ELSEVIER

Agricultural Economics 16 (1997) 171–184

AGRICULTURAL
ECONOMICS

The market efficiency hypothesis: the case of coffee and cocoa futures

Jean Bosco Sabuhoro, Bruno Larue *

CREA and Département d'Économie Agroalimentaire et des Sciences de la Consommation, Université Laval, Sainte-Foy, Québec, G1K 7P4 Canada

Accepted 18 March 1997

Abstract

This study tests the market efficiency hypothesis for coffee and cocoa futures using daily data for contracts with a maturity of 2 and 6 months. The hypothesis is tested sequentially. The first condition is that future spot and futures prices be cointegrated. If this condition is maintained, market efficiency requires the cointegrating vector to support a (0, 1) restriction that can be likened to an unbiasedness condition. Finally, market efficiency imposes zero restrictions on the parameters of the variables expressed in first differences in the specification of the error-correction representation of the relationship between future spot and futures prices. Brenner and Kroner [Brenner, R., Kroner, K., 1995. Arbitrage, cointegration, and testing the unbiasedness hypothesis in financial markets. *Journal of Financial and Quantitative Analysis* 30, pp. 23–42] argue that the cointegration condition is rarely met in practice. They attribute this outcome to potentially non-stationary net cost-of-carry which would make the parameters of the cointegration relation unstable. It is for this reason that Hansen's tests [Hansen, B.E., 1992. Tests of parameter instability in regressions with $I(1)$ processes. *Journal of Business and Economic Statistics* 10] about the stability of the parameters in cointegration regressions were used to supplement more traditional cointegration tests. Johansen and Juselius' cointegration tests [Johansen, S., Juselius, K., 1992. Testing structural hypotheses in a multivariate cointegration analysis of the PPP and the UIP for UK, *Journal of Econometrics* 53] could not reject cointegration for all four contracts while Hansen's L_C test favored cointegration only for the cocoa contracts. Nested and non-nested testing procedures were used to test the (0, 1) restriction on the cointegration vector. Unbiasedness was found to be robust across testing procedures. However, further testing about the specification of the error-correction representation revealed the existence of important short run deviations from unbiasedness. Even though these results hold strictly for a rather limited number of contracts and commodities, they are encouraging for futures markets advocates in developing countries. © 1997 Elsevier Science B.V.

1. Introduction

The contribution of primary commodity export earnings to national income is critical to many Less Developed Countries (LDC) (World Bank, 1994). The problem of instability in LDC export earnings (Gersovitz and Paxson, 1990) has motivated the implementation of a variety of export strategies such as buffer stocks, buffer funds, export quotas and the International Monetary Fund compensatory financing mechanism, to reduce price variability. These commodity agreements have seldom achieved their goal.

Although LDC countries account for nearly all of the production and the export of coffee and cocoa (Commodity Research Bureau Inc.), their participation in futures trading has been limited (Thompson, 1985; Ouattara et al., 1990) even though futures markets could be used by an exporting nation to hedge against the risk associated with spot price volatility. Futures markets have many advantages, among others, the reversibility of futures contracts,

* Corresponding author.

PII S0169-5150(97)00003-0

the voluntary participation to markets, the continuing operation of markets, the intertemporal allocation of resources (the futures price is an estimator of future spot price) and the transfer of the risk associated with random fluctuations of spot prices from hedgers to speculators. A critical issue for any developing country contemplating the use of futures markets is the cost of using these markets. The costs are essentially of three kinds. The first are transaction costs consisting of market margin calls and brokerage fees. The second arises from the returns that may be demanded by other investors for assuming the risk of future spot price volatility, which is the risk premium. The third kind of cost is the result of a potential market failure. If the market is not using publicly available information efficiently, futures prices become biased predictors of future spot prices, entailing additional costs in using the markets. This third category of costs encompasses the cost due to insufficient liquidities and to risk of manipulation of the futures markets.

Any study on these last categories of costs begins with the concept of futures market efficiency. There are three widely used definitions of market efficiency. The weak form of efficiency stipulates that the current commodity price incorporates all the information contained in price time series. The semi-strong form of efficiency goes further by stating that the current price includes all publicly available information. Finally, the strong form stipulates that the current price reflects all publicly and privately available information. According to the market efficiency hypothesis, no investor can earn extraordinary profits by predicting future prices on the basis of available information. Thus, prices must reflect the available pertinent information and change with the arrival of new information. Moreover, an equilibrium of prices characterized by a rational use of information has the advantage that systematic errors in expectations are impossible. In this light, the market efficiency hypothesis can be regarded as a joint hypothesis of rational expectations and risk neutrality.

The aim of this study is to test the efficiency hypothesis for coffee and cocoa futures. The efficiency hypothesis is tested by verifying that the futures price is an unbiased estimator of the corresponding future spot price. The efficiency tests involve variables that are likely to be non-stationary. If futures and future spot prices are found non-stationary and cointegrated, implying a long-run arbitrage relationship between them, then the sufficient conditions for unbiasedness are simple restrictions on the error correction mechanism between futures and future spot prices.

The analysis presented in the next sections differs from previous research on commodity futures in different respects. First, it focuses on two commodities whose exports are the major sources of revenues for several developing countries. Second, the sample covered by the data set coincides with a period where almost all international commodity agreements failed. Finally, four complementary econometric procedures are implemented to test the plausibility of the sufficient conditions for unbiasedness. We pay a special attention to the argument put forward by Brenner and Kroner (1995), which precludes the existence of a stable relationship between future spot and futures prices. They show that there cannot be a cointegration relation when the time series of the net cost-of-carry is non-stationary. This is tantamount to stating that the parameters characterizing the relationship between future spot and futures prices are unstable. The L_C test of Hansen (1992) for parameter instability in regressions with $I(1)$ processes appear to be 'tailor-made' to appraise the validity of Brenner and Kroner's argument.

The rest of the study is organized as follows. Section two presents the methodology regarding the implementation of efficiency tests and their relation to cointegration analysis. Section three dwells on the description of the data, while the results are presented in section four. The last section will discuss the results' implications for developing countries having to cope with unstable commodity prices.

2. Methodology on efficiency tests and non-stationary prices

This section discusses various testing procedures associated with the efficiency hypothesis. These testing procedures are based on regressions involving the levels of the futures and future spot prices, which are not likely to be stationary. The concept of efficiency has been analyzed in the context of commodity futures markets as well as for other asset markets (bonds, exchange rates, and treasury bills). In all cases, an efficient futures market is a market where prices reflect all publicly available information (Fama, 1970, 1991). Under such conditions, investors cannot earn abnormal profits by exploiting publicly available information.

Since the floating of currencies in the early seventies, many studies have investigated the market efficiency hypothesis, especially applied to exchange rates. Levich (1985), Hodrick (1987), Baillie and McMahon (1989) provide extensive coverage of the subject. Let $F_{t,n}$ be the natural logarithm of the futures price at time t for delivery at $t+n$, S_t the natural logarithm of the spot price at time t and S_{t+n}, the natural logarithm of the spot price at $t+n$. One approach to test the market efficiency hypothesis postulates that the futures price is an unbiased estimator of the future spot price or:

$$F_{t,n} = E(S_{t+n}/I_t), \tag{1}$$

where I_t is the information set upon which market participants condition their expectations at time t. The temporary deviations between $F_{t,n}$ and S_{t+n}, have a mean of zero and are non-autocorrelated. Early tests of the efficient market hypothesis are conducted by regressing S_{t+n} on $F_{t,n}$ in the following equation:

$$S_{t+n} = \alpha_0 + \beta_0 F_{t,n} + u_t, \tag{2}$$

and testing the hypothesis that $\alpha_0 = 0$ and $\beta_0 = 1$. This joint test assumes that the agents are risk-neutral and that they rationally use all available information. Violation of either hypothesis can lead to rejection of the joint hypothesis [1]. This test is applied by Kofi (1973), Frenkel (1981) and Kahl and Tomek (1986). Another popular approach avoids the problem associated with the probable non-stationarity of the levels of the variables by testing some restrictions about the regression of spot price changes on the basis:

$$(S_{t+n} - S_t) = \alpha_0 + \beta_0(F_{t,n} - S_t) + u_t. \tag{2'}$$

The efficiency requires that $\alpha_0 = 0$ and $\beta_0 = 1$. This test was used by Fama and French (1987), Froot and Frankel (1989) and Baillie and McMahon (1989).

Cointegration tests are often used to test for unbiasedness. They have two important implications for efficiency testing. First, prices from two efficient markets for two different assets cannot be cointegrated (Granger, 1986; Hakkio and Rush, 1989; MacDonald and Taylor, 1989; Copeland, 1991). Otherwise, there would be Granger causality and data on one asset price could be used to predict the price of the other asset. The second implication is related to the efficiency of the futures markets. Granger (1986, p. 217) and Copeland (1991, p. 187) have shown that for any $I(1)$ variable x_t, the optimal forecast of x_{t+n} conditioned on the full history $x_{t-j} \geq 0$, is cointegrated with x_{t+n}. It follows that the futures price of an asset, possibly a primary commodity, must be cointegrated with the future spot price as a necessary condition for unbiasedness. If S_{t+n} and $F_{t,n}$ are cointegrated, they will have an error correction model (ECM) representation:

$$\Delta S_{t+n} = au_{t-1} + b\Delta F_{t,n} + \sum_{k=1} \beta_k \Delta F_{(t,n)-k} + \sum_{k=1} \gamma_k \Delta S_{(t+n)-k} + e_t, \tag{3}$$

where e_t is the error term, u_{t-1} is the lagged residual of the cointegration regression (Eq. (2)) and represents the deviations from the long-run equilibrium. Thus, error correction models allow this period's price to vary in response to past disequilibria. In other words, this period's future spot change can be decomposed into a short-run component influenced by past changes in $F_{t,n}$ and S_{t+n} and by a long-run component that reflects the magnitude of past disequilibrium. Unbiasedness also requires that $-a = b = 1$ and $\beta_k = \gamma_k = 0$, and that the cointegration vector be equal to (0, 1). The latter implies the following ECM:

$$\Delta S_{t+n} = a(S_{t+n} - F_{t,n})_{-1} + b\Delta F_{t,n} + \sum_{k=1} \beta_k \Delta F_{(t,n)-k} + \sum_{k=1} \gamma_k \Delta S_{(t+n)-k} + e_t. \tag{4}$$

where u_{t-1} is replaced by $(S_{t+n} - F_{t,n})_{-1}$. This last restriction cannot be directly tested in the Engle–

[1] A rejection of the joint hypothesis does not mean that investors earn abnormal profits.

Granger procedure. We will use three methods to test that restriction.

The first compares the ECM represented in Eq. (3) to that represented by Eq. (4). The non-nested tests of Davidson and MacKinnon (1981) and Godfrey and Peseran (1983) are employed to discriminate between model (3) and model (4). If model (4) is preferred to model (3), or if both are judged equivalent, the null of (0, 1) cointegrating vector cannot be rejected. The interested reader is referred to the aforementioned articles.

The second method estimates Eq. (3) by non-linear least squares (NLLS) minimization. Since Eq. (4) is a restricted form of Eq. (3), the test about the sufficient efficiency conditions becomes a nested test. One has to test the hypotheses $-a\alpha_0 = 0$ and $-a\beta_0 = -a$ in the following equation:

$$\Delta S_{t+n} = a(S_{t+n} - \alpha_0 - \beta_0 F_{t,n})_{-1} + b\Delta F_{t,n} + \sum_{k=1} \beta_k \Delta F_{(t,n)-k} + \sum_{k=1} \gamma_k \Delta S_{(t+n)-k} + e_t. \tag{5}$$

According to Davidson and MacKinnon (1993), the estimation of Eq. (5) by NLLS is possible and the simulations of Banerjee et al. (1986) have shown that the NLLS estimates in small samples are generally superior to estimates obtained by two-stage least squares.

Finally, the third procedure follows the method outlined by Johansen and Juselius (1990, 1992) and tests directly the relevant restrictions on parameters characterizing the cointegrating relations. The (0, 1) restriction in the cointegration vector is tested as well as the weak exogeneity hypothesis for the futures price. This hypothesis in the context of market efficiency means that disequilibrium adjustments fall on the future spot price and not on the futures price. This result insures dynamic consistency in the sense that it is the current futures price that systematically reacts when there is a deviation between the current spot price and the past futures price.

As mentioned earlier, Brenner and Kroner (1995) have attempted to explain the low occurrence of cointegration between commodity future spot and futures prices in empirical studies. They argue that the results of cointegration tests depend entirely on the time series properties of the net cost-of-carry or differential in the life of the futures contracts, which is: $S_{t+n} - F_{t,n} = \alpha_0 - D_{t,n} + v_{t+n}$, where S_{t+n} and $F_{t,n}$ are as previously defined and $D_{t,n}$ is the expected net cost-of-carry. If the differential has a stochastic trend, whether caused by stochastically trended interest rates or convenience yields, then future spot and futures prices will tend to drift apart and would not be cointegrated. Beck (1994) argues that Brenner and Kroner's critique is valid only for the difference between $F_{t,n}$ and S_t (the basis) and does not apply to $F_{t,n} - S_{t+n}$ (the risk premium). Beck recommends to implement a unit root test on the risk premium to test the validity of Brenner and Kroner's argument. She rejected the null of unit root and concluded that the risk premium is stationary.

An alternative approach to deal with Brenner and Kroner's critique involves estimating the parameters of the relationship between the future spot and futures prices with the fully modified estimator and testing for stability. The fully modified estimator developed by Phillips and Hansen (1990) and Hansen (1992) has the advantage of correcting for the endogeneity bias and lends itself to parameter stability test. Appendix A discusses the L_C test for parameter stability. The L_C statistic is not only a parameter instability test but a test of the null of cointegration against the alternative of no cointegration. We think that most unit root/stationary/cointegration tests are not very powerful in small samples. The L_C test is no exception and this is why we use it along with other tests. We regard this test as a viable instrument to address Brenner and Kroner's critique. They argue that a cointegration relation between the spot price at $t+n$ and the futures price at t for delivery at $t+n$ is unlikely because the net cost-of-carry is probably non-stationary, hence 'unstable'. If this is the case, the elements of the cointegration vector cannot be stable and hence, there cannot be a (stable) long-run equilibrium relationship between futures and spot prices. The stability test does not look at structural change as a one time break in a cointegration relation. It tests whether the coefficients that describe the potential cointegration relation are martingales ($B_t = B_{t-1} + e_t$, where e_t is a matrix of white noise disturbances). If the vector of coefficients changes with every observation, there cannot be cointegration since a new trend starts with every new observation. In this light, this test of parameter stability in $I(1)$ regressions can be viewed as a test of cointegration.

3. Data description

Daily spot and futures prices from the Coffee, Sugar, and Cocoa Exchange (CSCE) are used in this study [2]. Standard contracts for coffee and cocoa are 37,500 pounds and 22,046 pounds (10 metric tons), respectively. One of the problems encountered in analyzing commodities futures contracts is that they do not have a specific maturity. Instead, there is a delivery period of two to three weeks at the beginning of the maturity month. Delivery months for coffee and cocoa are March, May, July, September and December. In this study, we have built two and six-month maturity contracts using daily observations from September 04, 1979 to January 31, 1990 for coffee and from September 01, 1983 to January 31, 1990 for cocoa. Two-month maturity contracts have the advantage of not overlapping. Moreover, two-month maturity contracts are short enough to make for an interesting comparison with relatively long six-month maturity contracts. Theoretically, the probability of rejecting the efficiency hypothesis is expected to increase with the maturity length. The correspondence matching between the spot and futures prices and the future spot prices is always a problem for studies on commodity futures. In this case, the following convention has been adopted. For six-month maturity contracts, spot and futures prices on the first trading day six months before the delivery month are chosen. The future spot price employed is the spot price on the first trading day of the delivery month. For two-month maturity contracts, spot and futures prices on the first trading day two months before the delivery month are chosen. The future spot price employed is the spot price on the first trading day of the delivery month (see Table 1). Such convention greatly reduces the number of observations available for the analysis. Five, fifty, and thirty observations per year are obtained for the coffee and cocoa contracts, respectively. This problem is the result of a lack of data on spot prices for the commodities studied, especially during the seventies. Palliating for the lack of observations on spot prices by using questionable proxies (futures prices at $t-1$) or by repeating the same spot observations as Fama and French (1987), Serletis and Scowcroft (1991) was rejected [3]. It is also worth noting that the overlapping problem of the six-month maturity contracts can induce autocorrelation in the efficiency regression residuals (Eq. (2)). This problem is documented in Hodrick (1987) and Baillie and McMahon (1989).

Table 1
Correspondence of prices: an illustration

Delivery month	Spot and futures prices	Future spot price
Coffee six-month maturity contracts in 1980		
March 1980	first trading day September 1979	first trading day March 1980
May 1980	first trading day November 1979	first trading day May 1980
July 1980	first trading day January 1980	first trading day July 1980
September 1980	first trading day March 1980	first trading day September 1980
December 1980	first trading day June 1980	first trading day December 1980
Coffee two-month maturity contracts in 1980		
March 1980	first trading day January 1980	first trading day March 1980
May 1980	first trading day March 1980	first trading day May 1980
July 1980	first trading day May 1980	first trading day July 1980
September 1980	first trading day July 1980	first trading day September 1980
December 1980	first trading day October 1980	first trading day December 1980

[2] The data were freely provided by the Center for the Study of Futures Markets (CSFM) at the University of Columbia. We contacted the Center to obtain more recent data but they no longer keep those data banks.

[3] We felt that a proper market efficiency test should rely on data series for futures and spot prices. Repeating the same spot observations to 'fill in' the missing daily observations in a given month has the advantage of inflating the number of degrees of freedom but restricts spot prices to be perfectly stable within a month.

4. Results

4.1. Unit root tests

Before implementing the efficiency tests, it is essential to assess the level of integration of the prices. A zero degree of integration or stationarity has important implications. For example, if the logarithms of prices were stationary, the traditional approach using regression of future spot prices on futures prices would be appropriate. There is substantial evidence in the literature that unit root tests of the Dickey–Fuller and Phillips–Perron (Phillips and Perron, 1988) type are sensitive to the lag specification and to the presence of large moving average terms (Agiakloglou and Newbold, 1992; Leybourne and McCabe, 1994). However, the Monte Carlo simulations of Hall (1994) show that the ADF test performs better when the lag length (p) is chosen from the data according to a model selection/information criterion, like the Schwarz information criterion, than when p is set to an arbitrary large number. We followed Hall's recommendation in choosing the lag length of the model specification. The optimal specification is a zero lag length. Thus, the Dickey–Fuller (DF) and Phillips–Perron (PP) unit root tests are implemented to verify that futures and spot prices are non-stationary. It is well known that unit root tests lack power in small samples. The KPSS test (Kwiatkowski et al., 1992) whose null is that of stationarity, can be regarded as a response to the problem of under-rejection of non-stationarity. The results of this test are sensitive to the number of lags used in the spectral window that is used in the non-parametric adjustment for autocorrelation. Table 2 shows the unit root tests (DF and PP) and stationarity test (KPSS) results on the logarithms of the futures prices ($F_{t,n}$) and the spot prices (S_t) as well as their first differences ($\Delta F_{t,n}$ and ΔS_t). The Critical values of the unit root tests are calculated using MacKinnon's formula results (MacKinnon, 1990) and correspond to the exact size of the sample. L-B(16) and L-B(9) are the Ljung-Box statistics for testing the null hypothesis of no autocorrelation in the residuals of equations used for unit root tests whose validity is sensitive to the presence of autocorrela-

Table 2
Unit root and stationarity tests in the logarithms of spot and futures prices

Variable	DF	PP	L-B(16)	Variable	DF	PP	L-B(9)
Coffee six-month maturity contracts				Cocoa six-month maturity contracts			
$F_{t,n}$	−2.59	−2.64	13.35	$F_{t,n}$	−3.03	−3.20	1.31
S_t	−2.66	−2.72	16.51	S_t	−3.49	−3.42	6.11
$\Delta F_{t,n}$	−6.34 [a]	−6.47 [a]		$\Delta F_{t,n}$	−6.80 [a]	−7.19 [a]	
ΔS_t	−6.24 [a]	−6.37 [a]		ΔS_t	−6.11 [a]	−6.47 [a]	
Coffee two-month maturity contracts				Cocoa two-month maturity contracts			
$F_{t,n}$	−2.43	−2.48	12.79	$F_{t,n}$	−2.89	−3.05	6.10
S_t	−1.96	−2.00	17.05	S_t	−1.89	−2.16	7.65
$\Delta F_{t,n}$	−8.19 [a]	−8.37 [a]		$\Delta F_{t,n}$	−7.60 [a]	−5.63 [a]	
ΔS_t	−6.00 [a]	−6.13 [a]		ΔS_t	−5.63 [a]	−5.95 [a]	
KPSS test (lag specifications rejecting the null of stationarity [b])							
Coffee six-month maturity contracts				Cocoa six-month maturity contracts			
Significant at 5%, 10%				Significant at 5% 10%			
$F_{t,n}$	0–1 lags 0–2 lags				0–8 lags 0–8 lags		
S_t	0–2 lags 0–8 lags				0–8 lags 0–8 lags		
Coffee two-month maturity contracts				Cocoa two-month maturity contracts			
Significant at 5%, 10%				Significant at 5% 10%			
$F_{t,n}$	0–1 lags 0–2 lags				0–3 lags 0–8 lags		
S_t	0–2 lags 0–8 lags				0 lag 0–2 lags		

Dickey–Fuller (DF) and Phillips–Perron (PP): H_0 = unit root, H_A = stationarity.
[a] Significant at the 5% level.
[b] KPSS specifications vary in terms of the lag truncation parameter that defines the spectral window. The number of lags vary from 0 to 8. The 5% and 10% CV are 0.146 and 0.119 respectively for specifications with trend.

tion. They are compared to critical values of 26.29 and 16.91. The statistical evidence reveals that the null hypothesis of no autocorrelation cannot be rejected. The calculated DF and PP statistics are small (in absolute values) relative to their 5% critical values and suggest a degree of integration in excess of zero. On the other hand, the null hypothesis of unit root is rejected for the first differences. Results of the KPSS stationarity test are known to be sensitive to the selection of a lag truncation parameter. In small samples, the power of the test is higher when low lag truncation parameters are chosen. Given that our objective is to be confident about rejecting stationarity when the series are truly non-stationary, it would seem logical to put more weight on KPSS stationarity statistics computed from low lag truncation parameters. The null of stationarity around a deterministic trend is rejected for all contracts at the 5% significance level for lag truncation parameters under 2, except for the coffee futures prices and the cocoa spot price for two-month maturity contracts. It is rejected for all contracts at the 10% significance level. Therefore, the KPSS results validate the unit root tests and it is safe to conclude that the logs of spot and futures prices are integrated of degree one.

Table 3
Cointegration tests between the future spot prices and the futures prices ($S_{t+n} = \alpha_0 + \beta_0 F_{t,n} + u_t$)

Engle–Granger two-step estimator: H_0: no cointegration				
Commodity	α_0	β_0	ADF	LM (1)
Coffee (6 months)	5.03	0.46	−3.20	26.41 [a]
Coffee (2 months)	0.71	0.92	−5.87 [a]	1.58
Cocoa (6 months)	1.52	0.80	−4.13 [a]	5.23
Cocoa (2 months)	2.21	0.72	−3.64 [a]	0.05
Johansen and Juselius' estimator: H_0: $r = 0$, $r = 1$				
Commodity	α_0	β_0	λ_{max}	Trace
Coffee (6 months)	0.62	0.93	39.91 [a]	47.55 [a]
			7.64	7.64
Coffee (2 months)	−0.67	1.06	44.92 [a]	49.27 [a]
			4.34	4.34
Cocoa (6 months)	−0.83	1.11	21.78 [a]	30.59 [a]
			8.81	8.81
Cocoa (2 months)	na	0.71	30.42 [a]	33.06 [a]
			2.64	2.64
Hansen's fully modified estimator: H_0: parameter stability				
Commodity	α_0	β_0	L_C	
Coffee (6 months)	5.29	0.44	0.90 [a]	
Coffee (2 months)	0.53	0.94	1.23 [a]	
Cocoa (6 months)	0.79	0.90	0.29	
Cocoa (2 months)	1.60	0.80	0.27	

[a] 5% level of significance.

4.2. Cointegration tests

Knowing that spot and futures prices are non-stationary and integrated of the same degree, the following step consists of verifying whether there exists a long-run relation between the four pairs of future spot prices and futures prices. The relationship between the futures price (at t for delivery at $t+n$) and the future spot price (at $t+n$) is directly related to the usefulness of the futures price as a predictor of the future spot price conditional on information set, I_t, at t. I_t includes the current and past values of the recent variables and details how they are interrelated. Furthermore, the futures price reflects past and current information as well as expectations about the future. Hence, participants in an efficient market form rational expectations and use all relevant and available information to predict the future development of prices.

Three tests are conducted to ascertain the cointegration between the two series. First, following Engle and Granger (1987), we estimated the cointegration regression (Eq. (2)) and implemented an ADF test on the fitted residuals. The upper part of Table 3 shows the estimation and test results. α_0 and β_0 are ordinary least square (OLS) estimates in the regression of S_{t+n} on a constant and $F_{t,n}$. An ADF test is implemented on residuals of the cointegration regression. The null hypothesis of no cointegration cannot be rejected for the six-month maturity coffee contracts and is rejected for the two-month maturity coffee and cocoa contracts since the calculated statistics are superior, in absolute values, to the critical values of 3.46 for coffee and 3.56 for cocoa. Then, we conclude that the future spot price and the futures price are non-stationary but follow a similar trend, except for the coffee's six-month maturity contracts. This cointegration result can be regarded as a necessary, but not sufficient, condition for market efficiency. Another condition requires that the residuals of the cointegration regression show no sign of autocorrelation. LM(1) is a Lagrange multiplier test of the null hypothesis of no autocorrelation of order 1. The calculated statistics are compared to a critical value of 3.84. The null cannot be rejected for the two-month maturity contracts; it cannot be rejected at the 2.2% significance level for the six-month maturity cocoa contracts whereas it is rejected for the six-month maturity coffee contracts. This last result is not surprising given the aforementioned problem with overlapping contracts. A glance at the estimated coefficients, α_0 and β_0, reveals that they are not close to the (0, 1) restriction, another requirement under the market efficiency hypothesis.

The middle part of Table 3 shows cointegration test results using Johansen and Juselius' maximum likelihood (ML) approach (a summary of the method is presented in Appendix B). α_0 and β_0 are the normalized intercept and futures price coefficients in the cointegrating vectors. The number of lags used in the ECM is 2, 1, 4, and 1, respectively for coffee (six and two-month maturity) and cocoa (six and two-month maturity) equations. The trace and maximal eigenvalues tests are conditional on the presence or absence of trend. The null of no trend cannot be rejected for the first three equations and is rejected for the last one. The calculated statistics are 0.64, 0.99 and 2.77, respectively, and are below the tabulated χ^2 with one degree of freedom (3.84). The calculated statistic for the last equation is 5.55 and exceeds its corresponding critical value [4]. The first (second) number under λ_{max} and trace columns is the likelihood ratio test of the hypothesis that the maximum number of cointegrating vector is 0 (1). The 95% critical values are 15.67, 9.24 for λ_{max} and 19.96, 9.24 for the trace test, respectively. For the two-month cocoa contracts, the critical values are 14.06, 3.76 for λ_{max} and 15.41, 3.76 for the trace test, respectively. The maximal eigenvalues and trace statistics presented in Table 3 indicate that the null hypothesis of no cointegration ($r = 0$) is rejected at the 5% significance level. On the other hand, the null of one cointegration relation cannot be rejected, which supports most of the results of the Engle–Granger procedure. There is a divergence between the two procedures for the six-month maturity coffee contracts.

The Johansen and Juselius approach does not put any constraint on the normalization of the cointegration vectors. In this case, the cointegration relations are more meaningful when interpreted in terms of the future spot price:

$$S_{t+n} = 0.62 + 0.93 F_{t,n},$$

(coffee six – month maturity contracts)

$$S_{t+n} = -0.67 + 1.06 F_{t,n},$$

(coffee two – month maturity contracts)

$$S_{t+n} = -0.83 + 1.11 F_{t,n},$$

(cocoa six – month maturity contracts)

$$S_{t+n} = 0.71 F_{t,n}.$$

(cocoa two – month maturity contracts)

The coefficients of $F_{t,n}$ are close to one, a result somewhat comforting. Nevertheless, further testing needs to be done to determine if the estimated parameters are close enough to the theoretical one derived from the market efficiency hypothesis. The results of these tests are presented in the next subsection.

The lower part of Table 3 shows the estimates and parameter instability tests for the fully modified regressions. The covariance parameters are calculated with the quadratic spectral kernel. In Hansen's terminology, the model is estimated with $k_1 = 0$ and $k_2 = 1$, meaning that a constant is included in the model and that a stochastic process is present in the regressor (futures price). In other words, the futures price has an $I(1)$ component plus a drift. The L_C test about the stability of the parameters of the cointegration relation is computed. The null is stability and the alternative is that the parameters are martingales, which imply that their mean is constantly changing. The 5% critical value is found in Hansen (1992) and is 0.575. The statistical evidence suggests that the coefficients are unstable for the coffee equations but stable for the cocoa equations. Given that the L_C test can be interpreted as a cointegration test, the cointegration test is maintained for the cocoa contracts but rejected for the coffee contracts.

In brief, the fully modified estimator's long-run coefficients are closer to the Engle and Granger's coefficients than to the ones obtained with Johansen and Juselius' approach. Given the partially conflicting results about the cointegration hypothesis, it

[4] The fourth equation is estimated with a trend and the cointegration relation has no intercept.

Table 4
Non-nested tests to compare restricted and unrestricted error correction models

Commodity	Test	H_0:(3) preferred to (4) [a]	H_0:(4) preferred to (3)
Coffee (6 months)	N-T test	−4.373 (0.000)	0.1581(0.874)
	J test	4.189 (0.000)	0.656 (0.511)
Coffee (2 months)	N-T test	0.610 (0.542)	−2.362 (0.000)
	J test	−0.601 (0.548)	−2.202 (0.010)
Cocoa (6 months)	N-T test	−1.326 (0.185)	−0.519 (0.603)
	J test	1.758 (0.079)	1.531 (0.126)
Cocoa (2 months)	N-T test	−2.032 (0.042)	0.623 (0.533)
	J test	3.149 (0.002)	−0.004 (0.997)

[a] (3) and (4) are the Eq. (3) and Eq. (4) in the main text.

might be worth-while to find out which set of results is more likely. Hargreaves (1993) recommends results from the Johansen and Juselius estimator if the model is well specified without highly autocorrelated cointegration errors and the fully modified estimator when one is unsure of the cointegrating dimensionality and is only estimating one cointegrating vector. Our diagnostics checks suggest that Johansen and Juselius' results should be reliable.

4.3. The error correction model and the sufficient efficiency conditions

The long-run relationship between the future spot price and the futures price consistent with the market efficiency hypothesis requires that $S_{t+n} - F_{t,n} = 0$. This (0, 1) restriction is tested in three ways. With regard to the Engle and Granger's procedure, non-nested tests are used to discriminate between the restricted and the unrestricted models. An alternative procedure consists of estimating Eq. (5) and testing the following restriction $(-a\alpha_0, -a\beta_0) = (0, -a)$. Finally, Johansen and Juselius' ML ratio test can be used to test the $(\beta_1, \beta_0, \alpha_0) = (1, -1, 0)$ restriction which implies a unitary elasticity between the future spot price and futures price ($\beta_1 = -\beta_0$) and that the futures price be an unbiased predictor ($\alpha_0 = 0$).

Table 4 presents the results from the non-nested tests. Numbers in parentheses beside the N-T and *J* statistics represent the probabilities of falsely rejecting the null hypothesis. For six-month maturity coffee contracts, the probability that the unrestricted model be more adequately specified than the restricted one is zero. Complementary information such as higher R^2 and more negative Akaike Information Criterion (AIC) and Schwarz Bayesian Information criteria (SBIC) also favors the restricted model [5]. Thus, the (0, 1) restriction on the cointegration vector cannot be rejected. For two-month maturity coffee contracts, the probability that the unrestricted model be superior to the restricted one is higher. The R^2, AIC and SBIC also point toward the rejection of the (0, 1) restriction. For both types of cocoa contracts, the selection criteria favor the restricted model. Based on these results, we can conclude that the (0, 1) restriction is rejected for one coffee equation (2 months) but cannot be rejected for the three other equations.

We now examine whether there are important short-run deviations from the long-run efficiency condition. For this purpose, we use an error correction model with several lags of ΔS_{t+n} and $\Delta F_{t,n}$, with the (0, 1) restriction imposed in OLS ECMs and tested in NLLS ECMs. Table 5 reports the best ECM specifications for nested tests in the more general from Eq. (3)). The market efficiency hypothesis implies that the restrictions $-a = b = 1$ and that all the lags in the summation terms are zero or $\beta_k = \gamma_k = 0$. These restrictions are rejected for the four OLS ECMs. For one coffee equation (6 months), the Wald statistic for the test of $-a = 1$ and $\forall \beta_k = \gamma_k = 0$ is 232.95, which is above its corresponding tabulated $\chi^2_{0.05,5}$. For the two-month coffee contracts equation, the Wald statistic about the possibility of $-a = b = 1$

[5] We went ahead with the testing of the (0,1) restriction for this case even though the existence of a cointegration relation is questionable since only the Johansen and Juselius's approach favors the cointegration hypothesis for all four contracts.

Table 5
Engle–Granger OLS and NLLS estimation of error correction models

Coffee (six months): OLS

$$\Delta S_{t+n} = \underset{(3.07)}{0.33}\,(S_{t+n} - F_{t,n})_{-1} - \underset{(-3.61)}{0.76}\,(\Delta S_{t+n})_{-2} - \underset{(-2.91)}{0.43}\,(\Delta S_{t+n})_{-4} + \underset{(2.25)}{0.31}\,(\Delta F_{t,n})_{-1} - \underset{(-2.98)}{0.39}\,(\Delta F_{t,n})_{-4}$$

D-W = 2.07; $R^2 = 0.35$; S.E. = 0.10; L-B(16) = 11.22

Coffee (six months): NLLS

$$\Delta S_{t+n} = \underset{(2.20)}{0.29}\,(S_{t+n} + \underset{(0.27)}{1.28} - \underset{(-2.30)}{1.13}\,F_{t,n})_{-1} - \underset{(-3.44)}{0.74}\,(\Delta S_{t+n})_{-2} - \underset{(-2.40)}{0.41}\,(\Delta S_{t+n})_{-4} + \underset{(2.17)}{0.32}\,(\Delta F_{t,n})_{-1} - \underset{(-2.60)}{0.39}\,(\Delta F_{t,n})_{-4}$$

D-W = 2.04; $R^2 = 0.37$; S.E. = 0.11; L-B(16) = 9.98; $\chi^2_{0.05,2} = 5.99$

Coffe (two months): OLS

$$\Delta S_{t+n} = -\underset{(-2.57)}{0.47}\,(S_{t+n} - F_{t,n})_{-1} + \underset{(6.16)}{0.72}\,\Delta F_{t,n} + \underset{(2.09)}{0.18}\,(\Delta F_{t,n})_{-3}$$

D-W = 1.89; $R^2 = 0.50$; S.E. = 0.09; L-B(16) = 14.68

Coffee (two months): NLLS

$$\Delta S_{t+n} = -\underset{(-2.92)}{0.56}\,(S_{t+n} - \underset{(1.24)}{1.81} - \underset{(5.27)}{0.80}\,\Delta F_{t,n})_{-1} + \underset{(5.94)}{0.71}\,\Delta F_{t,n} + \underset{(2.34)}{0.20}\,(\Delta F_{t,n})_{-3}$$

D-W = 1.87; $R^2 = 0.54$; S.E. = 0.09; L-B(16) = 15.10; $\chi^2_{0.05,2} = 5.99$

Cocoa (six months): OLS

$$\Delta S_{t+n} = -\underset{(-3.46)}{0.42}\,(S_{t+n} - F_{t,n})_{-1} - \underset{(-1.10)}{0.17}\,(\Delta F_{t,n})_{-2}$$

D-W = 2.22; $R^2 = 0.26$; S.E. = 0.08; L-B(9) = 7.92

Cocoa (six months): NLLS

$$\Delta S_{t+n} = -\underset{(-2.05)}{0.34}\,(S_{t+n} + \underset{(-0.75)}{2.34} - \underset{(3.24)}{1.30}\,F_{t,n})_{-1} - \underset{(-1.16)}{0.18}\,(\Delta F_{t,n})_{-2}$$

D-W = 2.53; $R^2 = 0.29$; S.E. = 0.08; L-B(9) = 10.36; $\chi^2_{0.05,2} = 5.99$

Cocoa (two months): OLS

$$\Delta S_{t+n} = -\underset{(-2.83)}{0.28}\,(S_{t+n} - F_{t,n})_{-1} - \underset{(-2.43)}{0.43}\,\Delta F_{t,n} - \underset{(-1.23)}{0.21}\,(\Delta F_{t,n})_{-4} + \underset{(1.83)}{0.47}\,(\Delta S_{t+n})_{-1}$$

D-W = 2.06; $R^2 = 0.32$; S.E. = 0.08; L-B(9) = 6.01

Cocoa (two months): NLLS

$$\Delta S_{t+n} = -\underset{(-1.94)}{0.40}\,(S_{t+n} - \underset{(106.6)}{1.00}\,F_{t,n})_{-1} + \underset{(1.92)}{0.56}\,(\Delta S_{t+n})_{-1} - \underset{(-1.55)}{0.37}\,\Delta F_{t,n} - \underset{(-1.19)}{0.20}\,(\Delta F_{t,n})_{-4}$$

D-W = 2.13; $R^2 = 0.33$; S.E. = 0.09; L-B(9) = 7.67; $\chi^2_{0.05,1} = 3.84$

and $\forall \beta_k = 0$ is 16.19, which is also above its tabulated $\chi^2_{0.05,3}$. The Wald statistics for the cocoa equations are 26.80 and 99.58 and exceed their corresponding critical values of 9.48. These results strongly suggest that there are short-run deviations from the long-run efficiency conditions.

The (0, 1) efficiency condition can also be verified by estimating Eq. (5) by NLLS and testing the hypotheses $(-a\alpha_0, -a\beta_0) = (0, -a)$. The estimated coefficients and statistical tests are presented in Table 5 along with the OLS results to facilitate comparisons. The numbers in parentheses represent t-statistics and the variables are defined as previously. The Wald statistics for the null hypothesis of $-a\alpha_0 = 0$ and $-a\beta = -a$ for coffee contracts and six-month cocoa contracts are 0.78, 3.69, and 0.99, respectively (the Wald statistic about the null hypothesis of $-a\beta = -a$ for two-month cocoa contracts is 0.46), which are below the tabulated $\chi^2_{0.05,2}$ and $\chi^2_{0.05,1}$ [6]. Thus, the null hypothesis cannot be rejected even for the two-month maturity coffee contracts, which contrasts with the non-nested test results.

The likelihood ratio tests of Johansen and Juselius

[6] The two-month maturity cocoa equation is estimated without the constant α_0, which is equal to zero by construction; so the hypothesis tested is $\beta_0 = 1$.

Table 6
Hypothesis tests on β and ψ

Hypothesis	Coffee (6 months)	Coffee (2 months)	Cocoa (6 months)	Cocoa (2 months)
$H_0: \beta_1 = -\beta_0$	0.26	1.06	0.50	8.76
$H_0: \beta_1 = -\beta_0$, $\alpha_0 = 0$	0.42	4.29	5.54	n.a.
$H_0: \psi_1 = 0$	2.31	3.00	12.67 [a]	4.00 [a]
$H_0: \psi_0 = 0$	32.18 [a]	34.53 [a]	0.29	27.72 [a]

ψ_1 and β_1 are associated with the future spot price.
ψ_0 and β_0 are associated with the futures price.
α_0 is the intercept in the β vector.
n.a.-not available.
[a] 5% level of significance.

(1990, 1992) can be used to test restrictions on β such as the ones implied by the market efficiency hypothesis. The test results are presented in Table 6. The hypothesis of a unitary elasticity between the future spot price and the futures price ($\beta_1 = -\beta_0$) cannot be rejected for three of the four equations. The exception is the two-month maturity cocoa contracts equation [7]. The inability to reject means that there is a proportional relationship between the futures price and the future spot price. The second hypothesis tested combines the unitary elasticity and the unbiasedness hypotheses (1, −1, 0). It cannot be rejected for the coffee equations and one cocoa equation (six-month maturity contracts), which means the futures price is an unbiased predictor of the future spot price.

Weak exogeneity is the last hypothesis tested. The results are presented in the last two rows of Table 6. According to Johansen and Juselius (1990), the ψ_1 and ψ_0 coefficients (as defined in Appendix B) provide information about the speed at which the future spot and futures prices come back in long-run equilibrium after a shock. If ψ_1 or ψ_0 is not statistically different from zero, then the variable is said to be weakly exogenous (Johansen and Juselius, 1992; Ericsson, 1992). The likelihood ratio tests support (reject) the weak exogeneity of the future spot price (futures price) for coffee equations. It can be inferred that the future spot price does not respond to deviations from the long-run cointegration relation, but the futures price does. In other words, when a shock brings about disequilibrium in the relationship between the current spot price and past futures price, the effect of the new information will produce an adjustment in the current futures price. Thus, the futures price reflects the information about the future evolution of prices, which supports the market efficiency hypothesis.

To sum up, we found empirical support for cointegration between the future spot price and the futures price and for a second necessary condition for efficiency, which is the (0, 1) restriction on the cointegration vector, the ECMs estimated with NLLS are the most maintained to the (0, 1) restriction in the cointegrating vector for all the equations. The non-nested tests rejected the (0, 1) restriction for one coffee equation (two-month maturity contracts), whereas the ML ratio tests did it for one cocoa equation (six-month maturity contracts).

5. Conclusion

The objective of this study was to test the market efficiency hypothesis for coffee and cocoa futures. Whether or not the markets are efficient is of preponderant importance for developing countries relying on exports of coffee and cocoa to finance much needed imports of intermediate inputs. These countries have been and still are concerned with the volatility of spot commodity prices. Historically, they have favored buffer stocks and export quotas to deal with price risk. In many instances, the management of these stocks turned out to be very expensive and the free rider problem on the import side undermined the quota system [8]. In such circumstances, pressures to reduce government expenditures have forced many of these countries to reconsider their way of dealing with price risk. In spite of that, they have been

[7] This equation is estimated with a trend. By construction, $\alpha_0 = 0$ since the cointegrating relation has no intercept.

[8] Importing countries not belonging to the International Coffee Agreement (ICA) were able to purchase coffee at a substantial discount. As is often the case with price discrimination schemes, importers paying lower prices profited from reexporting.

reluctant to embrace the futures markets alternative. This lack of interest can be explained by a variety of factors which include a strong belief that futures markets are inefficient. As investors, they know that inefficient markets impose costs supplemental to normal transaction costs.

One condition of the market efficiency hypothesis requires the future spot and futures prices to be cointegrated. It also imposes restrictions on the parameters of the cointegration relation and on other parameters of the error-correction representation. Brenner and Kroner state that most empirical studies reject the cointegration condition. They attribute this phenomenon to the potentially non-stationary net cost-of-carry. We use several testing procedures on two-month and six-month maturity contracts for coffee and cocoa to assess the robustness of the no-cointegration/market inefficiency result. While our results are not perfectly consistent across approaches, they weakly favor market efficiency. The Engle–Granger procedure supported the cointegration hypothesis for three of the four cases analyzed. The Johansen and Juselius ML procedure was even more supportive as it failed to reject cointegration in all cases. In contrast, Hansen's L_C test of parameter stability associated with the Fully Modified Estimator turned out evidence supporting stable cointegration relations only for the cocoa contracts. Hansen's L_C test is particularly appealing in light of the Brenner and Kroner argument, which implies unstable cointegration parameters. The alternative hypothesis test is that the parameters are martingales and thus change with every observation as opposed to one-time break 'structural change'.

Given that Johansen and Juselius' ML cointegration tests performed relatively well in recent Monte Carlo experiments (Hargreaves), we decided to maintain the cointegration hypothesis and test the other required conditions for market efficiency. We used three different methods to test the (0, 1) restriction on the cointegration vector which could be interpreted as the unbiasedness condition, and in most cases, it was not possible to reject the null hypothesis. However, short-run deviations from unbiasedness were noticeable, especially for the cocoa contracts. These results are heartening for proponents of futures markets and their use by developing countries. The empirical evidence tends to support the claim that the markets are not systematically biased. Of course, one should be cautious in attempting to generalize this encouraging conclusion. Future research is needed to investigate longer maturity contracts and other commodities.

Appendix A

As in Hansen (1992), consider a cointegration regression

$$y_t = Ax_t + u_t,\ t = 1,\dots,n, \qquad \text{(AA1)}$$

where u_t is a sequence of mean zero random vectors. Eq. (AA1) can be modified to incorporate possible parameter instability by allowing A to depend on time:

$$y_t = A_t x_t + u_t. \qquad \text{(AA2)}$$

The L_C test models the parameter A_t as a martingale process, which is, $A_t = A_{t-1} + \epsilon_t$; $E(\epsilon_t | Z_{t-1}) = 0$, $E(\epsilon_t \epsilon_t') = \delta^2 G_t$. In this context, the null hypothesis is written as the constraint that the variance of the martingale differences is zero: $H_0 : \delta^2 = 0$. The alternative is $H_A : \delta^2 > 0$, $G_t = (\hat{\Omega}_{1.2} \otimes M_{nn})^{-1}$, with test statistic

$$L_C = tr\left\{ M_{nn}^{-1} \sum_{t=1}^{n} S_t \hat{\Omega}_{1.2}^{-1} S_t' \right\}, \qquad \text{(AA3)}$$

where $\hat{\Omega}_{1.2} = \hat{\Omega}_{11} - \hat{\Omega}_{12} \hat{\Omega}_{22}^{-1} \hat{\Omega}_{21}$, $V_{nt} = M_{nt} - M_{nt} M_{nn}^{-1} M_{nt}$, $M_{nt} = \sum_{i=1}^{t} x_t x_t'$ and S_t are the scores of the problem. The asymptotic critical value for the L_C test is available in Hansen (1992). To see why the L_C statistic can be regarded as a test of cointegration between two variables, let Eq. (AA1) take the form

$$y_t = A_1 + A_2 x_{2t} + u_t, \qquad \text{(AA4)}$$

where A_1 is simply a constant. Assume that y_t and x_{2t} are not cointegrated, i.e., the error term u_t is $I(1)$. u_t can be decomposed into w_t and v_t where w_t is a random walk and v_t is stationary. Thus, (Eq. (AA4)) can be written as

$$y_t = A_{1t} + A_2 x_{2t} + v_t, \qquad \text{(AA5)}$$

where $A_{1t} = A_1 + W_t$. Eq. (AA5) is a special case of Eq. (AA2) which is the model of cointegration with non-stationary coefficients. In our application, w_t represents Brenner and Kroner's non-stationary net cost-of-carry. Thus, the L_C statistic is a test of the null of cointegration against the alternative of no cointegration.

Appendix B

The Johansen and Juselius method can be summarized as follows. A vector of p economic variables x_t can be represented in a vector autoregressive (VAR) form or a vector error correction (VEC) form such that:

$$\Delta x_t = \Gamma_1 \Delta x_{t-1} + \ldots + \Gamma_{k-1} \Delta x_{t-k+1} + \pi x_{t-k} + \phi + \epsilon_t, \quad \text{(BB1)}$$

where ϵ_t is a vector of well-behaved error terms, ϕ is a vector of intercept terms. The coefficient matrix π contains information about the long-run relationship between the series and lends itself to hypothesis testing. A matrix π with rank equal to p implies that x_t is a stationary system while a rank of zero means that x_t is a first-differenced vector time series model since there is zero cointegration relation. In the intermediate case where $0 < \text{rank} < p$, the individual series in x_t are cointegrated and the matrix can be decomposed into $(p \times r)$ matrices ψ and β, such that $\pi = \psi\beta'$. Johansen and Juselius test the null hypothesis that the rank of π is at most equal to r depending on the $p-r$ smallest square canonical correlations of $[x'_{t-k}, 1]$ relative to Δx. Two statistics, the trace and the maximal eigenvalues $(\lambda_{\max})$ determine the number of cointegrating vectors. Critical values can be found in Johansen and Juselius (1990) and Osterwald-Lenum (1992). In this study, $x_t = (S_{t+n}, F_{t,n})'$ and p is equal to 2. The cointegration test between the two variables is testing that the rank of π is equal to 1.

Diagnostic checks (autocorrelation, model specification, normality, heteroscedasticity) on the residuals of Eq. (BB1) are a prerequisite to cointegration tests. The Ljung-Box test reveals that the null hypothesis of no autocorrelation cannot be rejected for all equations at a 5% significance level. The Ramsey (1970) reset test indicates that the equations are properly specified. The Jarque-Bera test confirms that the residuals are normally distributed. The Lagrange multiplier test detects no heteroscedasticity in the residuals. Detailed results of the diagnostic tests are available from the authors upon request.

References

Agiakloglou, C., Newbold, P., 1992. Empirical evidence on Dickey-Fuller-type tests. Journal of Time Series Analysis 13, 471–483.

Baillie, R.T., McMahon, P.C., 1989. The foreign exchange market: theory and econometric evidence. Cambridge Univ. Press, Cambridge, 259 pp.

Banerjee, A., Dolado, J., Hendry, D., Smith, G.W., 1986. Exploring equilibrium relationships in econometric theory through static models. Oxford Bulletin of Economics and Statistics 48, 253–277.

Commodity Research Bureau Inc. Commodity yearbook, New York.

Beck, S., 1994. Cointegration and market efficiency in commodity futures markets. Applied Economics 26, 249–257.

Brenner, R., Kroner, K., 1995. Arbitrage, cointegration, and testing the unbiasedness hypothesis in financial markets. Journal of Financial and Quantitative Analysis 30, 23–42.

Copeland, L., 1991. Cointegration tests with daily exchange rate data. Oxford Bulletin of Economics and Statistics 53, 185–198.

Davidson, R., MacKinnon, J.G., 1993. Estimation and inference in econometrics. Oxford Univ. Press, New York, 874 pp.

Davidson, R., MacKinnon, J.G., 1981. Several tests for model specification in the presence of alternative hypothesis. Econometrica 49, 781–793.

Engle, R.F., Granger, C.W.J., 1987. Cointegration and error correction representation, estimation and testing. Econometrica 55, 251–276.

Ericsson, N.R., 1992. Cointegration, exogeneity and policy analysis: an overview. Journal of Policy Modeling 14, 251–276.

Fama, E., 1991. Efficient capital markets: II. Journal of Finance 46, 1575–1617.

Fama, E., 1970. Efficient capital markets: a review of theory and empirical work. Journal of Finance 25, 383–417.

Fama, E., French, K., 1987. Commodity futures prices: some evidence on forecast power, premium and the theory of storage. Journal of Business 60, 55–73.

Froot, K.A., Frankel, J., 1989. Forward discount bias: is it a exchange risk premium?. Quarterly Journal of Economics 104, 139–161.

Gersovitz, M., Paxson, C., 1990. The Economies of Africa and the prices of their exports. Princeton Studies in International Finance, no. 68.

Godfrey, L.G., Peseran, H., 1983. Tests of non-nested regression models: small sample adjustments and Monte Carlo evidence. Journal of Econometrics 21, 133–154.

Granger, C.W.J., 1986. Development in the study of cointegrated economic variables. Oxford Bulletin of Economics and Statistics 48, 213–228.

Hakkio, C.S., Rush, M., 1989. Market efficiency and cointegration: a application to the sterling and deutchemark exchange markets. Journal of International Money and Finance 8, 75–88.

Hall, A., 1994. Testing for a unit root in time series with pre-test data-based model selection. Journal of Business and Economics Statistics 12, 461–470.

Hansen, B.E., 1992. Tests of parameter instability in regressions with I(1) processes. Journal of Business and Economic Statistics 10, 321–335.

Hargreaves, C., 1993. A review of methods of estimating cointegration relationships. In Hargreaves, C. (Ed.). Non-stationary time series analysis and cointegration. Oxford Univ. Press, pp. 87–131.

Hodrick, R.J., 1987. The empirical evidence on the efficiency of forward and futures foreign exchange markets. Harwood Academic Publishers, New York, 174 pp.

Johansen, S., Juselius, K., 1992. Testing structural hypotheses in a multivariate cointegration analysis of the PPP and the UIP for UK. Journal of Econometrics 53, 211–244.

Johansen, S., Juselius, K., 1990. Maximum likelihood estimation and inference on cointegration with applications to the demand of money. Oxford Bulletin of Economics and statistics 52, 169–210.

Kahl, K., Tomek, W., 1986. Forward pricing models for futures markets: some statistical and interpretive issues. Food Research Institute Studies 20, 71–85.

Kofi, T., 1973. A framework for comparing the efficiency of futures markets. American Journal of Agricultural Economics 55, 584–594.

Kwiatkowski, D., Phillips, P.C.D., Schmidt, P., Shin, Y., 1992. Testing the null of stationarity against the alternative of a unit root. Journal of Econometrics, 54: 159–178.

Levich, R.M., 1985. Empirical studies of exchange rates: price behavior, rate determination and market efficiency. In: Jones, R.J. (Ed.). Handbook of international economics. North Holland, Amsterdam, pp. 979–1040.

Leybourne, S.J., McCabe, B.P.M., 1994. A consistent test for a unit root. Journal of Business and Economics Statistics 12, 157–166.

MacDonald, R., Taylor, M.R., 1989. Foreign exchange rates and cointegration: some evidence from the recent float. Economics Letters 29, 63–68.

MacKinnon, J.G., 1990. Critical values for cointegration tests. UC San Diego Discussion Paper 90-4.

Osterwald-Lenum, M., 1992. A note with quantiles of the asymptotic distribution of the maximum likelihood cointegration rank test tatistics. Oxford Bulletin of Economics and Statistics 54, 461–471.

Ouattara, K., Schroeder, T.C., Sorenson, L.O., 1990. Potential use of futures markets for international marketing of Côte d'Ivoire coffee. Journal of Futures Markets 10, 113–121.

Phillips, P.C.B., Hansen, B.E., 1990. Statistical inference in instrumental variables regression with I(1) processes. Review of Economic Studies 57, 99–125.

Phillips, P.C.B, Perron, P., 1988. Testing for unit root in time series regression. Biometrica, 75: 335–346.

Ramsey, M.B., 1970. Models specification error and inference: a discussion of some problems in econometric methodology. Bulletin of the Oxford Institute of Economics and Statistics, 32: 301–318.

Serletis, A., Scowcroft, D., 1991. Informational efficiency of commodity futures prices. Applied Financial Economics 1, 185–192.

Thompson, S., 1985. Use of futures markets for exports by Less Developed Countries. American Journal of Agricultural Economics 67, 986–991.

World Bank, 1994. World development report. Oxford Univ. Press, New York.