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Time Varying Risk Premia in Futures Markets

Prepared by Graciela Kaminsky and Manmohan S. Kumar*

Authorized for distribution by Peter Wickham

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Abstract

This paper undertakes an econometric investigation into the presence of risk premium in commodity futures markets. The statistical tests are derived from a formal model of asset pricing and are applied to futures prices in a variety of commodity markets. The results suggest that for several commodities there is evidence of a time varying risk premium, particularly in futures contracts maturing six months ahead. The implications of the study for the efficiency of the futures markets and the costs of using these markets for hedging are also noted.

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* University of California, San Diego, and the IMF, respectively. We would like to thank Peter Wickham and Blair Rourke for encouragement and advice. Raja Hettiarachchi and Huyen Le provided excellent research assistance.

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I. Introduction

In recent years there have been a number of studies suggesting that the expected excess returns to speculation in commodity futures markets are non-zero. 1/ Most of the studies find that futures prices have often systematically overpredicted future spot prices, sometimes for quite lengthy periods of time, implying that the mean excess returns to futures speculation in these markets are positive. Many observers, taking these results to imply a refutation of the efficient markets hypothesis, have gone on to draw important policy implications for the cost of using futures markets to hedge commodity price risk, and for using futures markets to forecast future spot prices. Others have pointed out, however, that since excess returns to futures speculation can be decomposed into a risk premium and a forecasting error, positive returns may largely reflect a significant futures risk premium. The objective of this paper is to pinpoint the cause of the rejection of the efficiency hypothesis and to enquire whether these excess returns can be explained by any formal models of risk premia. In particular, the paper aims at obtaining an estimate of the size of the risk premium in different commodity markets and an indication of its stability over time.

The methodology of this paper is to examine whether returns to futures speculation are consistent with the Capital Asset Pricing Model (CAPM) of risk premia. CAPM is an equilibrium model which is used to value assets under uncertainty. It has been used extensively to analyze returns in a variety of asset markets, including equity, bond and foreign exchange markets, but in the case of commodity futures markets, its use has been limited. CAPM implies that, in equilibrium, returns in futures markets should be proportional to the returns on a benchmark portfolio relative to the return on a risk free asset. The factor of proportionality is given by Beta--which is the covariance of returns to the asset in question and the returns on a benchmark portfolio. Within the framework of the CAPM, this paper applies to commodity futures markets the tests first proposed by Hansen and Hodrick (1983) in their study of the forward foreign exchange market. These tests impose the restriction that the conditional covariance of excess returns in the futures markets and the returns on the benchmark portfolio is constant. Since in some cases we reject the restriction of constant Betas, we also allow for time varying Betas that are modelled using different macro variables.

The discussion below is organized as follows: Section II examines the notion of risk premia in commodity futures markets and discusses the application of the CAPM model to identifying risk premia in these markets; it also notes the results of some existing studies in this area. Section III undertakes an empirical investigation under the assumption of

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1/ See, for example, Bodie and Rosansky (1980), Fama and French (1987), and Kaminsky and Kumar (1990).

constant Beta over time, while Section IV allows for a time varying risk premium. Section V analyzes the out-of-sample forecasting accuracy of the model and a last section provides some concluding comments.

II. Risk Premium and the CAPM Model

The notion that commodity futures prices contain an element reflecting a risk premium has a long history. It was first put forward by Keynes (1930) who argued that hedgers, wishing to reduce or limit their exposure to risk originating from future changes in spot prices, would have to pay a premium to speculators for taking over that risk. 1/ This notion led to the hypothesis of 'normal backwardation,' which maintains that futures prices should rise over the life of any given contract resulting, in effect, in compensation to speculators for their risk-bearing services. A positive risk premium assumes that hedgers are always net short and speculators long in the futures markets. An alternative view was put forward by Hardy (1940) who argued that for many speculators futures markets are akin to a gambling casino. Far from demanding and receiving compensation for taking over the risks of price fluctuation from the hedgers, speculators are willing to pay for the privilege of gambling in a socially acceptable way. According to Hardy's interpretation, the risk premium would be close to zero or negative.

A number of early empirical studies tried to examine the nature and size of risk premium by examining excess returns on speculation in a variety of futures markets. 2/

Excess returns ν_{t+n} are defined by

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

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 the futures price at time t, for a contract maturing at time T. In these studies, the null hypothesis of a zero risk premium is taken to imply that on average excess returns are equal to zero.

That is,

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

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

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1/ The notion of risk premium was apparently first advanced by Keynes even earlier in an article in the Manchester Guardian Commercial in 1923. It gradually developed into a formal theory with contributions from Kaldor (1938) and Hicks (1946).

2/ For a summary of these studies, see Peck (1985).

average higher, or lower, than prices at t. 1/ If ν_{t+n} is significantly greater than zero, this is taken to imply a confirmation of the Keynesian insurance scheme interpretation of futures markets. However, it was soon noted that a rejection of H_0 does not necessarily imply that investors behaved 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.,

$$\nu_{t+n} = f_{t+n} - f_t = [E(f_{t+n}) - f_t] + [f_{t+n} - E(f_{t+n})] = RP_t + v_{t+n}. \text{ 2/} \qquad (3)$$

Where $[E(f_{t+n}) - f_t]$ is the risk premium (RP_t), and $[f_{t+n} - E(f_{t+n})]$ is the forecast error v_{t+n}. The forecast error would result if investors' expectations of the behavior of futures prices were not borne out. Clearly ν_{t+n} being nonzero, does not necessarily imply that RP_t is necessarily nonzero.

An alternative approach to examining risk premium attached to any asset, and the one which is now widely accepted, is to analyze the premium in the context of the risk which might emanate, not from that particular asset, but that which affects a portfolio of assets. In this approach, the risk premium is measured by the covariance between the risk from the particular asset with that of a portfolio. Applying this approach to the futures market would mean that futures markets are regarded as no different in principle from the markets for any other risky portfolio asset. (See, for instance, Dusak (1973) and Jagannathan (1985)). So that despite some differences between futures market assets and other investment instruments, this approach would regard them all as equal candidates for inclusion in an investor's portfolio. The portfolio approach, by itself, makes no presumption as to the sign of the risk premium. It says, simply, that the return on any risky capital asset, such as futures markets contracts, is governed by that asset's contribution to the risk of a large and well diversified portfolio. 3/

To make the portfolio approach empirically operational, this paper utilizes Sharpe and Lintner's "Capital Asset Pricing Model" (CAPM). In this model, investors maximize expected utility subject to a budget constraint

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1/ 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.

2/ Since here we are only considering contracts of the same maturity date, in order to simplify the notation, we denote (f_t, T) by f_t, (f_{t+n}, T) by f_{t+n} and so on.

3/ As Dusak (op.cit.) emphasized, in contrast to the portfolio measure of risk, the Keynesian view would regard the risk of a futures market asset solely with respect to its price variability.

and in equilibrium, assets are priced such that the expected return from any asset compared to the expected return on a risk free asset should be proportional to the excess return of a benchmark portfolio over the return on a risk free asset. The factor of proportionality is given by the covariance of the return for the asset in question with the return on a benchmark portfolio. For example, the equilibrium k-period return for asset j will be:

$$E_t(R^j_{t+k}) = R^f_{t+k} + \beta^j_t E_t(R^b_{t+k} - R^f_{t+k}) \tag{4}$$

where

$$\beta^j_t = COV_t(R^j_{t+k}, R^b_{t+k})/VAR_t(R^b_{t+k})$$

where R^j_{t+k} is the return on asset j in period t+k, R^f_{t+k} is the return on a risk free asset, and R^b_{t+k} is the return on a benchmark portfolio; E_t is the expectation operator conditional on information in period t, and COV_t and VAR_t are the covariance and the variance respectively.

To apply the CAPM model to futures markets, it is first necessary to define the appropriate rate of return in these markets. It might appear that the margin on which all futures contracts are bought (and sold) could be treated as the capital investment and the ratio of net profit at closeout to the initial margin could be taken as the rate of return on investment. This procedure would not be, however, appropriate because the margin is in fact not a portfolio asset but merely a good faith deposit or a performance bond to guarantee compliance by the parties to the contract. (See, for instance, Dusak (1974) and Hazuka (1984)). If brokers had other ways of ensuring that traders did not make commitments beyond their means, then no such performance bonds would be required. A more appropriate candidate for the return on investment is the percentage change in the prices of any given futures contract. Since the agent invests no resources in the futures contract, this percentage change cannot be interpreted as a rate of return comparable to R^j_{t+k} in equation (4). But it can be interpreted essentially as the risk premium, $R^j_{t+k}-R^f_{t+k}$. Note that if an agent holds unhedged spot commodity his return on that will consist of two elements: first, the interest on the capital invested in the commodity, and secondly, any return, positive or negative, due to any unanticipated change in the price of the commodity. If the agent now hedges his holding, he thereby converts it to a riskless asset on which he earns only the riskless rate R_f. The purchaser of the futures contract who takes over the risk, has no capital of his own invested and hence earns no interest on capital, but he does receive the returns over and above interest, that is, $R^j_{t+k} - R^f_{t+k}$.

Hence, we can rewrite equation (4) as follows:

$$E_t[(F^j_{t+k}-F^j_t)/F^j_t] = \beta^j_t E_t(R^b_{t+k} - R^f_{t+k}), \tag{5}$$

with

$$\beta^j_t = \frac{COV_t[(F^j_{t+k} - F^j_t) / F^j_t, R^b_{t+k}]}{VAR_t(R^b_{t+k})}$$

and F^j_{t+k} is, as before, the price at t+k of a futures contract to deliver one unit of commodity j at the maturity of contract.

Equation (5) is the starting point for the empirical analysis of the time varying risk premia. In the next section, we discuss the test of the restrictions imposed by the CAPM model using data for one- and six-month returns on futures contracts for seven different commodities during the 1976-88 period.

Before undertaking that analysis, however, it is worth noting the results of a number of existing studies which have used formal models to examine empirically whether commodity futures prices contain a component reflecting risk. 1/ One of the earliest studies was by Dusak (1973) who used biweekly data for three commodities (corn, soybeans and wheat) over the period 1952 to 1967 and found that the hypothesis of zero systematic risk could not be rejected. However, Bodie and Rosansky (1980) in their study of a well diversified portfolio of commodity futures, consisting of 23 commodities, found the average return during 1950-76 to be well in excess of the risk-free rate. Both of these studies assumed that the betas, measuring the systematic component of the risk in futures contracts, are constant and that a stock index, such as the United States' S&P (Standard and Poor's) index of 500 stocks, is a good approximation of the aggregate wealth portfolio. Carter, Rausser and Schmitz (1983) relaxed both of these assumptions: they allowed the betas to be stochastic and in the proxy for the aggregate wealth portfolio, and included assets other than equity stocks. When this was done they found that the systematic risks in exactly the same futures contracts as those studied by Dusak were actually significantly different from zero.

Breeden (1980) applied a consumption based intertemporal asset pricing model to futures contracts for 20 commodities over the period 1960-78 using

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1/ As indicated above, there had been a number of statistical tests of risk premia before this study. These studies, however, had relied on some rather stringent assumptions and used ad hoc methodologies. For an interesting discussion of the studies, see, for instance, Peck (1985).

both quarterly and annual data. He found that a single period model indicated negative beta estimates, indicating that the futures price was greater than the expected future spot price. 1/ This implies either that the hedgers have net long positions, or speculators with long positions are expected to make negative returns on average. 2/ However, Breeden found that the consumption beta estimates for several of the same futures contracts had positive systematic risk as defined by the intertemporal model. For these contracts, normal backwardation was predicted. Hazuka (1984) also tested a consumption oriented model for several commodities that were classified according to storage characteristics. He examined only one-month-to-maturity returns of futures contracts for a range of agricultural commodities and metals. He found that the risk premium reflected in futures prices was significantly different from zero, although the estimates of the coefficients in his model were different from their theoretical values. 3/

Finally, a recent study by Jagannathan (1985) examined whether two-month returns to futures speculation in three markets (corn, soybeans and wheat) for the period 1960-78 were consistent with the consumption beta model of risk premia. He modelled 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 included changes in U.S. industrial production and the U.S. terms of trade. He found, however, that his model was rejected at all conventional levels of significance.

It is worth emphasizing that the rejection of a risk premia model is a rejection of a joint hypothesis: that of the specific model itself, and that of the hypothesis of a risk premium. (The literature on risk premia in foreign currency futures markets has emphasized this particular point. See, for instance, McCurdy (1989)). 4/ It may also be that one or more of the maintained assumptions in the models of risk premia are inappropriate. Furthermore, it is possible that auxiliary assumptions not implied by the model but imposed during estimation are inconsistent with the data. Whatever the reason, given the diversity of findings noted above, it is of interest to examine whether for the more recent time period there is any evidence of nonzero systematic risk in a variety of commodity markets. In

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1/ This situation, termed 'contango', is the opposite of 'normal backwardation' discussed earlier.

2/ In the latter case, one would view participation in futures markets as assumed by Hardy (op. cit.), that is, being more akin to gambling, which could lead to very different welfare implications from those in which these markets are perceived as means of sharing risk.

3/ Hazuka also imposed the condition that the consumption betas were constant over time.

4/ In foreign currency futures markets, although the random walk hypothesis has usually been rejected, most models of time varying risk premia have met with very limited empirical success. See, for instance, the surveys by Boothe and Longworth (1986), Hodrick (1987) and Meese (1989).

addition, one question which several of the above studies have not tackled is whether these risk premia change over time. Also none of the earlier studies has enquired whether, even when a particular model of risk premia is not rejected, it compares favorably or otherwise with alternative models in forecasting out-of-sample risk premia.

III. Constant Conditional Betas

1. Equation specification

In this section, the empirical testing of the model in equation (5) begins with the restriction that the β for any given commodity futures contract that satisfies this equation is constant over time. Of course, a rejection of the CAPM model under this restriction does not necessarily imply, as indicated in Section 2, a rejection of the underlying model of risk premia. In any case, it is a restriction which will be relaxed in the next section.

The tests below do not impose the additional restriction that the expected return on benchmark portfolio in excess of the nominal risk free interest rate is constant over time. Following Hansen and Hodrick (1983), $R^b_{t+k}-R^f_{t+k}$ is modelled as a latent variable. Under this assumption, all of the time variation in risk premia in the futures market will be captured by movements in the conditional means. Finally, as is traditional in these types of tests, rational expectations are assumed.

These assumptions allow the empirical model in (5) to be written as

$$(F^j_{t+k}-F^j_t)/F^j_t = \beta^j x_t + v_{t+k}, \tag{6}$$

where

$$x_t = E_t(R^b_{t+k}-R^f_{t+k})$$

and v_{t+k} is the conditional expectation forecast error. Under the assumption of rational expectations ϵ_{t+k} is orthogonal to the information set I_t. Since x_t is assumed to be unobservable by the econometrician, the empirical test is constructed by substituting in equation (6) the best linear predictor of x_t based on a subset of the information in agent's information set.

Thus, x_t can be defined as follows:

$$x_t = \alpha_0 + \sum_{s=1}^{q} \alpha_s z^s_t + \epsilon_t \tag{7}$$

where z_t^s is an instrumental variable and ϵ_t is the prediction error which has mean zero and is orthogonal to z_t^s. Substituting (7) in (6) we obtain

$$(F^j_{t+k}-F^j_t)/F^j_t = \gamma^j_0 + \sum_{s=1}^{q} \gamma^j_s z^s_t + \mu_{t+k} \tag{8}$$

where $\gamma^j_s = \beta^j\alpha_s$ for s=0,...,q; and $\mu_{t+k} = v_{t+k} + \beta^j\epsilon_t$ and it is also orthogonal to z_t.

The empirical test of the model as specified in equation (8) can be carried out by estimating a system of projection equations and testing the hypothesis that the coefficients in each equation are proportional to the coefficients in, for example, the first equation. In other words, the test implies a test of the restrictions $\gamma^j_s/\gamma^1_s = \beta^j/\beta^1$ for s=0,...,q. The nature of the test can be seen easily from the following:

Denoting by y_t the return $(F^j_{t+k} - F^j_t)/F^j_t$, (8) is equivalent to the following:

$$y^j_t = Z_t\gamma^j + \mu^j_t \tag{9}$$

where Z_t denotes the matrix of observations on the instrumental variables. Suppose there are only three commodities, and Z_t consists of three variables. Then the restrictions for a test of the joint hypothesis would be the following:

$$\frac{\gamma^j_1}{\gamma^1_1} = \frac{\gamma^j_2}{\gamma^1_2} = \frac{\gamma^j_3}{\gamma^1_3} = \frac{\beta^j}{\beta^1} \qquad j = 1...3 \tag{10}$$

Since β^j is unknown, we can rewrite the restrictions as follows:

$$\begin{aligned} \gamma^j_2\,\gamma^1_1 - \gamma^j_1\,\gamma^1_2 &= 0 \\ \gamma^j_3\,\gamma^1_1 - \gamma^j_1\,\gamma^1_3 &= 0 \end{aligned} \tag{11}$$

We have these restrictions for each j, j = 2, 3.

Thus in this case of three commodities the vector of restrictions would be given by the following matrix R:

$$R = \left[\begin{array}{c} \gamma_2^2 \gamma_1^1 - \gamma_1^2 \gamma_2^1 \\ \gamma_3^2 \gamma_1^1 - \gamma_1^2 \gamma_3^1 \\ \hline \gamma_2^3 \gamma_1^1 - \gamma_1^3 \gamma_2^1 \\ \gamma_3^3 \gamma_1^1 - \gamma_1^3 \gamma_3^1 \end{array}\right]$$

Since the empirical analysis is based on seven commodities and since there are q+1 regressors in each of the projection equations, there will be 7(q+1) regressors in the system but only (q+7) parameters when the proportionality restrictions are imposed. There are thus 7(q+1)-(q+7) parameter restrictions that can be tested. Let $R(\gamma)$ denote these restrictions. The test statistic was calculated as follows:

$$R\ (\hat{\gamma})' \left[\frac{\partial R}{\partial \partial} V \frac{\partial R}{\partial \partial}\right]^{-1} R(\gamma).$$

Under the null hypothesis that $R(\gamma) = 0$, the above statistic is asymptotically distributed as a χ^2 random variable with 7(q + 1)-(q+7) degrees of freedom.

2. Empirical results

Before considering the formal tests of the above hypotheses, it is worth noting some descriptive statistics of the data used in the study, as well as results of some preliminary tests. In Table 1 the means and the standard deviations of the excess returns are reported, as well as a measure of skewness and kurtosis. In addition, autocorrelations of the order 1 to 5 and a standard test for normal distribution of excess returns is also included. 1/

1/ This is the Jarque-Bera test for normality.

Under the null hypothesis of market efficiency, excess returns should be serially independent with a mean zero. 1/ When the entire sample period 1976-88 is used, the null hypothesis of zero unconditional mean cannot be rejected at the conventional levels of significance for any of the seven commodities. This result should be interpreted with caution, however, since it does not preclude excess returns from being positive for some periods and negative for others, yielding an average value not significantly different from zero. In fact, in a previous paper precisely such a result was obtained (Kaminsky and Kumar (1990)). For example, the excess returns in the case of the corn futures varied from being significantly positive during 1976-77 to being highly negative over the period 1986-88, suggesting the possibility at least of a time varying risk premium.

Table 1 also presents the correlogram both for the one-month and for the six-month excess returns. There is evidence of some correlation over time, especially for the six-month returns. This evidence is supported by the Jarque-Bera test, a parametric test with maximum power in large samples against skewed and leptokurtic alternatives to the normal distribution. It has an asymptotic χ^2 distribution with two degrees of freedom. The results from this test suggest that excess returns are not normally distributed. There can be several reasons why the hypothesis of a normal distribution may be rejected. One reason is that excess returns may not be serially independent. Another reason may be the presence of heteroscedasticity. Whatever the reason, the rejection of the normality assumption is consistent with the previous findings in the literature on the rejection of the efficiency hypothesis. Such a rejection leads to the important question of whether it is in fact due to market failure or due to the presence of risk premium. We next present the more formal tests of the risk premium hypothesis as elaborated in the preceding section.

As discussed earlier, a test of the risk premium hypothesis is a test of the model in equation (8). A number of different sets of regressors were included in the latent variable model based on some indication of the power of these regressors to explain excess returns in the commodity markets under consideration (see, for example, Kaminsky and Kumar (1990)). The regressors which yielded the best estimates included the corresponding basis for different futures contracts (i.e., $(F_t^j - S_t^j)/S_t^j$, where S_t^j is the spot price of one unit of commodity j and F_t^j is the price at time t of a futures contract) as well as the spot prices themselves. The results included in

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1/ This applies only to the one month rate of return. It is not the case for the six-month excess returns because the sampling interval (one month) does not equal the forecasting interval (six months). In the latter case, as Hansen and Hodrick (1980) show, excess returns will be moving averages of the order (k-1) where k is the forecast horizon. To eliminate this source of serial correlation, Table 1 presents the summary statistics using non-overlapping observations. In this case, too, under the null hypothesis of market efficiency excess returns should be serially independent.

Table 1. Sample Statistics

Commodity	Mean	Standard Deviation	Autocorrelations with lags 1	2	3	4	5	q	Skewness	Kurtosis	χ^2 (test for normality)
1 Month											
Corn	-0.0031	0.0230	-0.0078	0.0393	-0.0729	-0.0155	-0.0088	1.17	1.6815	10.48	773.99
Soybeans	-0.0007	0.0329	0.0954	-0.0133	-0.105	-0.129	0.0291	6.11	-0.1220	1.4261	13.346
Wheat	-0.0024	0.0267	-0.0224	-0.0077	0.0427	0.0211	0.0714	1.28	0.1307	0.1553	0.589
Cocoa	0.0015	0.0387	0.0162	-0.0093	0.0479	0.0699	0.271	13.0	0.2694	0.0429	1.862
Coffee	0.0044	0.0444	-0.0083	0.0950	0.0084	0.0941	-0.0526	3.37	0.4703	1.5105	20.183
Copper	0.0009	0.0373	0.0511	-0.0104	0.0528	-0.0236	0.107	4.55	-0.1059	3.14	63.44
Cotton	0.0013	0.0269	-0.106	0.0612	0.0044	0.0593	0.0751	3.89	0.6016	2.6113	52.698
6 Months											
Corn	-0.0091	0.079	0.0339	-0.0756	-0.142	-0.2982	-0.1070	4.13	1.1970	1.5863	8.248
Soybeans	0.0014	0.0726	0.1710	-0.0195	-0.0069	-0.0082	-0.0263	1.03	0.8595	0.4887	3.194
Wheat	-0.0092	0.070	0.189	0.127	0.0891	-0.3091	-0.2031	6.64	-0.1159	0.3004	0.144
Cocoa	0.0025	0.1040	0.2521	0.0914	0.117	0.2281	-0.1562	5.46	0.4747	-0.5712	1.226
Coffee	0.027	0.1197	0.1010	-0.0879	-0.107	-0.0590	0.1691	2.62	0.3358	-0.7083	0.953
Copper	-0.0015	0.0839	0.1771	0.0425	-0.093	0.016	-0.4150	1.70	1.1410	1.3006	6.899
Cotton	0.0902	0.0774	0.2070	-0.0050	-0.283	-0.2003	-0.0811	5.73	1.298	1.1848	8.042

Table 2 are based on the latter set of regressors. Since residuals in equation (8) may be serially correlated 1/ consistent estimates of the covariance matrix of the γ^j,s were calculated using method of moments (MOM) estimator proposed by Hansen (1982). Also, since in small samples the covariance matrix so estimated may not be positive definite, the Newey-West (1987) correction to guarantee positive definiteness was applied.

Before examining whether excess returns can be explained by the CAPM model, consider whether excess returns to futures speculation are nonzero. The null hypothesis is that all the γ^j are jointly zero for each commodity. As the last column in Table 2 indicates, for the six-month return, in the case of all commodities except cotton, the null hypothesis can be rejected at all conventional significance levels. The results for the one-month return for all commodities, as well as the six-month return for cotton, however, do not indicate significant evidence against zero excess returns. Next, consider the value of the χ^2 statistic to test the hypothesis that the nonzero excess returns are consistent with the CAPM model of risk premium (last line in Table 2). The value of the test statistic of the model restrictions is 9.07 for the six-month returns, indicating that the restrictions imposed by the model are not rejected. 2/ Similarly, in the case of the one-month return, the corresponding statistic is 3.03, and the restrictions are again not rejected.

Given that in the case of the six-month returns the model has significant power, the above evidence suggests that it is consistent with the hypothesis that investors are not risk neutral. In the case of one-month returns, however, the inability to reject the restrictions imposed by CAPM probably only reflects the fact that, in the unconstrained specification, the regressors are not particularly powerful explanatory variables during the sample period. Interestingly, these results are very similar to those found by other researchers when examining returns in other asset markets, such as the equity markets in the United States. For instance, Fama and French (1987) in an extensive study found that the one-month excess returns to equities could not be distinguished from a white noise process. However, when they evaluated whether stock prices follow random walk using returns at longer horizons the null hypothesis was strongly rejected.

One possible reason for the low explanatory power of these variables in the one-month return is that the relationship between excess returns and the instrumental variables may have changed over time. As a preliminary step in

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1/ As noted above, the errors in equation (8) may not be uncorrelated since the sampling interval does not necessarily equal the forecasting interval.

2/ The critical value, with 42 degrees of freedom, at the 5 and 10 percent significance levels, is 58.1 and 52.3 respectively.

Table 2. Estimates of the Constant Beta Model: 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)	χ^2
Food										
Corn	1	0.0	0.01	-0.07	-0.03	0.19	-0.06	0.03	-0.10	8.83
		(-1.35)	(0.13)	(-0.85)	(-0.53)	(2.10)	(-1.01)	(0.46)	(-1.23)	
	6	-0.01	0.03	0.24	-0.11	-0.17	0.09	-0.22	0.37	62.60
		(-2.40)	(0.49)	(2.56)	(-1.78)	(-2.12)	(1.51)	(-4.62)	(4.64)	
Soybeans	1	0.0	-0.03	-0.11	0.03	0.17	-0.04	0.09	-0.08	6.51
		(-0.30)	(-0.36)	(-1.29)	(0.50)	(1.73)	(-0.60)	(1.30)	(-0.98)	
	6	0.0	-0.06	0.08	0.06	-0.16	0.17	-0.18	0.42	46.78
		(-0.71)	(-0.82)	(0.79)	(0.85)	(-1.75)	(2.43)	(-3.29)	(4.64)	
Wheat	1	0.0	0.04	-0.09	-0.01	0.0	-0.5	0.0	0.0	4.62
		(-1.25)	(0.57)	(-1.21)	(-0.10)	(-0.1)	(-0.96)	(0.02)	(0.05)	
	6	-0.01	0.02	-0.05	-0.14	0.04	-0.12	-0.19	0.39	54.57
		(-2.18)	(0.35)	(-0.59)	(-2.22)	(0.50)	(-1.95)	(-4.16)	(4.94)	
Beverages										
Cocoa	1	0.0	0.01	0.01	0.09	-0.20	-0.01	0.01	0.0	5.42
		(0.63)	(0.12)	(0.07)	(1.14)	(-1.67)	(-0.18)	(0.17)	(-0.03)	
	6	0.0	-0.23	0.17	0.18	0.07	0.30	0.13	-0.33	35.95
		(-0.31)	(-2.37)	(1.18)	(1.79)	(0.59)	(3.06)	(1.75)	(-2.65)	
Coffee	1	0.0	0.12	-0.09	-0.05	-0.07	0.07	0.07	0.09	-0.10
		(1.35)	(1.17)	(-0.72)	(-0.54)	(-0.54)	(0.74)	(0.87)	(0.88)	
	6	0.01	-0.41	0.25	0.17	-0.13	0.25	-0.08	0.33	31.19
		(0.84)	(-3.55)	(1.44)	(1.39)	(-0.89)	(2.20)	(-0.90)	(2.16)	
Raw Materials										
Copper	1	0.0	0.09	0.04	0.03	-0.17	-0.14	0.11	-0.02	9.03
		(0.33)	(1.09)	(0.37)	(0.44)	(-1.50)	(-1.90)	(1.39)	(-0.20)	
	6	-0.01	0.0	-0.24	0.09	0.20	-0.21	-0.17	0.26	25.87
		(-1.01)	(0.05)	(-2.00)	(1.11)	(1.93)	(-2.68)	(-2.88)	(2.52)	
Cotton	1	0.0	-0.05	-0.03	-0.07	0.12	0.08	-0.06	0.04	8.66
		(0.47)	(-0.73)	(-0.45)	(-1.41)	(1.53)	(1.42)	(-0.95)	(0.59)	
	6	0.0	0.05	-0.17	0.07	-0.06	-0.12	-0.09	0.08	12.89
		(0.03)	(0.61)	(-1.46)	(0.84)	(-0.56)	(-1.64)	(-1.51)	(0.84)	

χ^2 for model restrictions: 1-month return 3.03; 6-month return 9.07

1/ These are estimates of equation 8. The dependent variable is the excess return for a given commodity. The right hand side variables are the percentage change in spot prices lagged once.

investigating the issue of parameter instability, the above tests were repeated, but this time with the sample divided into two subperiods. Since the 1980s have been highly unstable with respect to the volatility of commodity prices compared to the late 1970s, the two subperiods were chosen as follows: Sample 1 was for the period March 1976 to December 1980, while the second sample was from January 1981 to December 1988.

In Table 3 (columns (1) and (2)), the χ^2 results from estimating similar equations to the ones above but using only observations for the first sample period are presented, while in columns (3) and (4) the corresponding χ^2 for the second sample period are presented. A comparison between this table and the results in the last column of Table 2 is revealing. The explanatory power of the instruments (in the case of the one-month excess returns) does not increase even when the possibility of changes over time is allowed for. But interestingly when the sample is divided into two subsamples and equation (8) tested for the six-month returns, the restrictions implied by the CAPM for the first sample are rejected, in sharp contrast to results in Table 2. In this case, the χ^2 statistic for the test of the CAPM restrictions has a value of 106.4, so that the restrictions of the model are rejected at all conventional levels of significance. As noted earlier, however, the above tests are of a joint hypothesis, that is, of excess returns being explainable by CAPM and constant beta. While a constant beta specification can be consistent with the presence of risk premium, whether the betas are in fact constant is strictly an empirical issue and one which is investigated in the following section.

Table 3. χ^2 Values for the Constant Beta Model: Subperiods 1/

Sample	First Period		Second Period	
Time Horizon	1-month	6-month	1-month	6-month
Commodity				
Corn	10.53	164.18	7.84	34.39
Soybeans	7.70	146.12	7.15	55.15
Wheat	4.41	197.91	9.67	27.29
Cocoa	19.23	238.05	12.10	30.00
Coffee	15.55	135.38	10.55	29.99
Copper	1.27	67.36	9.40	16.61
Cotton	10.61	112.34	9.90	11.25
Test of restrictions	3.66	106.43	4.52	13.95

1/ The χ^2 values are for the model specified in equation (8).

IV. Time Varying Conditional Betas

The theoretical CAPM model only postulates the existence of a trade-off between risk and return at a given point in time. It does not impose the restriction that the conditional covariance between the return on an asset and the return on the benchmark portfolio is constant over time or that the conditional variance of the benchmark portfolio is constant.

The methodology adopted here to model the time varying conditional betas is to project them against a number of variables in the information set I_t. Suppose, for example, that the betas are not constant but move proportionally to some variables y_t.

$$\beta_t^j = \delta_0 + \delta^j y_t \tag{12}$$

Substituting (7) and (12) in (6) we obtain

$$(F_{t+k}^j - F_t^j)/F_t^j = [\delta_0 + \delta^j y_t][\alpha_0 + \sum_{s=1}^{q} \alpha_s^j z_t^s] + \eta_{t+k} \tag{13}$$

Equation (13) can be estimated empirically to obtain an indication of the time varying risk premium. But first one has to decide on the explanatory variables to be included in y_t. To increase the power of the tests it is important to include those variables that are likely to affect savings or investment, and therefore rates of return. The variables used to estimate the time varying betas were sequentially: the growth rate of U.S. consumption, the change in the U.S. treasury bill rate, growth in U.S. industrial production and changes in the terms of trade. The results, using the latter two sets of variables, were in general similar to the first two; therefore only the results pertaining to the first two are discussed below. Since there are seven commodities in the sample and since there are 2(q+1) regressors in each of the projection equations, there will be 14(q+1) regressors in the system but only (14+q) parameters when the proportionality restrictions are imposed. There are thus 14(q+1)-(q+14) parameter restrictions that can be tested. 1/

In Tables (4) and (5) we present the χ^2 statistics for the significance of the reduced form coefficients in the unrestricted model to evaluate the explanatory power of the model, using consumption and interest rates, respectively.

1/ In all the estimations we use only the corresponding basis to model the excess expected return on the benchmark portfolio.

As the results show, in the case of both consumption growth and the change in interest rates to predict the time varying betas, the model has large explanatory power, especially for the six-month returns. For instance, in the case of consumption, for the full sample period, for six months, the χ^2 value for the regression equations varies from 32.51 for cotton to 87.92 for cocoa. Except for cotton, all the other values are significant at the 5 percent level. Similarly, for the two subperiods, for all commodities for a six-month horizon, the model has large explanatory power. The values of χ^2 statistics for the test of restrictions for the six-month horizon implied by the model are small--25.99, 11.48, and 63.77--and are all less than the critical values of χ^2 at the 5 percent significance level. This implies that for the six-month horizon we do not reject the cross-restrictions implied by the CAPM--indicating that the nonzero excess returns can be explained in terms of a time varying risk premium. It is worth noting that in the case of the one-month forecast horizon, values of the χ^2 statistics for the test of restrictions are also very small. However, as Table 4 shows, the explanatory power of the model for a one-month horizon, as given by the individual equation χ^2 statistics, is quite low.

The results of using interest rates to model time varying betas are in general similar to the ones for consumption (see Table 5). For the one-month horizon for all sample periods, the explanatory power of the model as measured by the χ^2 statistics is again quite limited. Thus, for short horizons, one cannot deduce much about the validity of CAPM from the test of restrictions not being rejected. For the six-month horizons, for all sample periods, however, the explanatory power of the model is highly significant. The χ^2 statistic for the test of restrictions for the full sample and for the second sub-period is again very small. Although for the first period, the statistic has a large value, it is not significant at the conventional level of significance.

The contrast between the one and the six-month excess returns is illustrated in Figures 1 and 2 which compare the actual and predicted values of excess returns for the two forecast horizons respectively. As Figure 1 shows, the monthly variability in the one-month return for all seven commodities was very substantial. Given the results noted above, however, it is not surprising that the predicted values only capture a small proportion of this variability. In the case of the six-month horizon, the monthly variability is markedly less. At the same time, the predicted values of the excess returns captured much more closely the changes in the actual returns.

The above evidence was corroborated by an analysis of the residuals from the time varying models. As in Table 1, the mean, the variance, and the correlogram were computed and the tests for the normal distribution of the residuals were also undertaken. The results showed that for both forecast horizons, the assumption of normality could not be rejected at very high levels of significance. Furthermore, unlike the results in Table 1, intertemporal correlation among residuals was greatly reduced and never statistically significant.

Table 4. χ^2 Values for the Time Varying Betas Based on Consumption 1/

Sample Time Horizon	Full Sample		First Period		Second Period	
	1 Month	6 Month	1 Month	6 Month	1 Month	6 Month
Commodity						
Corn	18.67	87.86	25.1	250.0	14.6	72.5
Soybeans	17.35	74.49	32.6	274.4	22.7	113.08
Wheat	10.25	85.82	9.9	244.6	21.4	98.9
Cocoa	17.57	87.92	61.7	620.5	19.8	102.3
Coffee	14.89	65.24	19.3	203.5	13.0	51.8
Copper	22.01	66.31	10.8	127.0	37.5	43.5
Cotton	14.67	32.51	19.5	230.8	28.3	37.7
Test of restrictions	3.99	25.99	5.23	11.48	7.42	63.77

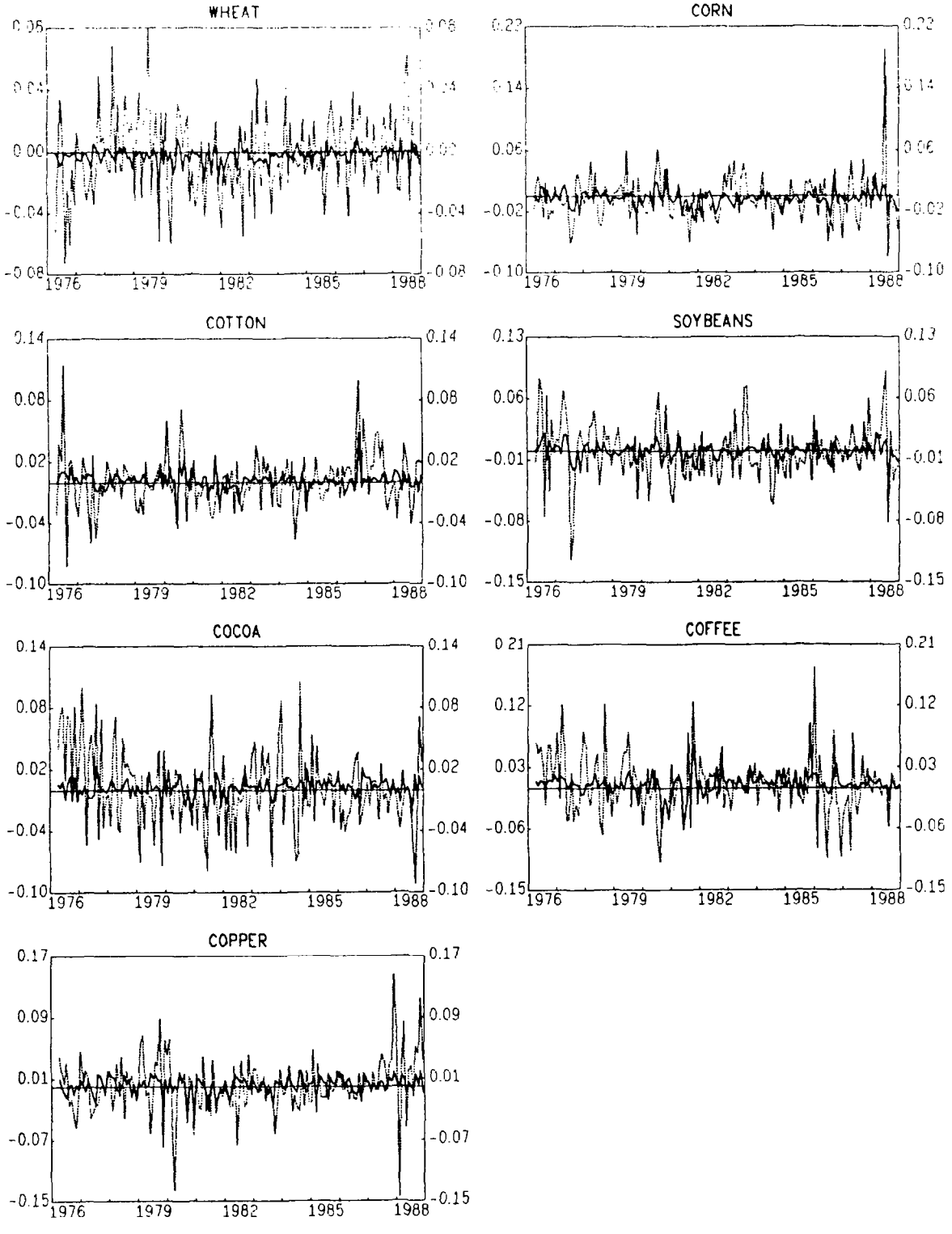
1/ The χ^2 values are for the model specified in equation (8).

Table 5. χ^2 Values for the Time Varying Betas Based on Interest Rates 1/

Sample Time Horizon	Full Sample		First Period		Second Period	
	1 Month	6 Month	1 Month	6 Month	1 Month	6 Month
Commodity						
Corn	24.38	123.31	18.9	427.3	17.8	87.2
Soybeans	13.75	97.71	19.4	283.2	10.8	116.2
Wheat	8.74	96.50	11.7	258.8	14.7	74.6
Cocoa	9.56	68.18	41.1	388.0	18.2	18.2
Coffee	20.36	46.97	51.0	208.6	74.8	77.2
Copper	15.57	64.17	16.4	101.0	16.7	80.8
Cotton	20.72	46.42	19.7	370.5	17.3	43.4
Test of Restrictions	4.70	12.58	9.05	107.15	5.38	19.54

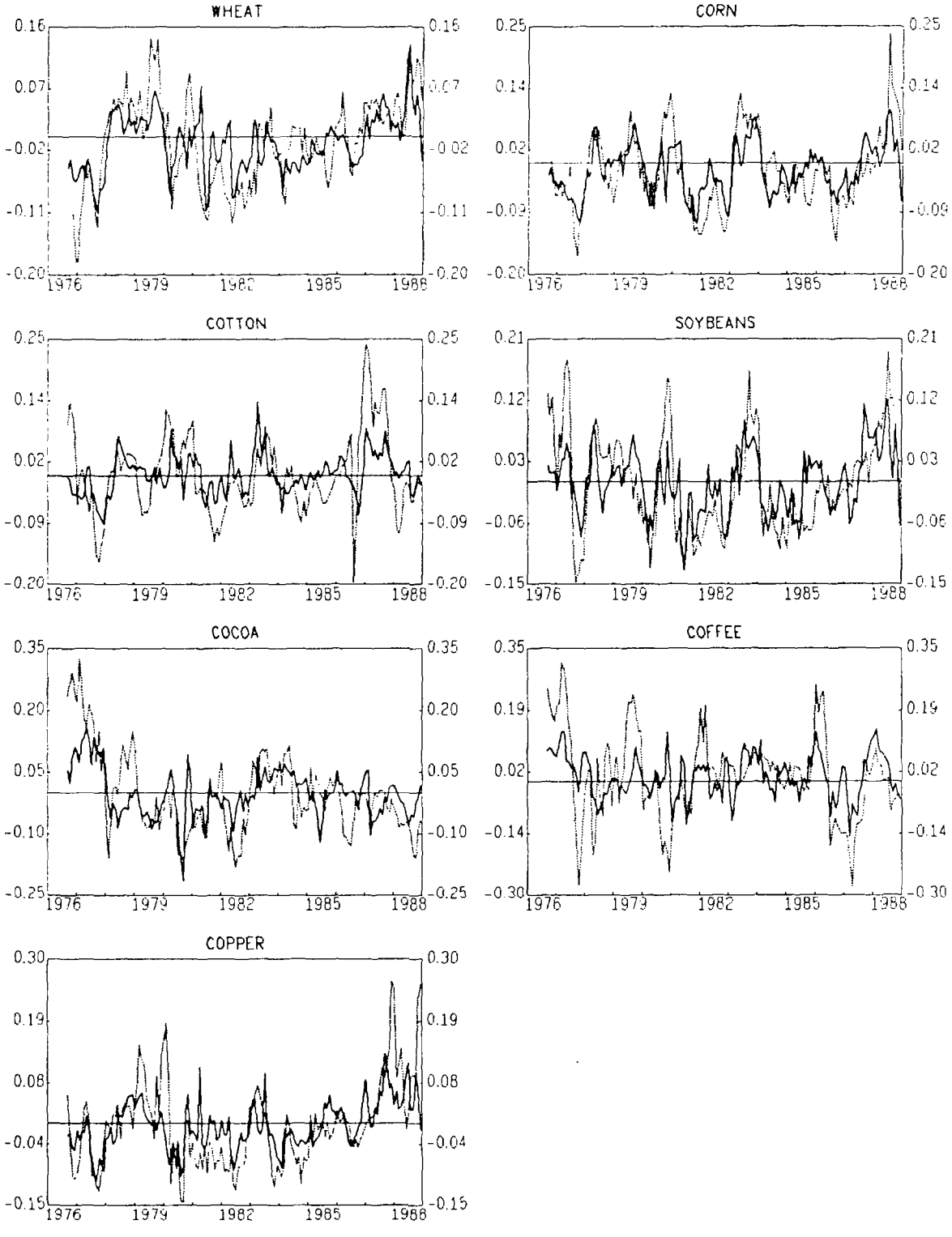
1/ The χ^2 values are for the model specified in equation (8).

Figure 1.
Actual and Predicted 1 Month Excess Returns 1/



1/ Dotted lines are actual values; solid lines are predicted values.

Figure 2.
Actual and Predicted 6 Months Excess Returns 1/



1/ Dotted lines are actual values; solid lines are predicted values.

V. Constant and Time Varying Betas and Out-of-Sample Forecasting

The above results suggest that time varying risk premia within the context of the CAPM appears to accord better with data than does a constant risk premia representation. This finding is, of course, based on the in-sample analysis. It does not necessarily imply that the risk premium can be better predicted using the constant risk model, than the time varying one. In order to consider this issue, this section compares the out-of-sample forecasting ability of the constant beta model with the time varying model.

The methodology was to compare the two models as given by equation (8) and equation (13). The model given by (8) was estimated using the basis as the explanatory variables whereas the model in (13) used the treasury bill rate for capturing the time varying beta.

There are, of course, a large number of indicators available for measuring the out-of-sample accuracy of any given model. In the exercise below, we use the conventional root-mean-square error, defined as follows:

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

where n = 1, 6 denotes the forecast horizon, N_n the number of forecasts for horizon n in the projection period for which the actual value f is known, and f^f the forecast value using alternatively equation (8) or (13). If the root-mean-square errors (RMSE) obtained from (8) are smaller than those of model (13), it would suggest that for out-of-sample forecasting the constant beta model is better, or is at least as good as the time varying model. If, on the other hand, RMSE from (8) are larger than those of model (13), it would provide additional support for the earlier results which suggested that for in-sample forecasting the time varying beta representation was more appropriate.

The results of the out-of-sample forecasting experiment are presented in Table 6. This table instead of presenting the RMSE for each model, only shows the ratio of RMSE statistics from equation (13) to the RMSE statistic obtained from equation (8) at the one- and six-month horizon for different sample periods. Clearly, if the ratio is larger than one, it would suggest that for the out-of-sample period being considered, the time varying beta model has no particular edge in forecasting futures prices compared to the constant beta model.

The first column in Table 6 presents the ratio of the RMSE for out-of-sample forecasts beginning January 1985 and ending December 1988. The first

Table 6. Constant Beta and Time Varying Beta Models: Comparison of Out-of-Sample Forecasts 1/

Commodity	Lag	Out-of-Sample Forecast			
		Jan. 1985-Dec. 1988	Jan. 1986-Dec. 1988	Jan. 1987-Dec. 1988	Jan. 1988-Dec. 1988
Corn	1	0.956	0.952	0.955	0.951
	6	1.009	1.002	0.984	0.987
Soybeans	1	0.991	0.963	0.957	0.936
	6	1.018	1.078	1.016	1.015
Wheat	1	0.996	0.991	0.997	0.987
	6	0.971	0.977	0.954	0.945
Cocoa	1	1.063	1.078	1.088	1.050
	6	1.005	0.999	0.977	1.004
Coffee	1	1.030	1.019	1.018	1.050
	6	1.005	0.999	0.977	1.004
Copper	1	1.024	1.025	1.024	1.016
	6	0.972	0.968	0.951	0.943
Cotton	1	0.974	0.964	0.963	0.983
	6	0.986	0.985	0.975	0.907

1/ The coefficients in the table are the ratios of the mean square error of time varying beta models to the constant beta models (equations 13 and 8, respectively).

observation is thus based on the regression estimated from April 1976 to December 1984, and the predicted value for January 1985. The second observation is then based on the regression from April 1976 to January 1985, with prediction for February 1985 and so on. The results in the table have two interesting features: first, around 60 percent of the values of the ratios are less than one giving support to the hypothesis that a model of time varying risk premium may be somewhat better for forecasting than the constant beta model. Secondly, for several of the commodities, especially those for which the time varying model appears superior, the errors are noticeably reduced when considering a six-month forecast horizon, compared to the one-month horizon. This latter result further supports the evidence obtained earlier about the relative power of the regression models for longer-term forecast horizons.

VI. Concluding Remarks

This paper has examined the extent to which it is possible to detect risk premium in a variety of commodity futures markets. The presence or otherwise of risk premium in these markets is of interest both from the point of view of the functioning of the markets as well as for a cost benefit analysis for agents using the market to hedge against price uncertainty. The methodology adopted in this paper was to regard futures markets as essentially similar to other asset markets and to use the Capital Asset Pricing Model to analyze the risk premium. Five main results emerged from the empirical investigation:

1. There was clear evidence that unconditional excess returns in all commodity markets were not significantly different from zero for short forecast horizons. This result was corroborated by an analysis of serial correlation coefficients of the orders of 1 to 5, which showed that for the one-month returns the coefficients fluctuated around zero. For the six-month returns, however, they were somewhat larger and significantly different from zero in about half of the cases. There was also clear evidence of non-normality in the distribution of excess returns.

2. The CAPM model of risk premia was estimated using projection variables and a constant beta specification. The model had significant power but it was found that the cross-restrictions of the model were not rejected for the full sample period, suggesting that the model was consistent with the presence of a significant risk premium.

3. When the model was estimated over subperiods, however, it was found that the restrictions of the model were rejected at high levels of significance. It was emphasized, however, that since the tests were those of a joint hypothesis--nonzero risk premium and CAPM being an accurate representation of it--the results did not necessarily imply the absence of risk premium.

4. Empirical testing of a time varying beta model confirmed that the rejection of the model over subperiods was indeed due to the parameters of the risk premium model varying over time. This result was obtained by the betas being modeled by a variety of instruments, including the growth rate of U.S. consumption and the U.S. treasury bill rate. An analysis of the residuals from this model showed that the systematic component due to the risk premia was absent and the distribution of the residuals was not significantly different from the standard normal distribution.

5. An examination of the out-of-sample forecasting ability of the time varying model, using standard tests of the accuracy of predictions, showed that it compared somewhat favorably with the constant beta model.

The above results appear to suggest that the rejection of the efficiency hypothesis, documented in a number of recent studies, especially over long forecast horizons, is probably due not so much to market failure as to the presence of a risk premium. Furthermore, the risk premium is most likely not constant over time and may vary according to a large number of both macro and market-specific characteristics. The results also suggest that since the commodity risk is nonzero, while for the sample as a whole, excess returns are around zero, the Keynesian interpretation of risk premium finds less support than some alternative interpretations which emphasize the speculative aspects of futures markets. An interesting extension of this work would be to examine in more detail the factors affecting the variation in risk premia over time.

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. (For the delivery months and other descriptive information for each of the commodities, see Kaminsky and Kumar (1990)).

For soybeans and copper, the analysis was limited to the five major contracts per year. For all commodities, 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 six months or before the contract expiry date are fairly thin. Excess returns for the seven commodities were computed for one- and six-month horizons. The key step in the computation was to form a continuous series of returns using the nearest contracts, which is described in detail in the study noted above.

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