	0.121 (1.21)	0.331 (1.87)	8.22 (0.0838)
Beverages						
Cocoa	1	.001 (.44)	.045 (.56)	-.081 (-.84)	.018 (.25)	1.36 (0.8511)
	3	.000 (.63)	-.007 (-.08)	.157 (1.16)	.326 (2.74)	19.59 (0.0006)
	6	-.011 (-.79)	.217 (1.49)	-.072 (-.72)	.288 (2.02)	9.14 (0.0577)
	9	-.019 (-0.94)	.140 (0.68)	.043 (0.32)	.225 (1.14)	6.02 (0.1977)
Coffee	1	.004 (1.09)	-.027 (-.26)	.101 (1.04)	.071 (.79)	2.78 (0.5953)
	3	.013 (1.50)	.194 (1.66)	.072 (.67)	-.223 (-1.52)	5.58 (0.2328)
	6	.007 (.43)	.042 (.33)	.051 (.43)	.033 (.21)	0.49 (0.9745)
	9	0.019 (0.83)	-0.374 (-2.19)	0.105 (0.96)	0.166 (0.77)	8.32 (0.0805)

Table 4 (concluded) Weak Test of Efficiency: Complete Sample 1/

Commodity	Horizon	β_0 (t-stat)	β_1 (t-stat)	β_2 (t-stat)	β_3 (t-stat)	$\chi^2(4)$ Marginal Significance Level 2/
Raw Materials						
Copper	1	.001 (.33)	.051 (.47)	-.130 (-.94)	.077 (.90)	2.65 (0.6180)
	3	.002 (.23)	-.028 (-.19)	-.004 (-.20)	.091 (.66)	0.69 (0.9526)
	6	-.002 (-.18)	.347 (3.18)	.067 (.49)	-.097 (-.60)	10.69 (0.0303)
	9	-0.002 (-0.11)	0.09 (0.43)	0.20 (1.04)	0.11 (0.59)	5.20 (0.2674)
Raw Materials						
Cotton	1	.001 (.41)	-.216 (-.97)	.151 (1.23)	-.131 (-.95)	2.50 (0.6446)
	3	.001 (.13)	.094 (.56)	.003 (.02)	-.123 (-.67)	0.58 (0.9653)
	6	-0.001 (-0.13)	-0.022 (-0.16)	0.045 (0.28)	0.113 (0.66)	0.78 (0.9411)
	9	0.002 (0.11)	-0.277 (-1.54)	-0.066 (-0.34)	0.142 (0.57)	3.86 (0.4253)

1/ These are the estimates for equation 4 in the text. The dependent variable in the excess return in each of the seven commodity markets. the right hand side variables include a constant and the lagged dependent variable with 1, 2, and 3 lags. The χ^2 is a test of the null hypothesis that expected excess returns are zero.

2/ Values of marginal significance level close to zero indicate evidence against the null hypothesis that one or more of the coefficients equals zero.

Intuitively, the use of past price information concerning other commodity markets, in addition to the "own" price information, should make it easier to earn excess returns compared to using the commodity's own price history only. This is so since presumably futures prices in other markets yield information which will complement or supplement the information from a commodity's past history.

The results of this test are presented in Table 5. Now, contrary to the results in Table 4, the null hypothesis that all the coefficients are zero is rejected for six out of seven commodities for the 6- and 9-month horizons, at 5 percent level of significance or higher. However, for the 1-month horizon, the null hypothesis cannot be rejected for any of the commodities whilst for the 3-month horizon, it is rejected for four out of the seven commodities. Given that this multi-commodity test is more powerful the results in this table do suggest that for short horizons the joint hypothesis of zero risk premium and no market failure cannot be rejected. However, for longer horizons these results can be regarded as fairly strong evidence against the efficiency of these futures markets, especially since the results are based on a thirteen-year period.

These conclusions are further corroborated by the final test of efficiency, whose results are presented in Table 6. As discussed earlier, in testing for non-zero expected real profits à la semi-strong test, we should run a regression with the excess returns on the left hand side and variables in the publicly available information set, on the right hand side. As in the efficient markets literature, we assume that if the information was in the public domain then it was available to the public and should have been reflected in prices. Of course, this ignores the cost of acquiring the information, but the justification for this position is that the costs of acquiring such public information are small compared to the potential rewards. In principle any variable in such an information set is a candidate in the regression equation. However, to improve the power of the test we should include those variables more closely related with, for example, the risk premia in these markets. In the following test we have introduced different macroeconomic variables for the U.S. such as the growth rate of consumption, the terms of trade, the inflation rate, the growth rate of industrial production, the growth rate of money supply and the riskless interest rate as measured by the treasury bills yield as well as the own lagged forecast error. These were chosen as explanatory variables because a number of existing studies suggest that they should affect investment and consumption decisions and therefore possibly rates of returns in the asset markets (cf. Jagannathan op. cit.). It is worth emphasizing that the use of the data for the U.S. is likely to be as good a proxy as any for the macrovariables in the information set. In particular the use of U.S. data would not lead to any weakening of the test or introduce any spurious bias.

Table 6 contains results of the regressions of excess returns in each of the commodity markets over the 1976-1988 period, on the above set of macrovariables. Rather than present the results of each of the coefficients, the table shows only the values of the χ^2 statistic for the

Table 5. Semi-Strong Test of Efficiency: Full Sample 1/

Forecast Horizon	β_0 (t-stat)	β_1 (t-stat)	β_2 (t-stat)	β_3 (t-stat)	β_4 (t-stat)	β_5 (t-stat)	β_6 (t-stat)	β_7 (t-stat)	$\chi^2(8)$ Marginal Significance Level
Food									
Wheat									
1	-0.003	0.059	-0.137	0.020	0.011	-0.038	-0.026	0.001	7.41
	(-1.30)	(0.53)	(-1.45)	(0.19)	(0.10)	(-0.76)	(-0.63)	(-0.02)	(0.4931)
3	-0.003	0.179	-0.018	-0.102	-0.160	-0.065	-0.119	0.088	15.92
	(-0.59)	(1.54)	(-0.15)	(-1.04)	(-1.51)	(-1.00)	(-2.49)	(0.93)	(0.0435)
6	-0.004	0.157	-0.204	-0.213	0.122	-0.036	-0.195	0.276	31.25
	(-0.44)	(1.48)	(-1.33)	(-1.99)	(0.94)	(-0.48)	(-3.01)	(2.56)	(0.0001)
9	-0.004	0.403	-0.610	-0.271	0.397	0.052	-0.215	0.347	76.78
	(-0.46)	(3.26)	(-4.44)	(-2.19)	(2.95)	(0.66)	(-3.04)	(3.45)	(0.0000)
Corn									
1	-0.003	0.065	-0.163	0.034	0.210	-0.027	0.036	-0.110	10.85
	(-1.40)	(0.55)	(-1.18)	(0.75)	(1.53)	(-0.29)	(0.88)	-2.06	(0.2103)
3	-0.007	-0.138	0.124	-0.108	-0.155	0.052	-0.054	0.234	19.68
	(-1.19)	(-1.09)	(0.77)	(-1.11)	(-0.96)	(0.70)	(-1.06)	(2.46)	(0.0116)
6	-0.007	-0.091	0.124	-0.117	0.096	0.040	-0.176	-0.397	24.78
	(-0.71)	(-0.54)	(0.62)	(-1.05)	(0.62)	(0.44)	(-2.92)	(3.33)	(0.0017)
9	-0.015	-0.065	-0.174	-0.016	-0.006	-0.013	-0.146	0.544	36.26
	(-1.12)	(-0.26)	(-0.82)	(-0.14)	(-0.04)	(-0.11)	(-1.79)	(4.33)	(0.0000)
Soybeans									
1	-0.001	0.048	0.173	-0.048	-0.228	0.068	-0.005	-0.069	3.81
	(-0.47)	(-0.35)	(-1.06)	(0.30)	(1.34)	(0.87)	(-.09)	(-1.05)	(0.8738)
3	-0.002	-0.068	0.137	0.018	-0.264	-0.146	-0.062	-0.166	8.86
	(-0.34)	(-0.56)	(0.72)	(0.15)	(-1.11)	(1.97)	(-0.94)	(-1.38)	(0.3542)
6	-0.000	-0.252	-0.130	-0.143	-0.228	-0.201	-0.155	0.462	73.69
	(-0.02)	(-1.55)	(-0.65)	(-1.14)	(-1.06)	(-2.46)	(-2.70)	(3.18)	(0.0000)
9	-0.004	-0.067	-0.201	0.219	-0.288	0.126	-0.126	0.632	107.72
	(-0.27)	(-0.35)	(-1.47)	(1.58)	(-1.80)	(1.30)	(-1.65)	(5.54)	(0.0000)
Raw Materials									
Copper									
1	0.001	0.118	-0.026	0.086	-0.117	-0.103	0.015	0.094	5.99
	(0.41)	(0.94)	(-0.28)	(-0.92)	(-0.89)	(-1.48)	(-0.31)	(0.78)	(0.6484)
3	0.003	0.428	0.089	-0.062	-0.220	0.048	0.027	-0.038	12.20
	(0.45)	(3.03)	(-0.41)	(-0.41)	(-1.62)	(-0.66)	(0.40)	(-0.28)	(0.1425)
6	-0.003	0.461	-0.491	0.030	0.286	-0.109	-0.081	0.262	34.00
	(-0.24)	(2.94)	(-2.49)	(0.22)	(1.33)	(-1.25)	(-0.95)	(0.18)	(0.0000)
9	-0.009	0.661	-0.973	0.005	0.497	-0.034	-0.149	0.134	171.89
	(-0.79)	(5.10)	(-6.75)	(0.02)	(2.93)	(-0.42)	(-2.39)	(0.96)	(0.0000)
Cotton									
1	0.001	0.072	0.025	0.103	0.036	0.079	-0.038	0.222	6.25
	(0.51)	(-0.71)	(0.19)	(0.78)	(0.27)	(1.36)	(-0.71)	(0.38)	(0.6193)
3	0.003	0.192	-0.011	0.113	-0.196	0.016	-0.035	0.613	5.95
	(0.54)	(1.39)	(-0.05)	(1.14)	(-1.35)	(0.25)	(-0.46)	(0.57)	(0.6528)
6	0.001	0.313	-0.194	0.192	0.238	-0.034	-0.052	0.040	15.32
	(0.14)	(1.40)	(-0.66)	(1.73)	(-1.11)	(-0.36)	(-0.67)	(0.34)	(0.0532)
9	-0.002	0.430	-0.444	-0.069	-0.144	-0.082	0.080	0.152	34.90
	(-0.12)	(2.08)	(-1.36)	(-0.67)	(-0.61)	(-0.73)	(0.95)	(0.76)	(0.0000)

Table 5 (concluded). Semi-Strong Test of Efficiency: Full Sample 1/

Forecast Horizon	$\beta 0$ (t-stat)	$\beta 1$ (t-stat)	$\beta 2$ (t-stat)	$\beta 3$ (t-stat)	$\beta 4$ (t-stat)	$\beta 5$ (t-stat)	$\beta 6$ (t-stat)	$\beta 7$ (t-stat)	$\chi^2(8)$ Marginal Significance Level
Beverages									
Cocoa									
1	0.001 (0.32)	-0.282 (-1.79)	0.010 (0.08)	0.140 (1.02)	-0.103 (-0.67)	0.038 (0.46)	-0.053 (-0.76)	0.023 (0.31)	10.67 (0.2211)
3	-0.003 (-0.46)	-0.359 (-2.07)	-0.057 (-0.37)	0.035 (-0.38)	0.305 (2.08)	0.172 (1.62)	0.055 (-0.67)	-0.059 (-0.51)	18.67 (0.005)
6	-0.011 (-0.89)	-0.477 (-2.52)	0.377 (1.64)	0.254 (1.59)	0.058 (0.28)	0.284 (2.42)	0.137 (1.56)	-0.816 (-0.51)	41.34 (0.0000)
9	-0.023 (-1.19)	-0.449 (-1.79)	0.593 (1.94)	0.392 (1.35)	-0.377 (-0.94)	0.347 (2.11)	0.153 (1.07)	-0.226 (-1.21)	20.08 (0.0100)
Coffee									
1	0.004 (1.52)	0.035 (-1.08)	-0.178 (1.79)	-0.179 (-1.85)	0.070 (-1.18)	0.147 (2.49)	-0.018 (0.79)	-0.115 (1.32)	8.50 (0.3862)
3	0.011 (1.52)	-0.215 (-1.08)	0.377 (1.79)	-0.310 (-1.85)	-0.268 (-1.18)	0.285 (2.49)	0.064 (0.79)	0.227 (1.32)	29.79 (0.0002)
6	0.014 (0.96)	-0.654 (-2.75)	0.517 (1.39)	-0.059 (-0.24)	-0.154 (-0.37)	0.239 (1.65)	-0.044 (-0.33)	0.355 (1.95)	12.67 (0.1237)
9	0.031 (1.54)	-0.327 (-0.93)	0.813 (2.07)	0.062 (0.21)	-0.710 (-1.61)	0.411 (1.92)	-0.202 (-1.14)	0.254 (1.28)	11.14 (0.1939)

1/ These are estimates of Equation 5. The dependent variable is the excess return for a given commodity. The right hand side variables are the excess returns for all commodities lagged once.

Table 6. Efficiency and Macrovariables: Tests of Significance 1/

	χ^2 (8) Forecast Horizon (Months)			
Commodity	1	3	6	9
Corn	9.19 (0.3265)	3.85 (0.8704)	8.22 (0.4123)	15.69 (0.0470)
Soybeans	4.37 (0.8223)	10.16 (0.2540)	16.78 (0.0325)	29.80 (0.0002)
Wheat	5.35 (0.7196)	3.26 (0.9170)	12.15 (0.1446)	17.48 (0.0255)
Cocoa	16.29 (0.0384)	27.89 (0.0005)	35.00 (0.0000)	41.86 (0.0000)
Coffee	6.97 (0.5399)	18.37 (0.0186)	17.75 (0.0232)	51.23 (0.0000)
Copper	7.74 (0.4593)	4.54 (0.8054)	22.87 (0.0035)	17.42 (0.0260)
Cotton	15.04 (0.0584)	14.54 (0.0687)	41.55 (0.0000)	7.80 (0.4532)

1/ The table shows the χ^2 and the marginal significance level for estimates of equation 6 in the test, for each of the seven commodities and four forecast horizons. The dependent variable in these equations is the "excess return" and the right hand side includes the following: lagged dependent variable, U.S. consumption, industrial production, terms of trade, money supply, interest rate, and CPI.

null hypothesis that excess returns are zero--that is, the composite hypothesis that all β's are zero. The results here reject the efficiency hypothesis for only two commodities for the 1-month forecast horizons, and three commodities for the 3-month horizon. For the 6- and 9-month horizons, the null is rejected for most commodities. For instance for the 9-month horizon, apart from cotton, in each of the other six commodities, the null hypothesis is rejected at a very low level of significance.

V. Out-of-Sample Forecasting Ability of Futures Prices

The above results suggest that we can reject the "efficient market hypothesis" for our sample of futures markets for the majority of commodities for the 6- and 9-month horizons and for some commodities for the shorter horizons. This finding is, of course, of considerable interest in itself. However, it cannot tell us whether in fact there are any ex ante variables that reliably predict excess returns over long periods. In other words, it cannot tell us whether we can improve in a consistent way the out-of-sample forecasting ability of futures prices. In order to tackle this issue, this section compares the out-of-sample forecasting ability of futures prices by themselves with the out-of-sample forecasting ability of the equations estimated in the Section above.

Two alternative models are compared:

$$f_{t+n} = f_t + \epsilon_{t+n} \qquad (10A)$$

$$f_{t+n} = f_t + \beta_0 + \beta'_m x_t + \epsilon_{t+n} \qquad (10B)$$

The first model (10A), which uses the current futures price as a predictor of all subsequent futures prices requires, of course, no estimation. In contrast to this, the model in equation (10B) includes the vector, x_t of exogenous variables in the information set, I_t. The variables in x_t are as described in Section IV (specifically, variables include categories (ii) and (iii) of I_t noted earlier).

Out-of-sample accuracy is measured by the root mean square error, which is defined as follows:

$$\text{root mean square error} = \left\{ \sum_{k=0}^{N-1} [f^f_{t+n+k} - f_{t+n+k}]^2 / N_n \right\}^{1/2} \qquad (11)$$

where n = 1, 3, 6, 9 denotes the forecast horizon, N_n the total number of forecasts in the projection period for which the actual value f is known, and f^f the forecast value using alternatively equation (10A) or (10B). If the root mean square error (RMSE) obtained from model (10A) is smaller than that of model (10B) we can conclude that the variables in (10B) fail to forecast or even explain out of sample as well as current futures prices. If, on the other hand, RMSE from (10A) is larger than that obtained from (10B) it would mean that forecasting of futures prices can be improved by using information other than that provided by past prices alone.

Equation (10B) was initially estimated for different choices of the variables in x_t, as in Tables 5 and 6, from the beginning of the sample, March 1976, up to the first forecasting period, December 1984. Using the point estimates of the coefficient in equation (10B) forecasts were generated at horizons of one, three, six, and nine months. Then the data for January 1985 were added to the sample, and the parameters of the model were re-estimated using rolling regressions. New forecasts were generated at one-, three-, six-, and nine-month horizons, etc. We continued to estimate the model until we used all the available data on f_{t+n+k}.

The results of the out-of-sample forecasting experiment are presented in Table 7. In this Table instead of presenting the root mean square error for each model we just provide the ratio of root mean square error statistic obtained from equation (10B) to the root mean square error statistic obtained from model (10A) at one- to nine-month horizons for different sample periods. Obviously, if the ratio is larger than one we conclude that the model in equation (10B) fails to improve the forecast of current futures prices.

Since the results using the macrovariables as predictors were in general weaker compared to the results using lagged forecast errors, we just present the results in which x_t only includes past forecast errors in the seven commodity markets (as in Table 5). The first column presents the ratio of the root mean square forecast errors for sample beginning in January 1985. There is a distinctive pattern in these ratios. Comparing the out-of-sample forecasting ability of futures prices with the forecasting accuracy of the variables in Table 5 at one- and three-month horizons, it appears that one cannot in general improve over the random walk model (equation (10A)). However, when the forecasting horizons are longer than six months the efficiency gained by using the model in Table 7 oscillates between a minimum of 2.4 percent for the 9-month horizon for wheat market to a maximum of 34.2 percent for copper. These gains in efficiency are maintained when other subsamples are evaluated. For example, during the 1986-1988 period the maximum efficiency gain occurs at a 9-month horizon in the soybeans market (32.3 percent) and in the copper market (29.7 percent). On the whole, the out-of-sample results give support to the contention that forecasting can be improved by using information from other markets, especially at longer forecast horizons.

There are two points worth emphasizing about the above results: Firstly, although they are somewhat at odds with the efficient market hypothesis, they are consistent with evidence from other asset markets. For example, Fama and French (1986) examined returns for all New York Stock Exchange stocks for the 1966-1985 period and found that when the tests focused on short horizons the predictable variation was a small part

Table 7. Estimates of Accuracy of Out of Sample Forecasts 1/

Commodity	Lag	Out-of-Sample Period Jan. 1985-Dec. 1988	Jan. 1986-Dec. 1988	Jan. 1987-Dec. 1988	Jan. 1988-Dec. 1988
Wheat	1	1.042	1.044	1.045	1.009
	3	1.161	1.170	1.206	1.204
	6	0.911	0.868	0.886	0.774
	9	0.976	0.797	0.792	0.735
Corn	1	1.034	1.037	1.038	1.029
	3	1.033	1.043	1.041	1.039
	6	0.939	0.886	0.889	0.975
	9	0.930	0.767	0.791	0.765
Cotton	1	1.099	1.115	1.117	1.030
	3	1.100	1.110	1.105	1.016
	6	1.064	1.032	1.020	1.000
	9	1.032	1.038	1.037	1.022
Soybeans	1	1.066	1.065	1.074	1.050
	3	1.141	1.162	1.183	1.155
	6	1.045	0.990	1.022	1.038
	9	0.664	0.690	0.677	0.609
Cocoa	1	1.045	1.070	1.104	1.074
	3	1.176	1.199	1.201	1.197
	6	1.107	1.101	1.020	1.002
	9	1.098	0.999	0.906	0.897
Coffee	1	1.051	1.037	1.037	1.011
	3	0.941	0.935	0.930	0.846
	6	0.966	0.970	0.954	0.987
	9	0.892	0.906	0.906	0.931
Copper	1	1.011	1.013	1.015	1.015
	3	1.068	1.061	1.060	1.055
	6	0.924	0.951	0.951	0.942
	9	0.658	0.699	0.703	0.691

1/ The coefficients in the table are the ratios of the mean-square-error of the model estimated in Table 5 and the random walk model (equations 10B and 10A respectively).

of total variation. However, at longer forecasting horizons the predictable variation increased considerably suggesting the presence of transitory components in the stochastic process followed by stock prices. In a similar vein, it would appear that in commodity markets for short forecasting horizons transitory components dominate, making it difficult to improve on the information embodied in past futures prices themselves. However, when forecasting over a longer horizon, additional publicly available information appears to lead to some improvement. The second point is that the results do not necessarily imply that an investor, in any given period, will be able to improve on the market. Earlier, we had noted the reasons for this--the excess returns might simply be capturing risk premium or there could be learning behavior in the face of incomplete information. An additional factor would be imperfections in the credit markets. For instance, liquidity constraints or the threat of bankruptcy mean that an investor would not necessarily obtain significant excess returns.

VI. Conclusions

The aim of this study has been to examine the extent to which futures markets for a number of widely traded commodities can be regarded as efficient. Whether or not the markets are efficient is of considerable importance to agents in developing countries, or indeed to any investor, who may want to use these markets to hedge against price risk. If markets are not efficient, then apart from the transaction costs of using these markets, investors have to incur additional costs due to inefficiency. The methodology adopted in this study took as a measure of efficiency excess returns in seven different commodity markets over the 1976-1988 period. Five main results emerged from the analysis:

1. For the entire sample period, unconditional excess returns were not significantly different from zero. If one assumes rational expectations, this would be consistent with zero risk premium and the observation that the efficiency costs of using the markets were not significant.

2. A detailed analysis of subperiods revealed, however, a more complex picture; for several of the commodities, excess returns continued to be statistically insignificant but for the rest, especially cocoa and wheat, returns were significantly positive. It was argued that this could be given *two alternative interpretations: the first is that there is no* market failure (i.e., futures prices are not biased predictors of future spot prices) and that excess returns simply reflect non-zero risk premium; alternatively, risk premium is zero but it does not necessarily imply market failure if the underlying processes generating spot prices are changing.

3. The 'weak form' tests of conditional efficiency showed that the null hypothesis of efficient markets is not rejected for three commodities but is rejected for the other four for most forecast horizons.

4. The 'semi-strong' tests confirmed that for short forecast horizons of one and three months, one cannot reject efficiency for most commodities. However, for six and nine month horizons, for most commodities, efficiency is rejected at quite high levels of significance.

5. The out-of-sample forecasting accuracy of futures prices compares favorably with the forecasting accuracy of own prices and other market prices at short horizons. However, for longer horizons, it appears that the random walk model can be improved on in a noticeable manner.

These five results indicate that it is not possible to make any strong generalizations on the efficiency of the commodity futures market for short-term forecast horizons. For longer periods, however, it does appear that several of the markets may not be fully efficient. Of course, even in these latter cases, the empirical rejection of the efficiency hypothesis does not imply market failure. In particular, if investors are risk averse, a non-zero excess return may only reflect a time-varying risk premium. The results of this study do not allow one to distinguish whether in fact this is the case. A natural extension of this study would be to isolate the risk premia and to examine how it varies over time.

Data Annex

This annex describes the data used for the empirical tests as well as the methodology employed for computing "excess returns."

A.1 Data

The bulk of the data on futures prices for the period March 1976 to December 1988, for the food and raw material commodities were obtained from the Commodity Futures Trading Commission (CFTC). The rest of the data for these commodities and almost all of the data on coffee and cocoa contracts were culled from the daily Wall Street Journal. For each of the seven commodities, data were obtained on price per unit of commodity for all of the outstanding contracts. (Table A1 gives the delivery months and other descriptive information for each of the commodities).

For soybeans and copper, the analysis was limited to the five major contracts per year. The price quotation was the settlement price on the first operating day of each month. In general, contracts trade for twelve months or more but the markets for nine months or before the contract expiry data care fairly thin.

A.2 Methodology for computing excess returns

Excess returns for seven commodities were computed for one-, three-, six-, and nine-month horizons. The key step in the computation was to form a continuous series of returns using the nearest contracts. This procedure is illustrated in Table A2 for wheat for one and six months. Consider, for example, the one-month return. To obtain a value for March 1988, the difference in the February 1988 and March 1988 price for the March 1988 contract is taken. For April and May values, the May contract is used, and so on. Consider next the six-month return: for March 1988 value, the difference in the September 1987 and March 1988 price for the March 1988 contract is taken. For the next two values for April and May, the May 1988 contract is used. For April 1988, the difference in the October and April price is taken for this contract. For May 1988, the difference in the November and May price is taken for the same contract. The returns for three months and nine months were constructed similarly for the same contract.

The next step was to take the time series for different returns and use them for the tests undertaken in the text. For example, in the case of the weak efficiency test with three lags, the following regression was run for the six-month horizon:

$$F_{t+6} - F_t = \beta_0 + \beta_1 (F_t - F_{t-6}) + \beta_2 (F_{t-1} - F_{t-7}) + \beta_3 (F_{t-2} - F_{t-8}) \quad \text{(A1)}$$

In such a case, if the excess return is given by the price difference over (December 1988 - June 1988) then prices over (June 1988 - December 1987), (May 1988 - November 1987), and (April 1988 - October 1987) are the three explanatory variables. The key point to note in this methodology is that the excess return for any given time period is computed using only one contract's prices, in each case the contract being the one with the maturity data at, or nearest, to the time period for which observation is required.

Table A1. Commodity Futures: Descriptive Data 1/

Commodity	Exchange	Price per unit of Commodity	Units of Commodity Per Trading Unit	Delivery Months
Food Products				
Corn	Chicago Board of Trade	Cents per bushel	5,000 bushels	March, May, July, September, December
Soybeans	Chicago Board of Trade	Cents per bushel	5,000 bushels	January, March, May, July, August, September, November,
Wheat	Chicago Board of Trade	Cents per bushel	5,000 bushels	March, May, July, September, December
Beverages				
Cocoa	Coffee, Sugar, and Cocoa Exchange	Cents per pound	22,046 pounds (10 metric tons)	March, May, July, September, December
Coffee	Coffee, Sugar, and Cocoa Exchange	Cents per pound	37,500 pounds (Approx. 250 bags)	March, May, July, September, December
Raw Materials				
Copper	Commodity Exchange Inc.	Cents per pound	25,000 pounds	January, March, May, July, September, October, December
Cotton (No. 2)	New York Cotton Exchange	Cents per pound	50,000 pounds	March, May, July, September, December

1/ For all seven commodities the sample period is March 1976 to December 1988.

Table A2. Computation of Excess Return: An Illustration

Forecast Horizon	Return	Contract Month	
1 month	March 1988 - February 1988	March	1988
	April 1988 - March 1988	May	"
	May 1988 - April 1988	May	"
	June 1988 - May 1988	July	"
	July 1988 - June 1988	July	"
	August 1988 - July 1988	September	"
	September 1988 - August 1988	September	"
	October 1988 - September 1988	December	"
	November 1988 - October 1988	December	"
	December 1988 - November 1988	December	"
6 months	March 1988 - September 1987	March	1988
	April 1988 - October 1987	May	"
	May 1988 - November 1987	May	"
	June 1988 - December 1987	July	"
	July 1988 - January 1988	July	"
	August 1988 - February 1988	September	"
	September 1988 - March 1988	September	"
	October 1988 - April 1988	December	"
	November 1988 - May 1988	December	"
	December 1988 - June 1988	December	"

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