Arbitrage, cointegration and testing the unbiasedness hypothesis in coffee futures traded at the CSCE

Malini, Nair

Texas AM University at College Station

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Principal Investigator
Malini Nair

INTRODUCTION

Coffee is critical to the national income accounting of Columbia (World Bank, 1994). The price variability felt in the Coffee exported from Columbia is extreme. However there is not much initiative on the part of Columbia to hedge against the variability (Sabuhoro and Larue, 1997). The developing countries, including Columbia account for nearly all the production and export of coffee and cocoa (Commodity Research Bureau Inc). Futures markets exist in these commodities, but the participation of Columbia is lacking in any of these endeavours. Sabuhoro and Larue (1997) suggest, "…Reversibility of futures markets, the voluntary participation to markets, the continuing operation of markets, the inter-temporal allocation of resources and the transfer of risks associated with random fluctuations of spot prices from hedgers to speculators are the attractions of futures markets when compared to the cash markets." Why would any developing country not consider utilising these markets? This might be due to the costs associated with hedging in these markets.

Essentially there are three kinds of costs in interacting with futures and options markets. They are transaction costs, risk premia and inefficiency premia. Transaction costs consist of possible margin calls, brokerage fees, taxes and bid-ask spread. Risk premium is the money paid by the hedgers to the speculators and others who bear the transfer of risk costs. Inefficiency premium is the cost of a market failure if all the publicly available information is not being utilised properly in operation of futures markets. Here futures prices become unbiased predictor of spot prices resulting in additional costs in using the markets. So a hedger is penalised for using a biased futures contract.

The ensuing analysis focuses primarily on the last two costs, the risk premium and the inefficiency premium. Both these concepts are related to the theory of market efficiency. According to market efficiency hypothesis, the chance of an investor earning extra-ordinary amounts of money by speculating in the futures markets is extremely rare. Prices should reflect all available and pertinent information and should immediately readjust itself upon reception of new information. There are three kinds of market efficiency. First of all, weak-form efficiency hypotheses that current commodity price reflects all the historical price information for that commodity. Second, the semi-strong form of efficiency state that current price includes all publicly available information. Last of all, strong form efficiency state that current price reflects all publicly and privately available information.

Baillie et.al. (1983), who studied the foreign exchange forward rates state that under the assumption of rational expectation and risk neutrality, a hypothesis can be derived, in which the forward rate is an unbiased predictor of the future spot rate. Furthermore, they say, a joint hypothesis that includes assumption of rational expectation and the risk premium of forward rate is zero. The rejection of the joint hypothesis, according to the authors, could be interpreted as rejection of rational expectations or as indicating that the risk premium is non-zero and time varying. Sabuhoro and Larue state that a market efficiency hypothesis can be considered as a joint hypothesis of rational expectations and risk neutrality. They suggest that the efficiency hypothesis can be tested by verifying that future price is an unbiased estimator of the corresponding future spot price. Hansen and Hodrick (1980) came forward with "simple efficiency hypothesis"; while studying foreign exchange markets. They suggest that, "If economic agents are risk neutral, costs of transaction are zero, information is used rationally and the market is competitive, the foreign exchange rate market will be efficient in the sense that the expected rate of return to speculation in the forward exchange market will be zero." Bilson (1981) who also worked on foreign exchange markets came forth with "the speculative efficiency" hypothesis. He constructed a model in which markets are efficient in the sense of removing any opportunities for risk. He suggests, "…The market is subject to speculation that is efficient, which means that the supply of speculative funds is infinitely elastic at the forward price that is equal to the expected future spot price." Haigh (2000), while analysing the Baltic Freight Futures Markets, gave structure to the unbiasedness hypothesis, stating that current futures price, F_{t-n} of a contract expiring at time t, should be equal to the spot price (S_t) that exists at time t. He argues that the failure of efficiency or the presence of risk premia will cause the rejection of the unbiasedness hypothesis. In order to test the hypothesis, he proposes the following equation:

$$S_t = \delta_0 + \delta_1 F_{t-n} + \mu_t \ldots\ldots\ldots\ldots\ldots (1)$$

where μ is the random disturbance.

The efficiency tests involve variables that are likely to be non-stationary (Sabuhoro and Larue, 1997). If futures prices and future spot prices are found to be non-stationary and cointegrated, the sufficient conditions for unbiasedness are simple restrictions on the error correction mechanism between futures and future spot prices. Brenner and Kroner (1995) examined the arbitrage, cointegration and the unbiasedness hypothesis in financial futures markets. They argue that cointegration between futures and spot markets are rarely found in commodity markets. They attribute it to a net cost of carry factor.

The analyses presented in the following sections are three fold. First, I conduct unit root analysis to check the existence of non-stationarity and optimal number of lags. Then, I conduct Johansen procedure (1998), which is designed to test cointegration between price series. The structure of my paper is as follows. First I lay out the estimation procedure that is adopted, including the details of methodology. Then data description will be given. The estimation and results are presented in a separate section and finally the conclusions from the results are offered.

THEORITICAL BACKGROUND

As indicated previously, long run unbiasedness is tested using the formula:

$$S_t = \delta_0 + \delta_1 F_{t-n} + \mu_t$$

where S_t is the expected spot price at time t, F_{t-n} the futures price at time t-n and μ_t is the disturbance term. The long-run efficiency is confirmed (Haigh, 2000) when the joint restriction, δ_0 equalling zero and δ_1 equalling one cannot be rejected. Ordinary Least Square (OLS) techniques cannot be employed to estimate this equation because if the series are non-stationary, OLS is unfairly biased towards rejecting the null hypothesis of unbiasedness. The existence of non-stationarity will occur simultaneously with infinite variance, and the resulting hypothesis testing will be suspect if nonstationarity is not dealt with. Nonstationarity is a characteristic of many market price series data. This is an implication of the "efficient market hypothesis", which states that efficient prices follow a random walk (Bessler and Fuller, 1993). A formal way to detect nonstationarity is the Dickey-Fuller test (Bessler, 2000). Here changes in X_t ($\Delta X_t = X_t - X_{t-1}$) are regressed upon a constant plus the levels of X_t lagged one period.

$$\Delta Y_t = \beta_0 + \beta_1 Y_{t-1}$$

Under the null hypothesis of nonstationarity; β_1 is zero.

When β_1 is significantly negative, nonstationarity is rejected. Augmented Dickey-Fuller tests has lags of the dependent variable in the DF regression. Schwartz Bayesian criterion is used to determine the optimal number of lags of the Augmented Dickey-Fuller tests. A series is said to be I(1) if it takes first difference to induce stationarity. Generally, the linear combination of two I(1) series is I(1). When the linear combination of two I(1) series are I(0), then the series are said to be cointegrated or in “long run equilibrium”. If the equation for spot price of coffee is

$$S_t = \delta_0 + \delta_1 F_{t-1} + \mu_t \ldots\ldots\ldots\ldots\ldots (2)$$

then cointegration means μ_t such that

$$\mu_t = S_t - \delta_0 - \delta_1 F_{t-1} \ldots\ldots\ldots\ldots\ldots (3)$$

where μ_t must be I(0).

If the series are cointegrated, then Engle and Granger (1987) show that they have an error correction representation. Engle and Granger propose a two-step procedure for estimating the parameters of the error correction model. First step as mentioned before, is the testing of the residuals for stationarity. The second step is to estimate the parameters of the spot price equation as given in (2). If there is stationarity of residuals, then OLS regression yields a very consistent estimator of the cointegrating parameters δ_0 and δ_1 (Enders, 1995). Third step is to write the error-correction model incorporating the residuals (Bessler and Fuller, 1993) as:

$$\Delta S_t = \sum_{k=1}^{r} G(k)\Delta S(t-k) + \sum_{k=1}^{r+1} H(k)F(t-k) + u_t$$

$$\Delta F_{t-1} = \sum_{k=1}^{r} I(k)\Delta S(t-k) + \sum_{k=1}^{r+1} J(k)F(t-k) + v_t$$

where: Δ is the difference operator; *u(t)* and *v(t)* are white noise residuals; *G(k), H(k),I(k)* and *J(k)* are parameters to be estimated. The limitation of Engle-Granger technique is that the hypothesis testing is not possible on parameter estimates (Haigh, 2000). The maximum likelihood method of Johansen (1988) and Johansen and Jesulius (1990) is an alternative method of analysis. This procedure has been extensively used in hypothesis testing, especially of unbiasedness of parameter estimates. Sabuhoro and Larue used a comparison of ECM, NLS and Johansen techniques in testing the unbiasedness in Cocoa and Coffee markets. Haigh (2000) used Johansen technique to test unbiasedness in BIFFEX markets. Bessler and Fuller (1993) used it to test the cointegration between US wheat markets. The Johansen method considers the cointegration problem as one of reduced rank regression (Bessler, 2000). The procedure is based upon error correction representation:

If S_t is the vector of series under consideration

$$\Delta S_t = \eta + \Gamma(1)\Delta S(t-1) + \ldots + \Gamma(k-1)\Delta S(t-k+1)$$
$$+ \Pi S(t-k) + \varepsilon(t)$$
$$\text{where}$$
$$\Gamma(i) = -\left[I - \Pi(1) - \ldots - \Pi(i)\right] \text{ for}$$
$$i = 1,2,\ldots k-1;$$
$$\text{and}$$
$$\Pi = -\left[I - \Pi(1) - \ldots - \Pi(k)\right]$$

Here the $\Pi(i)$ is a p×p matrix of auto regressive parameters from VAR in levels S_t of lag order k, η is a constant and $\varepsilon(t)$. The parameter matrix, Π associated with the lagged level of $S(t-k)$ contains information about the number of cointegrations. There are three possibilities

a) If Π is of full rank, the series are stationary and there are no cointegrations.

b) If Π has zero rank, then it contains no long-run information and an appropriate model is a VAR in differences;

c) If rank is positive, but less than n, then there exist matrices α and β such that $\Pi = \alpha\beta'$; the latter case, $\beta' S_t$, is stationary, even though S_t is not (Bessler 2000).

DATA

Daily data of Colombian coffee was used in the analysis. The beginning date was January 3, 1961 and the ending date was August 30, 1999. The data was obtained from Bridge / CRB historical data series. Colombian coffee is traded at Coffee and Sugar Commodity Exchange (CSCE) in New York. Standard contract is of a size 37,500 pounds (10 tons). Units of pricing are cents per pound. Delivery occurs on the months of March, May, July, September and December. Since the delivery months are discrete, rolling-over techniques were used to create continuous series. Rolling-over technique involves the movement to the data of trading of the contract of nearest expiry month, once the delivery date of a contract is reached.

The mean value of price of a pound of coffee in a futures contract is 104.2828 cents and that of a pound of Colombian coffee in cash market is 108.8458 cents. Futures prices are generally lower than the cash prices. This indicates normal backwardation inside coffee markets. The standard deviation of the futures contracts are lower; i.e. 57.67 when compared to 60.67. This is due to the fact that in the cash market, volatility is higher. Minimum of futures contracts is lower at 29.49; while in the cash market, the minimum is 39. The maximum in the cash market is slightly lower at 335 cents while the maximum futures price of coffee is 335.63 cents.

ESTIMATION & RESULTS

Augmented Dickey Fuller test was used to test the presence of unit roots (nonstationarity). The null hypothesis was presence of non-stationarity. The MacKinnon 1% critical values were lesser than the value of the test statistic in the case of cash as well as futures, hence the null hypothesis of nonstationarity could not be rejected. The superiority of Augmented Dickey Fuller test over the Dickey Fuller test is three fold (Enders). DF test assumes errors are independent and have a constant variance. This is a huge assumption to make once do not know the data-gathering process. Secondly, the true order of auto regressive process is unknown to the researcher, therefore there is problem in selecting the appropriate lag length. The last problem arises from the fact that Dickey-Fuller test considers only one unit root. However in the case of my estimation, the usage of the Dickey-Fuller test and the Augmented Dickey Fuller test did not make a difference.

Table 1: Results from Augmented Dickey Fuller test conducted on Coffee Cash and Futures

LAGS	**MacKinnon Criterion Statistic**	
	FUTURES	CASH
	Statistic	Statistic
3	-2.8263	-2.1151
2	-2.7797	-2.1012
1	-2.8154	-2.0431
1% Critical Value	-3.4343	-3.9647

The technique used for the identification of the number of lags was Schwartz Bayesian Criterion (SBC). Ideally, the SBC should be as low as possible. Akaike Information Criterion (AIC) can also be used, but SBC has better large sample properties, in that it is asymptotically consistent while AIC is biased towards selecting an over parameterised model (Enders, 1995). According to the tests conducted, lowest possible SBC was for one lag in both the cash and futures data. Hence one lag was adopted in the estimation procedure.

An Error Correction Model was estimated incorporating the Johansen procedure. The Johansen procedure was included to test for the unbiasedness hypothesis. The restrictions vector of {1, -1, 0} represents that hypothesis. The prices were normalised upon futures prices. The unbiasedness hypothesis implies that the previous periods' futures price is an unbiased predictor of the current spot price. The test was a likelihood ratio test and distributed as χ^2. The χ^2 value obtained was 2.43. The degrees of freedom were 2 and the 95% table value was 5.99. This meant that null hypothesis of unbiasedness could not be rejected. Thus previous periods' futures price is an unbiased predictor of expected current spot price, implying that there was no risk premium in the market and there was long-run market efficiency, thereby reducing the amount of arbitrage to minimum. This result was consistemt with the study conducted by Sabuhoro and Larue (1997). The restricted and the unrestricted estimates are given in table 2.

Table 2: Restricted and Unrestricted Estimates of Cash and Futures Prices of Coffee

Regression	**Futures**	**Cash**	**Constant**
Unrestricted	1	-0.587	-40.942
Restricted	1	-1	0.000

Three seasonal dummy variables were incorporated to test for the seasonality of data. The advantage of centered dummies were that the seasonal dummies do not change the limit distribution of the rank tests (Hansen and Jesulieus, 1997). This was appealing, as asymptotic features are particularly important in the calculation of the likelihood ratio tests. The t-values of the four seasonal dummy variables incorporated indicate mixed results. In the regression of Cash upon futures, all the seasonal dummy variables are significant. In the regression of futures upon cash, all the variables, except the dummy variable representing season one were significant. This means that seasonality affects the Colombian coffee markets. This is an expected result since the coffee production in Colombia may be influenced by weather fluctuations and time valued demand and supply factors. Also given the evidence provided by Sabuhoro and Larue (1997) the high price variability of Coffee in Colombia during harvest time could explain the presence of the significant seasonal dummy variables.

Table 3: Parameter Estimates and Significance of Seasonal Dummy Variables in Estimation of Futures on Cash and Cash on Futures

	Seasonal Dummies		
	1	**2**	**3**
FUTURES(t-1)	-0.211	-0.078*	-0.169*
CASH	-0.025*	0.109*	-0.017*

* represent significance at 95% confidence level

CONCLUSIONS

The objective of this study was to test the market efficiency hypothesis of Colombian coffee. This is of extreme importance to Colombia because the exports of coffee from this country provides for valuable foreign exchange and provides employment for her people. Historically this country has been concerned with the volatility of spot markets and used buffer stocks and quotas to protect her from price risk (Sabuhoro & Larue, 1997). Hedging in futures markets is a way to avoid price risk. This study is particularly important as it tests whether the coffee markets are efficient as efficient markets are. This is a way for Colombia to avoid the imposition of costs supplemental to normal transaction costs that may be common in inefficient markets. These costs limits the effective hedging programs which are vital to the risk management of a commodity like Coffee in Colombia and other developing countries that export coffee. Similar studies can be conducted in coffee exported from other developing countries.

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