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The Efficiency of the U.S. Cotton Futures Market (1986-2006): A Test for Normal Backwardation and Identification of Economic Indicators

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Abstract

The cotton futures market was analyzed to determine pricing patterns and explain pricing with an equilibrium asset pricing framework. Results are consistent with the efficient market hypothesis over the long-run. Pricing trends existed within contracts and by seasons. Cotton futures do not show significant risk premiums over other financial assets.

Introduction

Because of the importance of marketing risk management to the multi-billion dollar cotton industry, cotton futures prices have often been included in studies of other agricultural futures prices to detect any price patterns. It is interesting to note that in two comprehensive studies of futures market prices (Kolb, and Bessimbinder and Chan), cotton was found to have different results than other agricultural futures. There is a gap in the literature as to whether that pattern has persisted, thus there is a need to update the previous studies in cotton futures markets.

Two major classes of empirical research have been used to examine futures pricing. One approach is to use sequences of prices and develop statistical tests on the prices over time to identify the presence of either contango or normal backwardation. Another conceptual framework derives from the concept of equilibrium asset pricing. There are many equilibrium asset pricing studies in the finance literature, the most well known being the Capital Asset Pricing Model (Sharpe). The economic theory sections will focus on those empirical studies that have particular relevance for the cotton market. We begin our paper by giving a brief description of the data used in our analysis. We then divide the paper into two main categories: Pricing Patterns and Economic Indicators. Each main category has been subdivided into three sections. The first section discusses the economic theory underlying our research. It is followed by a discussion of the methods used to conduct our tests, and concludes with an explanation of the results. The paper closes with a discussion of the findings for the two categories of pricing patterns and economic indicators.

Data

Data consisted of daily settlement prices for the Cotton No. 2 futures contract, traded at the New York Board of Trade. There are five different cotton futures contracts, representing its delivery month: March, May, July, October and December. Twenty years of daily settlement prices (1986-2006) for each of the five monthly cotton contracts were analyzed for the normal backwardation tests, resulting in twenty individual contracts for each contract month. A total of 100 individual cotton futures contracts were used in this study. Each contract consists of 24 months of daily settlement prices beginning in 1997. Prior to 1997, each contract consisted of 18 months of daily settlement prices. Yearly average settlement prices for the five different contracts, from 1986 through 2006, ranged from a minimum of about 46 cents a pound to a maximum of about 84 cents a pound. Total number of daily cotton futures settlement price observations totaled over 42,750.

Additional data used to represent economic indicators were gathered from the DataStream database. They included the Dow Jones Industrials Dividend Yield, the U.S. Treasury Constant Maturities 3-Month Middle Rate, the U.S. Corporate Bond Moody's BAA Middle Rate, the U.S. Corporate Bond Moody's AAA Middle Rate, and the U.S. Treasury Benchmark Bond 10 Years. Data for the monthly economic indicators begins in July 1989 and ends in December 2006.

Pricing Patterns

Economic Theory

John Maynard Keynes originated the theory that futures prices are less than the expected future spot price leading to the expectation that the futures prices rise over time to equal the expected future cash price at the expiration of the contract. This theory was described by Keynes as normal backwardation. The opposite behavior is known as a contango. Keynes explains the normal backwardation pattern by considering the risk preferences of speculators and hedgers. He hypothesized that “speculators are net long and that hedgers pay speculators for bearing risk,” which in turn leads to a pattern of rising futures prices. According to Kolb,

> “In order for normal backwardation to prevail, short traders must be more highly risk averse than long traders in the aggregate. In this framework, the highly risk-averse short traders use futures to hedge unwanted risk…………As a speculator, the long trader enters the market and provides risk-bearing services only if he expects a profit. The excess of the expected future spot price over the current futures price is the speculator’s expected profit and his reward for bearing risk.”

The speculator’s reward for bearing risk is also referred to as a risk premium.

Many tests to find evidence of normal backwardation have been conducted in various futures markets (Kolb and Zulauf). These studies have used slightly different methodologies, or have tested for other factors that may lead to different conclusions about normal backwardation. In addition, each study has used a different set of data that represents different time periods. This has lead to varying and often completely different results, leading to disagreement by academic scholars on the normal backwardation hypothesis as it applies to different futures markets. A thorough review of past studies is required to gain a better understanding of the different methodologies used and the results that these tests found to draw educated conclusions.

Many of the studies of agricultural commodities testing for market returns, risk premiums, and/or normal backwardation have focused on soybeans, wheat, and corn. Most studies find no evidence of normal backwardation. If normal backwardation is deemed to be present in a market, the efficient market hypothesis is called into question (Zulauf and Irwin).

The efficient market hypothesis (EMH) is the leading theory to describe the price patterns of securities traded in competitive markets. Citing Fama, Zulauf and Irwin write that the price relationship predicted under the EMH is that the futures price is a linear function of the past price, and price increments are purely random. When there is no drift in this price process, and it takes the characteristic of a pure random walk, expected price differences equal 0. Under these conditions, there is no predictability in pricing that can lead to trading strategies that offer profitable opportunities without risk.

Departures from the theory may be described by either a positive price bias (normal backwardation) or a negative price bias (contango). Keynes referred to this price pattern as "normal" backwardation, rather than a bias or inefficiency, because he reasoned that it represents compensation to speculators for their willingness to bear risk. Other authors have used the term "risk premium" to describe the price patterns that deviate from the EMH (Bessembinder and Chan).

Kolb authored the most comprehensive study of the time series patterns of commodity futures prices. Kolb conducted a test of normal backwardation for 29 different commodities over the 1960 through 1991 period. His main finding was that "normal backwardation is not normal." He found that some commodities exhibited weak evidence of normal backwardation and that those commodities that did not follow normal backwardation exhibited behavior similar to a contango. His results for the cotton market in particular were that the cotton futures market "partially conforms to the normal backwardation hypothesis." In his background research, he referenced studies conducted by Carter, Rausser and Schmitz (1983) and Raynauld and Tessier (1984), among others. Carter et al. found evidence of normal backwardation in wheat, corn, and soybeans; however, results from the study conducted by Raynauld and Tessier, on corn, wheat, and oats, are inconsistent with the normal backwardation hypothesis. They did, however, find evidence of a risk-premium.

Methods

Kolb outlines two assumptions about the normal backwardation hypothesis, which we assume in our update and extension of his approach. First, the futures price must equal the cash price at expiration. This is also known as the "no-arbitrage" principle of futures markets. Secondly, since the expected future spot price at expiration is an unknown value, and given the first assumption, a proxy can be used for the cash price at expiration. This proxy is the futures price at expiration.

According to Kolb, there are three main "testable implications" of the normal backwardation hypothesis. The first is that futures returns should be positive, while the second is that futures prices prior to expiration should lie below the terminal futures price. The third implication is that futures prices should be lower the longer the time remaining until maturity.

Three tests, devised by Kolb and replicated here, were conducted to test for the existence of normal backwardation in the U.S. cotton futures market. Each of the tests corresponds to one of the three testable implications of the normal backwardation hypothesis, respectively. $F_{i,t}$ is used to represent the futures price for an individual cotton futures contract. The subscript i is the total number of days within a contract, while *t* represents the days remaining until expiration of that contract.

Positive Futures Returns

Under normal backwardation, the expected daily simple and logarithmic returns should be greater than zero, "implying that futures prices should rise over time." To test this assumption, the average daily return for each individual contract in each of the five delivery months was calculated, in both logarithmic form and in simple returns:

(1) $$E[\ln\left(F_{i,t}/F_{i,t+1}\right)] > 0 \qquad \textit{and} \qquad E[\left(F_{i,t}/F_{i,t+1}-1\right)] > 0$$

First, the average of the logarithmic and daily returns was calculated across all twenty years within each of the five different contracts. Next, the average of the logarithmic and daily returns was computed combining each yearly average of the five different contracts, resulting in a single average for the entire cotton futures market for the period of 1986 through the present. The aggregated daily and logarithmic returns, for each of the five contracts and for the market as a whole, were then tested to determine if their mean was greater than zero.

Futures Prices Prior to Expiration Are Below Terminal Futures Price

Daily differentials, which are defined as the relative difference between the futures price and the subsequently observed futures price at expiration, for each individual contract, were calculated to test if the expected value of the futures price prior to expiration does indeed lie below the terminal futures price.

The differential is defined as a measure of the percentage by which the futures price at a given time falls below the terminal futures price on that contract.

(2) $$D_{i,t} = \left(F_{i,t}/F_{i,o}\right) - 1.$$

Under the normal backwardation hypothesis, the expected value of the calculated differential should be negative for any day before expiration.

(3) $E\left(D_{i,t}\right) < 0$ *for* $t > 0$.

The normal backwardation condition implies that differentials should be smaller when there is more time remaining until expiration.

First, the average of the differentials was calculated across all twenty years within each of the five different contracts. Next, the average of the differentials was computed combining each yearly average of the five different contracts, resulting in a single average for the entire cotton futures market for the period of 1986 through the present. The aggregated differential averages, for each of the five contracts and for the market as a whole, were then tested to determine if their mean was greater than zero.

Futures Prices are Lower the Longer the Time Remaining Until Maturity

In addition to the statistical tests on aggregated returns, Kolb used a linear regression model to examine price patterns, in which he regressed the differentials over time. If it is the case that prices rise during the life of the contract, then the percentage by which the current price falls below the price at expiration should decrease with the life of the contract. The dependent variable in the regression model, the futures price differential, is defined in equation (2).

Time is measured in number of days remaining before expiration; thus, early in the contract life, t is large. For most of the contracts in our dataset, t = 1, 2,…, 375 (approximately) although it should be noted that beginning in 1997, contract duration increased to more than two calendar years. Differentials were not calculated for the movement to the contract expiration day ($t = 0$).

The normal backwardation hypothesis implies that the differentials should be inversely related to the time remaining until the contract matures. The regression specification to test for the hypothesized pricing pattern is:

(4) $$D_{i,t} = \alpha + \beta_i t + \varepsilon_t \qquad for \qquad t > 0.$$

The coefficient on t is expected to be negative under normal backwardation.

(5) $$\beta_i < 0 .$$

As is typical for time-series regression models for very high frequency data, the residuals ε_t are likely to be correlated across time. When autocorrelation is present, tests of statistical inference on the coefficients are not reliable using OLS methods. Kolb corrected for this problem in his very large dataset by randomly selecting observations and estimating the parameters of equation (4) from a sub-sample of the data that did not show evidence of autocorrelation. While this method was considered, it was not sufficient to remove autocorrelation problems in certain subsets of data examined. Therefore, our procedures to correct for autocorrelation in the regression-based test were different from those used by Kolb. A generalized least squares estimator, the Yule-Walker method, was used to correct for this problem, using the AUTOREG procedure in SAS version 9.1.3.

Results

After updating the tests of normal backwardation formulated by Kolb, we find that there is little to no evidence of normal backwardation in the cotton futures market during 1986 through 2006. This result differs significantly from Kolb's findings that cotton partially conforms to the idea of normal backwardation. We find very weak to no evidence of the existence of normal backwardation in the cotton market for our first test of average daily and logarithmic returns (table 1).

The mean returns for each of the five contract months, and the combined contracts, had t-tests that were not statistically significant from zero, meaning that the normal backwardation hypothesis can neither be accepted nor rejected.

Table 1. Test 1 Results: Logarithmic and Simple Daily Returns on Cotton Futures, 1986-2006

	March	**May**	**July**	**October**	**December**	**Combined**
Logarithmic Returns	0.00001	0.00005	-0.00001	-0.00012	-0.00009	-0.00003
(t-test)	(0.00051)	(0.00429)	(-0.00088)	(-0.00983)	(-0.00791)	(-0.00269)
Daily Simple Returns	0.00008	0.00013	0.00008	-0.00004	-0.00002	0.00004
(t-test)	(0.00681)	(0.01054)	(0.00586)	(-0.00351)	(-0.00182)	(0.00366)

Source: Authors' calculations using NYBOT daily cotton futures settlement prices.

Our results to test if futures prices, prior to expiration, are below the terminal futures price yielded positive average differentials for each of the five contract delivery months and for the combined contracts (table 2). However, the t-tests for the mean differentials for each contract and the combined contracts were not statistically significant from zero; therefore, the normal backwardation hypothesis for the differentials test can neither be accepted nor rejected.

Table 2. Test 2 Results: Differentials of Cotton Futures Prices Relative to Expiration Price, 1986-2006

	March	**May**	**July**	**October**	**December**	**Combined**
Mean Differentials	0.02130	0.03435	0.04204	0.01597	0.06043	0.03482
(t-test)	(0.19774)	(0.31170)	(0.36930)	(0.16679)	(0.58950)	(0.32846)

Source: Authors' calculations using NYBOT daily cotton futures settlement prices.

Subsequent to the correction for autocorrelated errors, the results of the regression-based tests on the 20-year dataset suggest significant contango, that is, prices decrease as the time to expiration nears (table 3). This result was found for all contracts, combined, and for the March contract. This is a reversal of Kolb's findings on cotton for the 1960 through 1991 period.

Table 3. Test 3 Results: Regression for Rising Cotton Futures Prices, 1986-2006, Yule-Walker Method of Autocorrelation Correction.

	All contracts	March Contract
Intercept	0.004274	-0.009191
Beta	0.000211	0.000184
Standard error	4.5815E-6	9.4791E-6
t-statistic	46.02	19.44
ρ (before correction)	0.996	0.996
Durbin-Watson (after correction)	1.993	1.979
R^2	0.0472	0.048
n	42,725	8,457

Source: Authors' calculations using NYBOT daily cotton futures settlement prices.

The seasonality of the cotton futures contracts needs to be taken into consideration to determine if there are pricing patterns within specific time intervals. Results for seasonality tests show more significant evidence of contangos than normal backwardation (Chavez, Robinson, and Salin).

Economic Indicators

Economic Theory

While the empirical studies described in the pricing patterns section can identify the presence of deviations from the efficient market hypothesis, those tests do not explain the sources of the pricing patterns. Equilibrium asset pricing theories were developed to differentiate market-level systematic risk from the specific risks associated with a particular security.

Bessembinder and Chan provide a leading example of this conceptual approach to the study of futures prices.

Asset Pricing Theories

Because cotton futures contracts are a type of financial asset, it is important to explore a formal asset-valuation framework as the basis for the statistical and econometric analysis. The theoretically-rigorous intuition about the basic principles underlying the prices of assets in general will provide a means by which to check the reasonableness of the results of the futures contracts. In addition, the vast empirical literature in the field of financial asset price modeling will be relied upon in choosing the appropriate model specifications that will be used to provide an up-to-date analysis of the cotton futures market.

Equilibrium asset pricing is based upon the economic theory of inter-temporal consumption. The graphical approach to the two-period consumption choice is based on Nicholson. A key result from the simple two-period framework is that the ratio of marginal utilities over consumption in the two periods determines choice of investment. Key determining factors include the rate of return (interest rate) and the individual's time preference. This simple model did not take into account risk.

Building from the basic economic principles of the two-period model, financial economists have developed a variety of economic models to explain the observed prices of assets whose returns are risky and whose payoffs can only be realized after the passage of time. A general framework proposed by Cochrane follows. Subsequently, a specific case for shares in publicly traded firms, the well-known Capital Asset Pricing Model (CAPM), is described.

Models of Equilibrium Asset Pricing

Given the basic theory of consumer behavior, inferences can be made about what the price of an asset must be in order to be consistent with consumer choice. These asset pricing principles are presented in a unified treatment by Cochrane. The basic premise is that the current market price of an asset which conveys the right to a future payoff must be the discounted value of the future payoff. The appropriate discount factor is related to subjective preferences on risk, and to the ratio of marginal utilities over future and present consumption.

Capital Asset Pricing

Factor pricing models, including the CAPM, are developments aimed at modeling the relationship of the stochastic discount factor to observed data. The CAPM, as described by Bodie and Merton, is an equilibrium theory, based on the theory of portfolio selection. The specifications typically include various state variables that proxy for the ratio of marginal utilities of future and present consumption. In the consumption-based approach to asset pricing, the argument behind the structure of the CAPM is that consumption is closely tied to wealth. Wealth is proxied by the well-diversified market portfolio, the only explanatory factor in the basic CAPM.

Multi-factor Pricing

Refinements of the CAPM that are referred to as the ICAPM (Intertemporal CAPM) include multiple factors that reflect macroeconomic conditions. These multi-factor "beta models" hold that asset price changes are related to changes in economic state variables. Those state variables are proxies for future consumption. The results of such models indicate which state variables "price risk," that is, which variables represent the systematic risk that investors must be compensated for bearing. For those states that are identified as pricing risk, a beta coefficient measuring the sensitivity of the particular security being priced (the dependent variable) can be determined, and forecasting performance can be evaluated.

Bessembinder and Chan (1992) developed an equilibrium-type model for pricing futures contracts. They questioned whether the variables that had recently been found to have predictive power in forecasting equity and bond returns have an influence on futures market returns. The goal is to identify common shocks across securities markets. These common instruments could then be a way to price systematic risk. They studied agricultural commodity futures, currency exchange futures, and metals futures, finding that "…futures are subject to different sources of priced risk than are equities" (p. 169). The factors in the equilibrium model that forecast futures prices included yield on Treasury bills, equity dividend yields, and the junk bond premium. These variables represent market-wide risk and are likely important controls in any model that is designed to explain pricing patterns in a particular futures market such as cotton. They were interested in whether the variables that had recently been found to have predictive power in forecasting equity and bond returns would have an influence on futures market returns.

Methods Used

The formulation for the empirical work derives from the beta representation of the expected return on assets. The beta representation of factor pricing has a long history in the empirical finance literature. The basic concept is that asset prices are described as a linear function of the discount factor that equates the marginal utility over future and present consumption (Cochrane). A general algebraic specification is:

(6) $$E(\tilde{r}_{i,t} \mid Z_{t-1}) = \sum_{k=1}^{K} \beta_{ik} E(\tilde{\lambda}_k \mid Z_{t-1}).$$

The expected return (r) on asset i, conditional on state variables Z, is linearly related to the expected factor prices of risk, represented by λ. The factor prices of risk are also conditioned on state variables Z. The coefficients β_{ik} represent the sensitivity of asset i to the k factors whose risk is price by λ.

The explanatory factors are chosen to represent expected future growth in consumption; thus they proxy, generally, for an investors' preference for future consumption over present consumption. This rationale leaves researchers with wide discretion regarding the specific variables that are used in empirical work. The indicators used in this paper have been found to be predictive of other securities' returns in previous models of this type (Bessembinder and Chan). It is important in this model framework to choose factors that are *not* asset-specific (Cochrane). Any features that are asset-specific will be encompassed within the beta coefficient, which represents the market-level behavior of the asset with respect to the factor. Hence, we do not include any explanatory variables that are known to be important in a conceptual framework that derives from the economic theory of demand, such as the value of competing fibers, or conditions specific to the key export markets for cotton fiber.

Because this model was developed for the pricing of only one risky asset (the cotton futures contract), and the data on factors are in the form of excess returns (by differencing the factor and the risk-free rate (3-month Treasury), the means of the factors are defined directly as the factor risk premium (λ) for that factor. The beta coefficients to be estimated represent the sensitivity of the cotton futures returns to a change in the factor price of risk. We use the lag of the factors in this application, following Bessembinder and Chan.

Other variables that describe the conditional distribution of future asset returns can also be included in a factor model of asset pricing. It is important to carefully consider the econometric approach, to avoid a "fishing expedition." Cochrane argues that the other variables to represent news “should be proven to forecast something.” Instruments are used, to proxy for an economic state and avoid being correlated with the errors.

The monthly returns were calculated using the nearby December futures settlement prices. A regression was then run with cotton futures returns as the dependent variable and the excess returns of the Dow Jones dividend yield, the junk bond premium and the 10-year Treasury as the independent variables. No other industry-specific factors are included in this framework. These factors are selected on the basis of their being good proxies for growth in aggregate marginal utility of consumption. We first test to determine if the intercepts are zero. Next we look at the combined power of the betas to determine forecastability.

Results

The first test of the factor model results is to determine whether the estimated intercept is zero, as it should be in the excess return formulation of the data (Cochrane). On average, factor price risk along with the test security (cotton futures) should account for all predictable excess returns and there should be no significant average return to be reflected in an intercept coefficient. Our data satisfies this condition (*t* statistic of 0.062 is insignificant, table 5) and therefore is a reasonable formulation of a multi-beta factor model.

The next question of interest is regarding the explanatory power of the betas. Betas measure the exposure of asset *i* to each factor’s risk, and combined, they indicate “forecastability.” When all beta coefficients are simultaneously not indistinguishable from zero, then it is said that the factors do not have forecast power. The estimates for beta (table 5) indicate that no individual beta is statistically different from zero. Cotton futures do not have any apparent risks that distinguish them from the other assets included in the model. With regard to each specific coefficient, the estimates indicate that cotton futures returns are positively related to dividend yield on equities, but are less risky (coefficient size less than 1). When equity excess returns increase by one percent, cotton futures excess returns increase by only 0.158%. Cotton futures returns move in opposite direction to the variation in high-yield corporate bond premiums.

Using the estimated beta coefficients with the observed factors from 1986 to 2006, the predicted values of monthly excess returns on cotton futures contracts are illustrated (figure 1). Risk premiums for cotton futures have been both positive and negative over the period 1987 to the present, according to the fitted values from the equilibrium pricing model. Excess returns were predicted to be positive during the early 1990s and during the most recent period. In the most recent months (2006), holders of cotton futures contracts could expect monthly returns slightly below those earned from the risk-free asset. Non- diversifiable risk for an investor to hold cotton futures is, on average, 0.1702 percent, when calculated from the model parameters

$$E(R^e) = \beta'\lambda . \tag{7}$$

The excess return never reaches 1% over the risk-free rate, according to these findings.

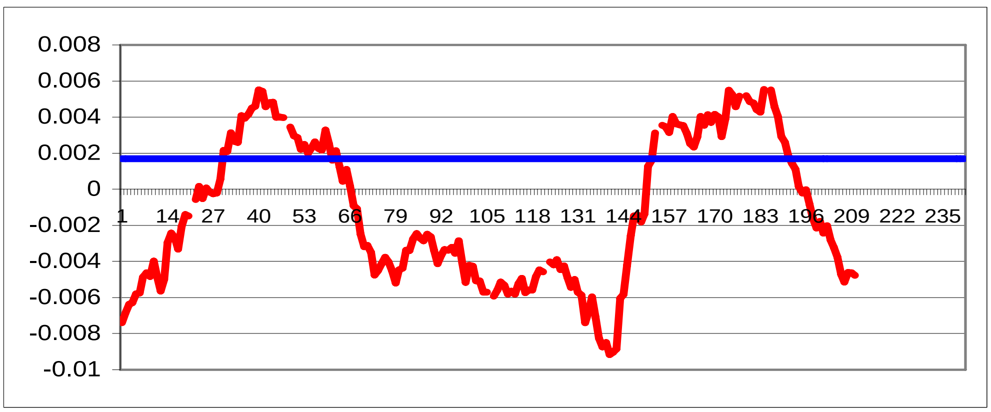
The persistence of excess returns to cotton futures is an interesting question raised by examining the figure. For the conditions prevailing in the securities market in general, the duration of positive excess returns on cotton futures was more than two years, before a gradual decline in returns. There was a fairly rapid shift in excess returns from the negative to positive ranges around t =140, which could be a signal of structural changes in the preferences of investors or some industry or asset-specific conditions.

Table 4. Excess Returns of Factors in the Equilibrium Asset Pricing Model

	n	Mean	Std Dev	Minimum	Maximum
Dividend yield	210	-0.01937	0.01736	-0.0477	0.0132
Junk bond premium	210	-0.03478	0.019248	-0.0729	0.0029
U.S. government bond	210	0.015922	0.012167	-0.00785	0.03807

Source: Authors' calculations using DataStream Data.

Figure 1. Predicted Excess Returns on Cotton Futures, by Month, 1987-2006



Source: Authors' calculations using DataStream data.

Table 5. Coefficient Estimates for Factor Model of Cotton Futures Returns, 1987-2006

	Estimate	Std error	*t* statistic	Prob > *t*
Intercept	-0.00312	0.01738	-0.18	0.8576
Equity dividend yield (Dow Jones 30 industrials)	0.15844	0.87679	0.18	0.8568
Junk bond premium (Moody's)	-0.04907	0.63623	-0.08	0.9386
U.S. Government long bond	0.19246	0.6281	0.31	0.7596

premium

All explanatory variables are in excess return format (differenced by the 3-month Treasury bill yield), lagged one month.

Source: Authors' calculations using DataStream data.

Discussion

In conclusion, we find that the overall cotton futures market from 1986 through 2006 did not display evidence of a positive price bias. Some evidence was found for a negative price bias (contango). Structural changes within the cotton market may explain these results, which differed from Kolb's findings. The U.S. cotton market was largely a domestic market before Kolb published his research. Today, the U.S. cotton market is largely export-oriented. Seasonality of the cotton market, which was omitted in the original study, is another possible explanation for the differing results.

We found that cotton futures do not have any apparent risks that distinguish them from the other assets included in the regression model used to test for economic indicators. Evidence from our model indicates that cotton futures returns are positively related to dividend yield on equities, but are less risky (coefficient size less than 1). We also found that cotton futures returns move in opposite direction to the variation in high-yield corporate bond premiums. The relatively small difference in expected rates of return to cotton futures provides support for efficiency in the futures market.

The two complementary approaches to analysis of futures prices provide a better understanding of the cotton futures market and its forecastability. The analysis of up-to-date market conditions in general is supportive of market efficiency. While there are likely other factors that could be considered in further research on short-term trends, over the long-run there are not persistent indications of inefficiency in the market for cotton futures.

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