Information in the Term Structure of Commodity-specific Interest Rates in the Chicago Wheat Futures Market

by

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The purpose of this paper is twofold: (1) to define the commodity-specific interest rate and to construct data series of such rates; (2) to use those data to investigate the efficiency of the market's use of information.

First, the commodity-specific interest is defined in terms of the commodity itself rather than in monetary value. It is equivalent to the spread between spot and futures prices for a commodity, adjusted for fluctuations in prices and money interest rates. Conceptually the commodity-specific interest is the price of the convenience yield, which is the net flow of services yielded by a unit of inventory over the specified time period. The price of the convenience yield can be also expressed in a rate per period as the commodity-specific interest rate. Furthermore, the multiple delivery structure of futures contracts allows us to derive the term structure of commodity-rates of interest. The empirical application is conducted in Chicago wheat futures market and the behavior of the computed wheat-rate of interest is examined during 1977-1986.

Second, forecasts of future price spreads implied from the term structure of commodity-rates of interest are used to investigate the information content of current spot-futures price spreads. Since it is generally believed that the term structure contains invaluable information of the market's own expectations about future states of the market, the expectations structure implicit in the term structure is examined. Assuming that the term structure reveals the expected future course of interest rates, the predicting power of the implied forward rates from the term structure is measured.

The impact of monetary factors on the predictive power of the term structure is examined based on the observation that high real interest rates caused by the Federal Reserve's movement to allowing interest rates to vary freely in 1979 initiated a structural adjustment in the agricultural futures markets. The empirical evidence support the notion that commodity futures markets became less efficient in the intermediate stage of adjustment.

The rest of the paper is organized as follows. Section 1 develops the concept of the commodity-specific interest rate based on the works of Keynes (1936), Brennan (1986), and Williams (1986). Section 2 describes the construction of commodity-specific interest rates using spot and discounted futures prices. Section 3 explains an approach measuring information content of forward rates derived from the term structure, the results of which are in section 4.

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1. The concept of the commodity-specific interest rate

J.M Keynes introduced the theory of normal backwardation in futures markets. However, less well known is his commodity-rates of interest or commodity-specific interest rates[1]. The idea that every durable commodity has a rate of interest in terms of itself was seen in Keynes' theory of interest rates even though he himself argued that commodity-specific interest rates are uninteresting compared to the interest rate on money. But commodity-specific interest rates have a special implication if we study the relationship between the spot and futures price.

The own rates of interest of commodities are different among commodities. Keynes pointed out that commodity-rates of interest measured in terms of themselves are composed of three parts :i) a yield (denoted by y) from assisting some process of production or supplying services to a consumer; ii) a carrying cost (denoted by c) including a depreciation cost; iii) a liquidity premium (denoted by l) as the amount which a person is willing to pay for a potential convenience exclusive of a yield or a carrying cost attaching to the asset. Following this argument the own-rate of interest can be expressed as $y-c+l$. Since for each commodity the relative importance of these three attributes are significantly different, commodity-specific interest rates are different among commodities. For harvestable and storable commodities, for example, where y is nil and c is almost the same over commodities, the differences in own-rates of interest may entirely depend on their liquidity premiums. According to Keynes a liquidity premium comes from the power of disposal over an asset. Since a liquidity premium is obtained from accessibility to a commodity, it can be regarded the same as the *convenience yield* in the futures market literature.

When firms hold inventories against unexpected changes or supply, what they really want is not the commodity itself but the services from the commodity, the convenience yield. Since they hold inventories to have a secure supply, it is not necessary for them either to own the raw materials or administer the storage. Their primary concern is making it sure that they have immediate access to the raw materials.

According to Williams (1986), a futures contract is a very convenient way of borrowing a commodity implicitly. The logic of his argument can be summarized as follows. A commodity on the spot is a bundle of two characteristics, access to the commodity over some period of time and the right to future use beginning at the end of that period. Therefore, a good already on the spot differs from a good on order because it provides access to raw materials over the intervening time. With futures markets, a firm buying a good on the spot can sell its right to that commodity in the future by contracting to deliver in the future. Then the firm is left with only what it wants, the access to the commodity over the corresponding period. Therefore, a short hedging operation, the combination of buying spot and simultaneously selling for future delivery, is same as borrowing the commodity. Dealers in commodities can conduct a hedging operation as an implicit way of buying the convenience yield.

In an independent study, Brennan (1986) also discussed the price of borrowing one unit of the commodity for a given period of time. Specifically, Brennan used the term convenience claim as a claim to the net (of carrying charges) flow of services yielded by a unit of inventory over a specified time period. If we express the price of a convenience claim in a rate per period, it is equivalent to Keynes' commodity-rate of interest. Even though there is no explicit market for the claim, its purchase can be implicitly performed by a purchase of one unit of the good on the spot, offset by a short position in a futures contract.

2. Derivation of commodity-specific interest rates

Based on Keynes' claim that the difference between the spot and futures prices for a commodity bears a definite relationship to the commodity-rate of interest, we will calculate the commodity-specific interst rate for wheat in this paper. A problem in calculating the commodity interest rate using the quoted spot and futures prices is that a futures contract is quoted in terms of money for future delivery and not in terms of the commodity itself for spot delivery. This problem is solved by discounting futures prices by a full carrying charge and by normalizing all the spot and discounted futures prices by the spot price.

At any given point of time we have a spot price and a series of futures prices with various maturities. Since the futures prices are expressed in terms of dollars at the time of delivery, we need to transform them into current dollars by subtracting the storage cost. Then the difference between the spot price and the discounted futures price is usually positive since a commodity on hand provides a valuable service to the owner, i.e., accessibility to the commodity, compared to a commodity on future delivery. Consequently, this difference can be recognized as the price of the convenience yield for the specified time period.

Now we will develop a method to evaluate the price of a convenience yield in the commodity term. Let $S(t)$ be a spot price of wheat at time t and $F_d(t,\tau)$ a discounted futures price for delivery at time $t+\tau$ evaluated at time t. To express the value of a discounted futures price not in terms of money but in terms of the commodity itself we normalize all the discounted futures prices by the current spot price of wheat. Then the spot price of wheat is one and the discounted futures price is expressed as $P(t,\tau) = F_d(t,\tau)/S(t)$. The price of a τ-period normalized convenience yield is expressed as $Q(t,\tau) = 1 - P(t,\tau)$. However, this can be converted into a rate per month just as the price of borrowing money is expressed in interest rates per annum. Furthermore, since we have a set of current prices for future wheat, this cross-sectional structure of current prices makes it possible to quote the average returns or yields on different maturity convenience yields.

Consider a convenience yield from a commodity at date t with maturity $t+\tau$. The price of a normalized convenience yield of maturity τ is expressed as,

$$Q(t,\tau) = 1 - P(t,\tau) = 1 - \frac{1}{(1 + R(t,\tau))^{\tau}} \qquad (1)$$

where $R(t,\tau)$ is the yield or the commodity-specific interest rate for the commodity[2]. The value of the convenience yield can be expressed either by the commodity-specif interest, $Q(t,\tau)$, or by the commodity-spercific interest rate, $R(t,\tau)$. The expression for the commodity-specific interest rate can be obtained from equation (1),

$$R(t,\tau) = [1 - Q(t,\tau)]^{-1/\tau} - 1.0$$
$$= P(t,\tau)^{-1/\tau} - 1.0$$
$$= \left[\frac{F_d(t,\tau)}{S(t)} \right]^{-1/\tau} - 1.0 . \quad (2)$$

The curve generated by plotting the yield, $R(t,\tau)$, against the maturity, τ, is the yield curve or the term structure of commodity interest rates. And if we denote $r(t)$ as the one-period rate of commodity interest at time t, the spot rate of interest is,

$$r(t) = R(t,1)$$
$$= \frac{S(t)}{F_d(t,1)} - 1.0 . \quad (3)$$

Furthermore, given a set of commodity-specific interest rates of all maturities, the future course of the one-period commodity interest rates (forward rates) can be determined as

$$f(t,\tau-1) = \frac{P(t,\tau-1)}{P(t,\tau)} - 1.0$$
$$= \frac{(1+R(t,\tau))^{\tau}}{(1+R(t,\tau-1))^{\tau-1}} - 1.0 . \quad (4)$$

Specifically, forward rates which are derived in this way are supposed to incorporate the market's subjective expectations about the future spot rates. Hence we use forward rates to investigate the efficiency of the market's own use of information. One of the most interesting facts about the term structure is what it reveals about the expected future course of interest rates. The predicting power of the forward rates from the term structure will be examined in the next section.

3. The predictive power of forward commodity interest rates

An attempt to measure the information content of the term structure of commodity-specific interest rate is made in this section. This is concerned with the predictive power of forward commodity interest rates derived from the term structure. Derived forward rates can be regarded as the market's own expectations of future spot rates. Since forward rates are not quoted directly from the market but are implied from the behavior of the market they are good proxies for all information available at the moment.

A simple comparison of the standard deviation of $f(t,\tau)-r(t+\tau)$, the difference between the forward rate and the subsequently observed spot rate, and the standard deviation of $r(t+\tau)-r(t)$, the change in the spot rate gives a notion about the forecasting power of implied forward rates from the term structure. Table 1 offers evidence that the standard deviation of the error of the forward rate observed at time t as a forecast of the spot rate $r(t+\tau)$ is less than that of the error of the naive forecast that $r(t+\tau)$ will equal $r(t)$.

This section uses a regression approach developed by Fama to measure the information in the forward rates about future spot rates and risk premiums.

Table 1

Standard deviation of $f(t,\tau)-r(t+\tau)$ and $r(t+\tau)-r(t)$;1977-1986.

τ	$f(t,\tau)-r(t+\tau)$	$r(t+\tau)-r(t)$
1	.00262	.00278
2	.00230	.00322
3	.00264	.00358
4	.00278	.00415
5	.00278	.00409
6	.00291	.00426
7	.00302	.00424
8	.00305	.00404
9	.00313	.00377
10	.00361	.00370
11	.00411	.00367

Methodology

For the purpose of the empirical study, forward rates can be simply decomposed into a forecast of the future spot rate and a risk premium which obscures the predictive power of forward rates as

$$f(t,\tau) = E_t[r(t+\tau)] + \phi(t,\tau) \quad . \qquad (5)$$

By this expression, the forward rate for month $t+\tau$ observed at time t contains, $E_t[r(t+\tau)]$, the expected future spot rate for month $t+\tau$, and also contains $\phi(t,\tau)$, the risk premium. Equation (5) illustrates the possibility that the forward rate may not be unbiased estimate of the future spot rate. The difference between the two is defined as the risk-premium expected to prevail during the period.

If we rewrite equation (5) by subtracting $r(t)$ from both sides of the equation, we get

$$f(t,\tau)-r(t) = E_t[r(t+\tau)-r(t)] + \phi(t,\tau). \qquad (6)$$

The LHS of the equation is our choice of the variable that represents information set at time t to predict both the risk-premium prevailing until

$t+\tau$ and the expected future change in the spot rate. The RHS of the equation (6) can be further manipulated as,

$$E_t[r(t+\tau)-r(t)] + \phi(t,\tau)$$

$$[r(t+\tau)-r(t)] + E_t[r(t+\tau)-r(t+\tau)] + \phi(t,\tau)$$

$$= [r(t+\tau)-r(t)] + [f(t,\tau)-r(t+\tau)].$$

By this manipulation, the forward-spot differential, $f(t,\tau)-r(t)$, can be expressed as a combination of the change in the spot rate, $r(t+\tau)-r(t)$, and the realized forecast error of the forward rate, $f(t,\tau)-r(t+\tau)$. Using this expression, we can construct the following time series regressions which regress the change in the spot rate, $r(t+\tau)-r(t)$, and the realized forecast error of the forward rate containing a risk premium, $f(t,\tau)-r(t+\tau)$, on the current forward-spot differential, $f(t,\tau)-r(t)$.

$$r(t+\tau)-r(t) = a_{1\tau} + b_{1\tau}[f(t,\tau)-r(t)] + u_1(t+\tau) \qquad (7)$$

$$f(t,\tau)-r(t+\tau) = a_{2\tau} + b_{2\tau}[f(t,\tau)-r(t)] + u_2(t+\tau) \qquad (8)$$

Estimates of these equations tell us whether the current forward-spot differential, $f(t,\tau)-r(t)$, has a power to predict either the future change in the spot rate, $r(t+\tau)-r(t)$ or the risk premium, $\phi(t,\tau)$. If $b_{1\tau}$ is reliably positive, the nature of the regression indicates that the forward rate observed at time t has information about the future spot rate to be observed at time $t+\tau$. If $b_{2\tau}$ is reliably positive, the risk premium component of the forward-spot differential has variations that show up reliably in $f(t,\tau)-r(t)$.

Given the assumption that $E_t[r(t+\tau)]$ is a rational (or efficient) forecast of $r(t+\tau)$, the regression coefficients in (7) and (8) can be interpreted as

$$b_{1\tau} = \frac{\text{cov}[f(t,\tau)-r(t),\ r(t+\tau)-r(t)]}{\text{var}[f(t,\tau)-r(t)]}$$

$$= \frac{\text{cov}[\phi(t,\tau)+E_t[r(t+\tau)-r(t)],\ r(t+\tau)-r(t)]}{\text{var}[f(t,\tau)-r(t)]}$$

$$= \frac{\text{cov}[\phi(t,\tau)+E_t[r(t+\tau)-r(t)],\ E_t[r(t+\tau)-r(t)]]}{\text{var}[f(t,\tau)-r(t)]}$$

$$= \frac{\mathrm{cov}[\phi(t,\tau),E_t[r(t+\tau)-r(t)]] + \mathrm{var}[E_t[r(t+\tau)-r(t)]]}{\mathrm{var}[f(t,\tau)-r(t)]}$$

$$= \frac{\mathrm{cov}[\phi(t,\tau),E_t[r(t+\tau)-r(t)]] + \mathrm{var}[E_t[r(t+\tau)-r(t)]]}{\mathrm{var}[E_t[r(t+\tau)-r(t)]] + 2\mathrm{cov}[\phi(t,\tau),E_t[r(t+\tau)-r(t)]] + \mathrm{var}[\phi(t,\tau)]} \qquad (9)$$

$$b_{2\tau} = \frac{\mathrm{cov}[f(t,\tau)-r(t),\ f(t,\tau)-r(t+\tau)]}{\mathrm{var}[f(t,\tau)-r(t)]}$$

$$= \frac{\mathrm{cov}[\phi(t,\tau)+E_t[r(t+\tau)-r(t)],\ f(t,\tau)-r(t+\tau)]}{\mathrm{var}[f(t,\tau)-r(t)]}$$

$$= \frac{\mathrm{cov}[\phi(t,\tau)+E_t[r(t+\tau)-r(t)],\ \phi(t,\tau)]}{\mathrm{var}[f(t,\tau)-r(t)]}$$

$$= \frac{\mathrm{cov}[\phi(t,\tau),E_t[r(t+\tau)-r(t)]] + \mathrm{var}[\phi(t,\tau)]}{\mathrm{var}[f(t,\tau)-r(t)]}$$

$$= \frac{\mathrm{cov}[\phi(t,\tau),E_t[r(t+\tau)-r(t)]] + \mathrm{var}[\phi(t,\tau)]}{\mathrm{var}[E_t[r(t+\tau)-r(t)]] + 2\mathrm{cov}[\phi(t,\tau),E_t[r(t+\tau)-r(t)]] + \mathrm{var}[\phi(t,\tau)]} \qquad (10)$$

where the third equalities follows from the assumption that the expected future spot rate in forward rate is rational.

In the special case when $\phi(t,\tau)$ and $r(t+\tau)-r(t)$ are not correlated, the regression coefficients $b_{1\tau}$ and $b_{2\tau}$ split the variation of the forward-spot differential into two parts; the proportion due to the variation of the expected change in the spot rate and the proportion due to the risk premium. When two components of the forward-spot differential are correlated, the covariance between $\phi(t,\tau)$ and $E_t[r(t+\tau)-r(t)]$ enters both in $b_{1\tau}$ and in $b_{2\tau}$. The regression coefficients still include the portion of $\mathrm{var}[f(t,\tau)-r(t)]$ due to $\mathrm{var}[\phi(t,\tau)]$ and $\mathrm{var}[E_t[r(t+\tau)-r(t)]]$, but the simple interpretation of $b_{1\tau}$

and $b_{2\tau}$ obtained when $\phi(t,\tau)$ and $E_t[r(t+\tau)-r(t)]$ are uncorrelated is lost. However, if $b_{1\tau} > 1/2$, it follows that $var[E_t[r(t+\tau)-r(t)] > var[\phi(t,\tau)]$ which indicates that most part of variation in the forward-spot differential is due to the expected change in the spot rate rather than the risk premium.

In estimating equation (7) and (8) by ordinary least squares regression we have a serial correlation problem since a sampling interval is smaller than the forecast horizon when $\tau > 1$. That is, if the sampling interval is finer than the forecasting interval, it can be shown that under the null hypothesis the disturbance for the regression is a moving average process of some order. Although ordinary least squares yields consistent parameter estimates under the null hypothesis, this serial correlation problem cause the estimates of variance-covariance matrix to be inconsistent. Therefore test results based on this inconsistent matrix can not be reliable. One way to avoid it is to use only non-overlapping observations with OLS estimation, while sacrificing most of the observations[3].

However, in our test, the method originated by Hansen and Hodrick (1980) is used to get a consistent covariance matrix for OLS estimates in the presence of serial correlation. The modified variance-covariance matrix (Σ) is given as

$$\Sigma = \hat{\sigma}_u (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\hat{\Omega}\, \mathbf{X}\ (\mathbf{X}'\mathbf{X})^{-1}$$

where $\mathbf{X}$ is a (T X 2) matrix defined from equation (7) or (8), and $\hat{\Omega}$ is a (T X T) symmetric matrix constructed as follows. First, calculate

$$R_u(j) = \frac{1}{T} \sum_{t=j+1}^{T} u(t)u(t-j) \quad j=1,2,\ldots,\tau-1.$$

where u(t) is the OLS residual from (7) or (8) for observation t with sample size T. Next, form

$$\hat{\Omega} = \begin{bmatrix} 1 & R_u(1) & R_u(2) & \cdots & R_u(\tau-1) & 0 & \cdots & 0 \\ R_u(1) & 1 & \cdot & & & \cdot & & \vdots \\ R_u(2) & \cdot & 1 & \cdot & \cdot & & & 0 \\ \vdots & & & & & & & R_u(\tau-1) \\ \cdot & \cdot & \cdot & 1 & \cdot & \cdot & & \cdot \\ R_u(\tau-1) & & & & & & & \vdots \\ 0 & \cdot & & & 1 & & \cdot & R_u(2) \\ \vdots & \cdot & & & & \cdot & 1 & R_u(1) \\ 0 & \cdots & 0 & R_u(\tau-1) & \cdots & R_u(2) & R_u(1) & 1 \end{bmatrix}$$

One problem of this estimate is that $\hat{\Omega}$ need not be positive definite in finite samples. Thus the use of the corrected covariance matrix may result in negative standard errors[4].

4. The empirical evidence

Data layout

Data for futures prices and spot prices of wheat are quoted from the Chicago Board of Trade *Statistical Annuals* for the ten years from 1977-1986. The relevant prices for each month are the closing prices of the third friday (or if they are not available, the mid-point of the range of closing prices), in tenths of a cent per bushel.

To calculate carrying charges data for the costs of storage is needed. However, since published data for warehouse fees for wheat are not available, they are taken from informal information to be 3.0 cents per bushel per month in 1977 and 5 cents per bushel per month in 1986; figures for the intervening period are obtained by a linear interpolation. Insurance fees are neglected since they are too small to matter. Data on interest costs are calculated using the current prime rate plus one percent[5].

By subtracting storage costs from the actual futures prices, we obtain discounted futures prices which are used to calculate the commodity interest rate. Since we use monthly data for the analysis, discounted futures prices are interpolated to get continuous monthly time series for the no contract months. Using formulas given in previous section, yields and forward rates are calculated. Monthly data for Chicago stocks of wheat are also compiled from the *Statistical Annuals*.

Estimation results

According to expressions for $b_{1\tau}$ and $b_{2\tau}$ in (9) and (10), the sum of the slopes must be 1.0. Therefore, it is enough to present the estimation results for the regression of $f(t,\tau)-r(t)$ on $r(t+\tau)-r(t)$. Table 2 shows the forward-spot differential regression equation (7) and the coefficient $b_{1\tau}$ reports the predicting power of the forward-spot differential as a predictor of the change in the spot rate. The deviation of $b_{1\tau}$ from 1.0 can be regarded as a direct measure of the variation of the premium in the forward rate since $b_{2\tau} = 1 - b_{1\tau}$.

The slope coefficient ($b_{1\tau}$) in the regression contains the proportion of the expected change in the spot rate. If the covariance between $\phi(t,\tau)$ and $E[r(t+\tau)-r(t)]$ is either zero or very low, the variation in the forward-spot differential is mainly due to the expected change in spot rate rather than the risk premium since $b_{1\tau} > 1/2$ for $\tau = 1,\dots,10$. Estimation results for τ=4,5 need to be paid more attention since figures for b_{14}, b_{24}, which are greater than one, indicate negative b_{24}, b_{25}. The negative estimates of b_{24}, b_{25} can be obtained only when the covariance between $\phi(t,\tau)$ and $E[r(t+\tau)-r(t)]]$ is negative and larger in magnitude than the positive $var[\phi(t,\tau)]$. Since b_{14} and b_{24} are only slightly greater than one and all other $b_{1\tau}$'s are less than one, the most plausible scenario for our results is that both $cov[\phi(t,\tau), E[r(t+\tau)-r(t)]]$ and $var[\phi(t,\tau)]$ are substantially smaller than $var[E[r(t+\tau)-r(t)]]$ in magnitude. In the case when the covariance is negative, the simple interpretation of $b_{1\tau}$ as the proportion due to the variation of the expected change in the spot rate is no longer possible. Neverthless the slope coefficient estimates in Table 2 generally suggest that (a) most of the variation in the forward rate is due to the expected variation in the spot rate, and (b) the risk premium and the expected spot rate are negatively correlated if they are correlated, and the degree of correlation seems to be low.

Table 2

Estimated regression of r(t+τ)-r(t) on f(t,τ)-r(t):1977-1986.

$$r(t+\tau)-r(t)= a_{1\tau} + b_{1\tau}[f(t,\tau)-r(t)] + u_1(t+\tau).$$

Dependent Variable	Coefficient $\hat{a}_{1\tau}$	Coefficient $\hat{b}_{1\tau}$	test $a_{1\tau}=0$ p value	test $b_{1\tau}=1$ p value	test $a_{1\tau}=0, b_{1\tau}=1$ p value	R^2	D-W
Δr(t+1)	-.002 (.003)	.615 (.118)	.396	.001	.002	.19	2.4
Δr(t+2)	-.005 (.003)	.861 (.138)	.08	.31	.06	.50	1.5
Δr(t+3)	-.005 (.003)	.828 (.142)	.20	.12	.03	.48	1.3
Δr(t+4)	-.004 (.005)	1.07 (.184)	.35	.69	.62	.55	1.3
Δr(t+5)	-.005 (.005)	1.03 (.159)	.33	.85	.60	.55	1.1
Δr(t+6)	-.005 (.005)	1.00 (.089)	.31	.98	.60	.54	1.2
Δr(t+7)	-.005 (.005)	.93 (.146)	.31	.63	.53	.50	1.1
Δr(t+8)	-.005 (.006)	.88 (.150)	.38	.43	.50	.44	1.2
Δr(t+9)	-.01 (.007)	.70 (.121)	.17	.014	.001	.38	1.1
Δr(t+10)	.018 (.008)	.52 (.095)	.027	.000	.000	.33	1.1
Δr(t+11)	.023 (.009)	.42 (.092)	.011	.000	.000	.30	.96

The standard errors of the regression coefficients are adjusted for possible autocorrelation induced by the overlap of monthly observations on changes in the spot rate.

An alternative measure of the forecast power of forward rates is the coefficient of determination, R^2. The value of R^2 can be considered as a lower bound measure of the explanatory power of the forecasts in forward rates[6]. The magnitude of R^2 shown in Table 2 is consistent with the evidence shown in the slope coefficient. Figure 1 plots four-month changes in spot rate and the fitted values from the regression of r(t+4)-r(t) on f(t,4)-r(t). The high R^2(.55) of the regression suggests predictive power in four month forward rate in forecasting four-month changes in one-month spot rate.

Table 2 also reports the results of the forward-spot differential unbiasedness regression. Note that most of the intercept coefficients are not significantly different from zero and the slope coefficients are not significantly different from one. The test of unbiasedness (a_τ=0, b_τ=1) tells us that the null hypothesis can not be rejected at 5% level in many cases (τ=2,4,5,6,7,8). However, forward-spot differentials for the long-term contracts (τ=9,10,11) should not be regarded as unbiased estimates of changes in spot rates. Specifically, the reliably positive intercept coefficients (τ=10,11) suggests the existence of the risk-premium in the long-term contracts.

Subperiod results and interpretations

Empirical evidence thus far suggests that wheat futures prices used to construct commodity-specific interest rates contain invaluable information to predict future states of the market during the period 1977-1986. However, it is believed that commodity markets have been significantly influenced by changing U.S. monetary policies during the sample period.

In this subsection we examine whether the predictive ability of the term structure has changed across recent monetary regimes that are characterized by different degrees of interest rate targeting by the Federal Reserve. Our main aim is to provide additional evidence concerning the dominance of monetary factors in the determination of agricultural commodity prices in recent years. Since our sample is from January 1977 through December 1986, we divide it into three subperiods which roughly correspond to the three official monetary regimes; they are in chronological order, i) interest targeting (January 1977 - October 1979), ii) lack of any interest targeting (October 1979 - October 1982), iii) partial interest targeting (October 1982 - December 1986).

Traditionally, real interest rate is believed to influence agricutural commodity markets through the cost of money in the determination of carrying costs. However, a major adjustment occurred in U.S. monetary policy in 1979 provided some new influences for agricultural commodity markets. Tight monetary policy and resulting high interest rates made U.S. commodities less attractive in foreign markets and the resulting reduced demands took away the required impetus to utilize agricultural commodities at the same high rate of growth experienced in the late 1970s. The direct impact of the "liquidity crisis" from high interest rates on the commodity futures was verified in a reduced volume of trade as traders convert their liquidity assets (including futures) into cash. High real interest rates also reduced speculative participation, which is believed to increase market efficiency, in grain futures as securities and money market funds, offering high interest rates with less risk, drew more attention. Therefore, it is certain that commodity futures markets were plagued by a series of composite negatives related with monetary policy during the period.

Now we turn to examine how the structural adjustments in agricultural commodity markets caused by the unprecedentedly high interest rates was reflected in the predictive power of the term structure. Table 3 reports the slope coefficients with their standard errors and the R^2's of the term structure regression equation (7) during the subperiods.

The slope coefficient estimates which indicate the presence of predictive power are significantly positive in every period. This implies that futures market has played its information role during the whole period regardless of exogenous shocks. The forward rates are always better forecasts of future spot rates than those of risk premium. However, it should be noted that both the slope coefficient and R^2 dropped significantly in the second period[7]. The weak domestic and foreign economies, liquidity problem, and the absence of "hedging-buy" mentality to beat inflation have all contributed to a reduction of confidence in the market. Specifically, unstable prices (both commodity prices and real interest rates) combined with unexpected demands cutback which was well below the expectations caused the predictive power of the term structure decline substantially in the second subperiod.

The predictive power for changes in spot rates clearly increased in the third period. Therefore it can be said that the second period was the intermediate stage of structural adjustment in agricultural commodity futures markets caused by reduced economic activity as a result of high real rates of interest. Although negative environments in U.S. agriculture continued in the third period, "faith" in the market in terms of forecasting power of market's own expectations was recovered during the third period. In summary, it appears that the predictive power of the term structure was influenced by changes in monetary policy. Since the commodity-specific interest rate includes both spot and futures price, this suggests that the expectations structure in agricultural commodity markets is very sensitive to U.S. monetary policy changes.

Table 3.

The predictive power of the term structure: subperiod results

$$r(t+\tau)-r(t) = a_{1\tau} + b_{1\tau}[f(t,\tau)-r(t)] + u_1(t+\tau).$$

	period 1 Jan.77-Oct.79		period 2 Oct.79-Oct.82		period 3 Oct.82-Dec.86	
τ	$b_{1\tau}$	R^2	$b_{1\tau}$	R^2	$b_{1\tau}$	R^2
1	.817 (.158)	.46	.881 (.138)	.55	.470 (.218)	.09
2	.710 (.236)	.37	.509 (.151)	.21	1.009 (.102)	.63
3	.870 (.202)	.44	.624 (.158)	.28	.916 (.118)	.56
4	1.008 (.248)	.50	.731 (.294)	.33	1.352 (.106)	.72
5	.967 (.205)	.52	.776 (.295)	.32	1.317 (.119)	.73
6	.998 (.205)	.55	.685 (.310)	.28	1.285 (.130)	.69
7	.971 (.159)	.50	.806 (.287)	.41	1.136 (.144)	.60
8	1.033 (.108)	.56	.794 (.301)	.34	1.036 (.121)	.49
9	.769 (.173)	.46	.799 (.136)	.46	1.017 (.253)	.40
10	.620 (.141)	.47	.844 (.110)	.55	.570 (.102)	.21
11	.521 (.116)	.49	.777 (.155)	.51	.475 (.160)	.18

5. Summary

The role of the convenience yield in explaining the price spread between the spot and futures prices of a commodity has been received much attention since Kaldor (1939) firstly discussed it. Our objective in this paper has been to construct a new price of the convenience yield using Keynes' theory of commodity- specific interest rates and to find its empirical implications. Since the multiple delivery structure of futures contracts allows us to study the term structure of commodity-rates of interest, the information content of forward rates implied by a term strucutre was examined.

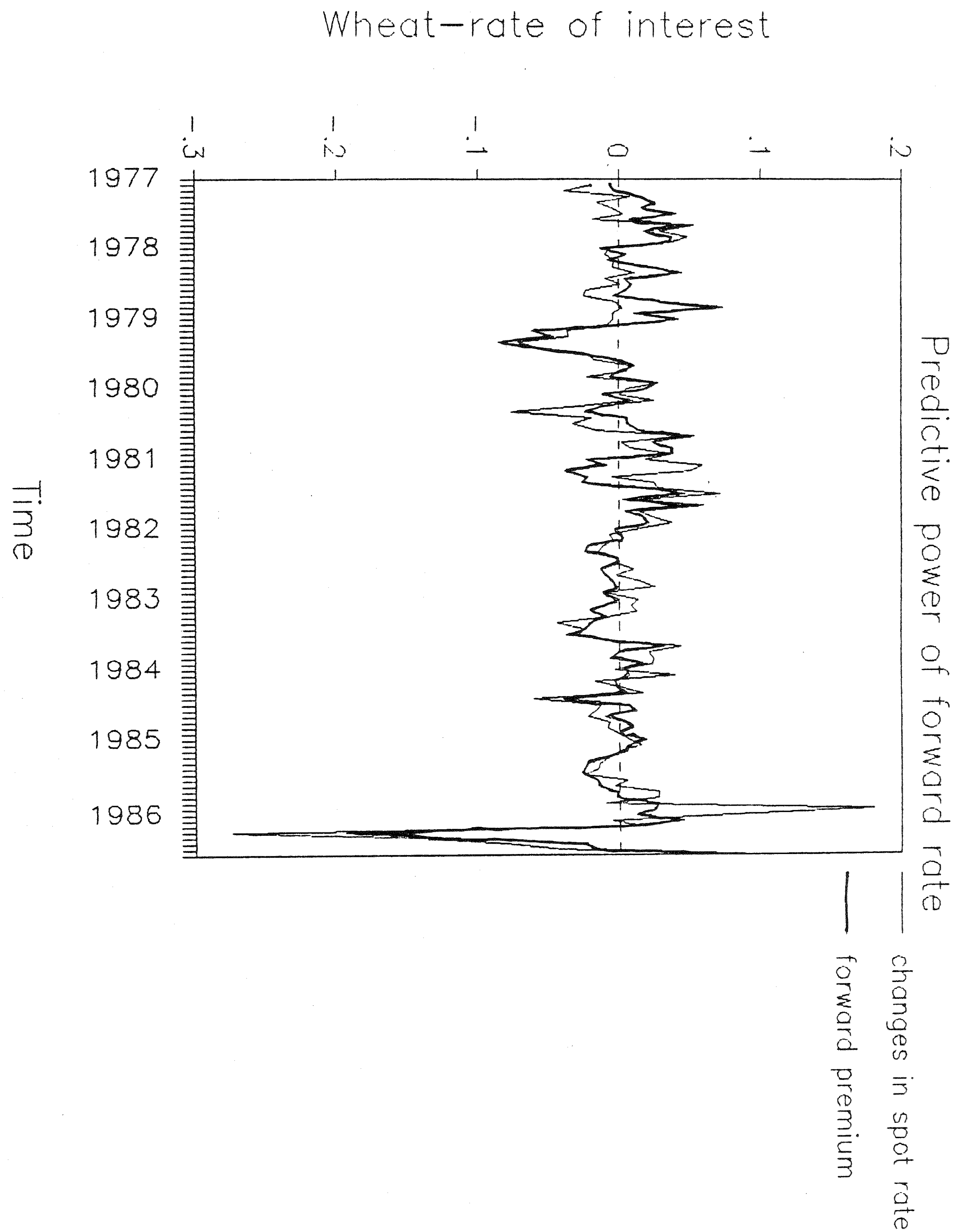
The study revealed that forward rates reflect the market's subjective expectations resonably well. Using the estimated forward rates as proxies for the market's own use of information, time series regressions were conducted to show that the Chicago wheat futures market was relatively efficient during the period 1977-1986. However, it appears that the informational role of the market was influnced by monetary factors.

Footnotes

1. Keynes suggested that for every kind of capital asset there must be an analogue of the rate of interest on money. See Keynes (1936), PP 222-229.
2. At date $t+\tau$ the convenience yield will have no value.
3. If $\tau > 1$, u_t in equation (7) (or (8)) is not white noise but is equal to a $(\tau-1)$-order moving average process. In this case, GLS (generalized least squares) estimator is also inconsistent since GLS requires the strict exogeneity of the independent variables, which implies that the knowledge of the future innovations does not influnce current expectations. But knowledge of the future innovations would be extremely useful in forecasting future spot rates, so the strict exogeneity assumption is inappropriate.
4. RATS econometric package has a special function to make the covariance matrix Ω to be always positive definite by allowing a broader class of spectral windows.
5. Interest is the cost of commodity ownership since money is almost always borrowed against the inventory. CBOT (1982) recommends to use prime rate plus one percent to calculate financial costs of holding inventories.
6. This statement is valid when $b_{1\tau}$ is less one. From (9),

$$\frac{R^2}{b_{1\tau}} = \frac{var[E[r(t+\tau)-r(t)] + cov[\phi(t,\tau),E[r(t+\tau)-r(t)]]}{var[r(t+\tau)-r(t)]}$$

7. The coefficient estimates and R^2's for $\tau = 9,10,11$ are higher in the second period than in other periods. This suggests that the risk premium in deferred months was extraordinarily samll in the period, which corresponds to a sunstantial decline in open interest of the deferred contract.


Wheat-rate of interest
Predictive power of forward rate
changes in spot rate
forward premium
Time
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
-.3
-.2
-.1
0
.1
.2

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