HEDGING TANKER FREIGHT RATES WITH

FORWARD INTER-CRUDE SPREADS

Abstract

The market for tanker freight rates has been notoriously volatile since the inception of this industry sector near the beginning of this century. Since the latest tanker market recession in the mid-1980s, there have been increasing attempts to decrease freight rate risk. One obvious method of avoiding spot market freight risk is the use of time charters. However, long-term time charters have been few and far between and charterers may be more reluctant than before to enter such binding agreements. An alternative way of managing freight risk, however, has been the use of forward and futures markets. One such example is the market for futures contracts on the Baltic Freight Index, which are traded in London. This type of contract, however, is rather geared towards dry bulk market participants. Tanker market participants, on the other hand, have very limited choice, and sometimes use crude oil futures to hedge some of their freight risk.

This paper examines the possibility of using inter-crude forward spreads – as opposed to outright forward crude oil contracts – to cover freight rate exposure. To do this, a time series of weekly data for one-month and two-month WTI-Brent spreads is compared against a time series of weekly data for freight rates for crude carriers operating on the U.S.Atlantic Coast-UK route, in order to determine whether a linkage can be established between the two series. Both series are found to be approximately difference stationary – i.e. integrated of order one – and tests show that the two series are cointegrated. Although cointegration per se is not a proof of linkage, the results can be interpreted as evidence that the two markets move in parallel.

In conclusion, the results seem to indicate that there is scope for the use of inter-crude forward spreads to hedge freight rate risk in a few selected sea routes. Although spreads and freight rates do not always move in concordance, spreads could still be an attractive hedging solution, because they represent by construction a smaller absolute price volatility, and are more relevant to freight rates that the absolute price of crude oil itself.

Introduction

The existence of volatility in freight markets is a well-known fact and its moderation is desirable both by suppliers and users of transport services. In the bulk markets, stability of income is provided by the use of time-charter fixtures, which may not be desirable, however, if shipowners and/or charterers do not wish to undertake long-term transport commitments.[1]

The existence of a derivatives market serves two main purposes – price discovery, and risk hedging. In sea freight, such a market exists in the form of futures contracts on the Baltic Freight Index which are traded on the London Commodity Exchange. The underlying 'asset' for these contracts – BFI – is a basket of mainly voyage fixtures for a number of dry bulk commodities (grains, coal, iron ore and bauxite). It is obvious that BFI futures are irrelevant to the tanker market, leaving tanker operators and users with very few choices. Attempts for the launching of a similar freight futures contract for tankers have been made, but were not met with success.

Tanker owners and charterers have little choice but to use either time charters, or outright positions on crude oil and products futures, or simply accept freight rate risk. Although one might argue that freight rate risk could be hedged with outright futures position in crude oil – or oil products, if necessary – such positions represent higher risk, because the range of price movements is wider than that for spreads.

This paper discusses the possibility of using future spreads to hedge freight risk and investigates its feasibility by looking at the connection between spreads and freight rates.

The link between spreads and freight

A future spread is the simultaneous sale and purchase of the same number of different, but close, futures contracts. Spreads can span across time, e.g. the purchase of a contract for Brent crude to be delivered in May and the simultaneous sale of a contract for Brent crude to be delivered in July, in which case they are called *calendar* spreads. More interestingly, spread positions can be initiated using different types of the same commodity. For example, a *crack* spread can be initiated by buying May IPE Brent crude and selling May IPE Gasoil, and an *inter-crude* spread could be constructed by buying West Texas Intermediate (WTI) crude and selling Brent crude.

This last example is of particular interest, because it involves two most important markets for crude oil: North America and Western Europe. North America is a net importer of crude, with WTI prices reflecting the supply/demand situation in the domestic US market. On the other hand, Brent crude is a predominantly exported crude, with most of it directed to the North American market.

As Edwards and Ma (1992: p.95) note "...theoretically, regional price differences in a commodity should be equal to transportation costs between the regions. However, variations in regional supply and demand patterns, seasonality, and the availability of transport often result in regional prices differing by more than transportation costs."

Indeed, transportation costs (i.e. sea freight) is not the sole factor affecting the WTI-Brent spread. Local demand/supply imbalances are expected to influence the convergence or divergence of the prices of the two crudes. However, transportation cost should be the dominant element, and our data show a consistent premium paid for WTI, i.e. the WTI-Brent spread is constantly positive.

[1] Time-charters, as any other contractual commitments, bear of course a degree of default risk.

FIGURE 1

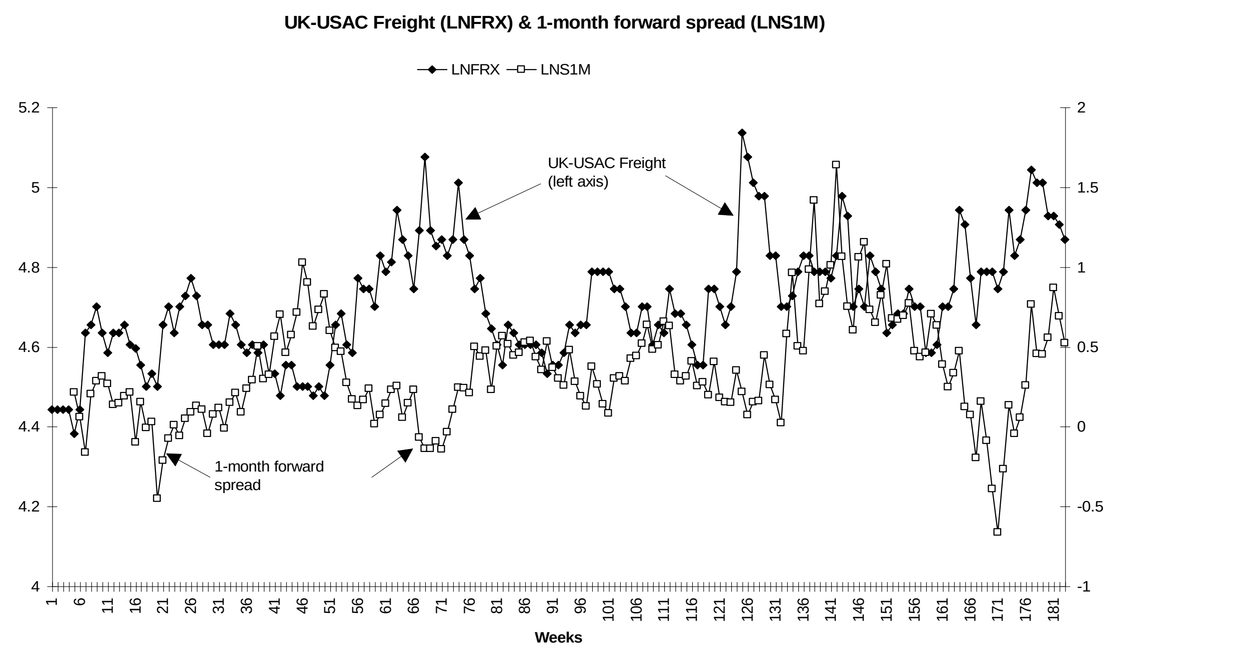
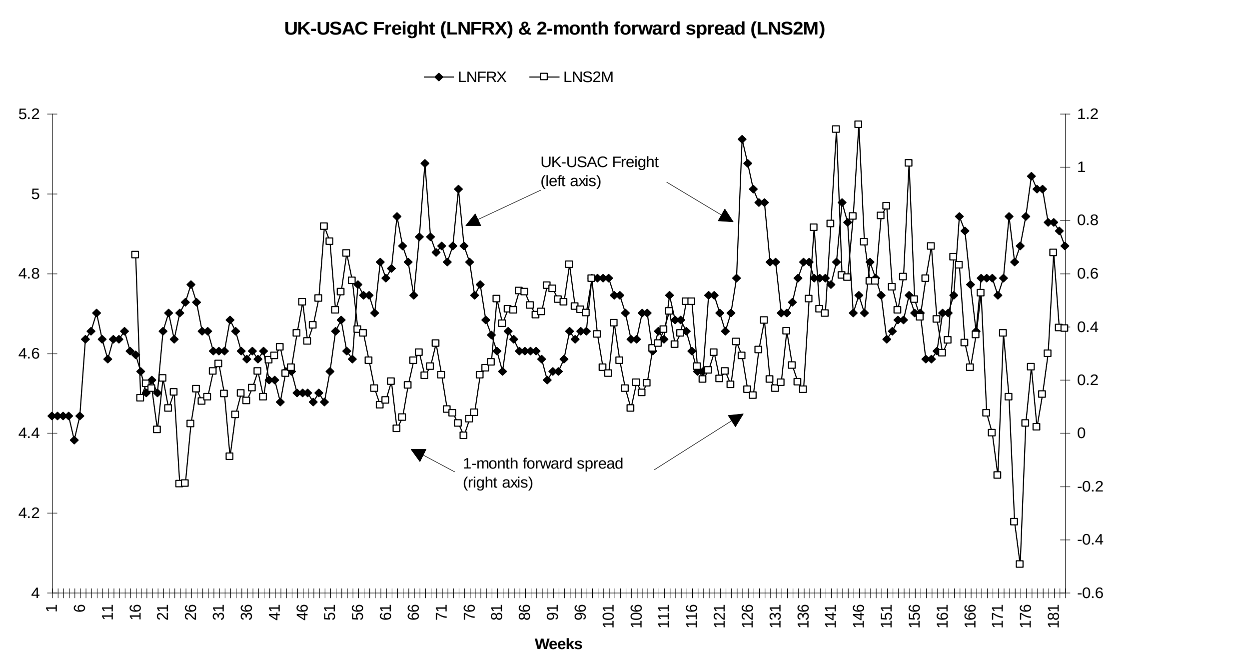


FIGURE 2



As far as the relationship between WTI-Brent spread and cross Atlantic freight rate is concerned, we would expect this to be negative. As the spread diminishes, Brent crude becomes relatively more expensive. Since Brent is the imported crude, this denotes the need for more imports which indicates an increased need for sea transport, thus pushing freight rates upwards; the end result is that a lower spread is associated with higher freight rates and vice versa.

Methodology

Linkage between cash (spot) and forward/futures markets is necessary for the efficient operation of the latter, both for price discovery and for risk hedging. Since the 1950s, there have been studies that have dealt with market efficiency and the link between cash and futures prices, with the aim to determine whether price changes are forecastable or not. The conventional approach to examining the linkage between cash and futures markets has been to regress cash prices on contract maturity on previous futures prices and then observe the intercept coefficient and the slope. More recently, semi-strong form tests have been used to determine whether efficiency exists in a variety of commodities and financial markets (e.g. Garcia et al., 1988; Goss, 1983, 1988; Gupta and Mayer, 1981; Leuthold and Hartman, 1979).

With the seminal work of Engle (1981) and Engle and Granger (1987), cointegration was added to the arsenal of techniques used to analyse economic relationships. Since the formulation of this technique, numerous papers have been written, both refining it, and applying it in several different contexts. Several papers have used cointegration to examine whether futures and cash markets are linked. For example, Bessler and Covey (1991) apply it on U.S. cattle prices; Chowdhury (1991) uses it for copper, lead, tin and zinc on the LME; Hakkio and Rush (1989) apply it to the sterling and deutschemark markets; and Ghosh (1993) and Wang and Yau (1994) use it on intra-day observations of the S&P500 index.

One of the difficulties of analysing economic relationships is the fact that many economic – and financial – time series are non-stationary, i.e. they exhibit a persistent trend. When non-stationary series are linearly combined, they usually generate a non-stationary process, as well. So, a linear combination of $I(1)$ – i.e. integrated of order one – processes will usually be $I(1)$. More generally, if x_t and y_t are both $I(d)$, then the linear combination $u_t = y_t - ax_t$ will usually be $I(d)$. It is possible, however, that u_t is integrated of a lower order, say $I(d\text{-}b)$, where $b>0$, in which case a long-run relationship is implied. In the special case that $d=b=1$, both x_t and y_t are $I(1)$, and their linear combination u_t is $I(0)$. When this occurs, the two series are said to be cointegrated of order zero, i.e. u_t is white noise.

The formal definition of a cointegrated process was made by Engle and Granger (1987): the components of the *n*-dimensional vector[2] $\mathbf{z}_t$ are said to be *cointegrated of order d,b*, denoted $\mathbf{z}_t \sim CI(d,b)$, if (i) all components of $\mathbf{z}_t$ are $I(d)$; and (ii) there exists at least one vector $\alpha(\neq 0)$ such that $\mathbf{u}_t = \alpha' \mathbf{z}_t \sim I(d\text{-}b)$, $b>0$. The vector α is called the *cointegrating vector.*

The contribution of the cointegration methodology lies in the fact that it can be applied on non-stationary series, and detect whether these series move together, i.e. whether there is a long-term relationship between them. Put differently, if two or more series are cointegrated, they have an error correction representation, implying that a proportion of the disequilibrium in one period is expected to be corrected in the next period, resulting eventually in a long-term equilibrium.

The procedure of testing time series for cointegration usually consists of two stages: (i) testing whether each of the series is stationary; and (ii) testing whether series with the same degree of integration are cointegrated. Step (ii) has been approached in two different ways: (a) regressing cash prices on futures prices – *the cointegrating regression* – and testing whether the regression residuals are stationary; and (b) estimating the cointegrating vector using the full

[2] Letters in bold indicate vectors.

information maximum likelihood approach, as suggested by Johansen (1988, 1991) and Johansen and Juselius (1990).

Step one is equivalent to testing for the existence of unit roots in a time series. A simple, asymptotically valid method of testing for unit roots is to employ the 'augmented Dickey-Fuller (ADF) regression'. In the general case this regression can be written as:

$$\nabla x_t = \beta_0 + \beta_1 t + (\rho_1 - 1)x_{t-1} + \sum_{i=1}^{k}\delta_i \nabla x_{t-i} + \alpha_t \tag{1}$$

where, ∇x_t is the first order difference of x_t, β_0 and, β_1 are coefficients, and $\delta_i \nabla x_{t-i}$ is the ith order difference of x_t.

Testing for a unit root is equivalent to testing whether ρ_1–1=0, i.e. whether ρ_1=1. The t-ratio calculated for the coefficient of x_{t-1} in (1) can be compared to the critical values for the τ_t statistic proposed in Dickey and Fuller (1979), which can be found in Table 8.5.2 in Fuller (1976; p.372).

After establishing the order of integration for all series, say X_t and Y_t in our case, a test for cointegration is performed by testing the residuals u_t from the cointegrating regression

$$X_t = c + dY_t + u_t \tag{2}$$

for stationarity. The ADF test is used once more by running the regression shown in (1). The variables are cointegrated only if one can reject the null hypothesis that the t-statistic for the lagged-level term is zero. The critical values for these tests are given in MacKinnon (1990).

There are several residual-based cointegration tests, see for example Phillips and Ouliaris (1990), Park, Ouliaris, and Choi (1988), Stock (1990), and Hansen (1990). However, as Pesaran and Pesaran (1991; p.166) suggest, "the residual-based cointegration tests are inefficient and can lead to contradictory results, especially when there are more than two $I(1)$ variables under consideration. A more satisfactory approach would be to employ Johansen's ML procedure. This provides a unified framework for estimation and testing of cointegrating relations in the context of vector autoregressive (VAR) error correction models."

More specifically, Johansen's approach relies on the hypothesis that $\mathbf{x}_t$, an $m \times 1$ vector of $I(1)$ variables, follows a VAR(p) process. The error correction representation of the VAR(p) model with Gaussian errors is:

$$\Delta\mathbf{x}_t = \mu + \Gamma_1\Delta\mathbf{x}_{t-1} + \Gamma_2\Delta\mathbf{x}_{t-2} + \ldots + \Gamma_{p-1}\Delta\mathbf{x}_{t-p+1} + \Pi\mathbf{x}_{t-p} + \mathrm{B}\mathbf{z}_t + \mathbf{u}_t \tag{3}$$

where: $\mathbf{z}_t$ is an $s \times 1$ vector of $I(0)$ variables, which may be included in the model to ensure that the disturbances $\mathbf{u}_t$ are as close to being Gaussian as possible; Γ_1, Γ_2, ..., Γ_{p-1}, Π are $m \times m$ matrices of unknown parameters; B is an $m \times s$ matrix; and $\mathbf{u}_t \sim N(0, \Omega)$.

Suppose now that each individual variable x_{it} is $I(1)$, although r linear combinations of $\mathbf{x}_t$ are stationary. Johansen's ML procedure estimates (3) under the hypothesis that Π has a reduced rank $r<m$, where $\Pi=\mathbf{a}\boldsymbol{\beta}'$, with $\mathbf{a}$ an $m\times r$ matrix and $\boldsymbol{\beta}'$ an $r\times m$ matrix. Johansen (1989) shows that, under certain conditions, the reduced rank condition above implies that the process $\Delta\mathbf{x}_t$ is stationary, $\mathbf{x}_t$ is non-stationary and $\boldsymbol{\beta}'\mathbf{x}_t$ is stationary.

Microfit provides useful sub-routines for the straightforward calculation of cointegrating vectors. The number of cointegrating vectors r is determined sequentially; first the hypothesis is checked that there are no cointegrating relations (r=0); if this hypothesis is rejected, the hypothesis is tested that there is at most one cointegrating relation ($r \leq 1$); and so on. Based on the specified number (r) of possible cointegrating vectors (β'), these vectors are subsequently estimated.

Data

The raw data comprise three series of weekly observations, over the period from September 1993 to March 1996; a total of 134 observations. The selected period is restricted by the lack of a long, consistent, weekly series of freight rates for spot fixtures of tankers of specific sizes, on particular routes.

Freight rates are for spot fixtures of 80,000 dwt crude carriers, travelling from the UK to the US Atlantic Coast (USAC); they are quoted in Worldscale terms and are compiled by Clarkson Research Studies in London, who publish them in *Clarkson Intelligence Weekly*. For the construction of the inter-crude spread series, daily observations for the 1-month and 2-month forward contracts for West Texas Intermediate (WTI) and Brent Blend are extracted from the Datastream on-line database. Daily observations are then transformed into weekly data points and the inter-crude spread (in $/barrel) is simply the difference between WTI and Brent.

The spread series are lagged in order to match the freight rate observations – 4 lags for the 1-month forward spread, 8 lags for the 2-month one. Finally, the natural logarithms of all observations are used in the calculations, in order to improve symmetry in the time series, as suggested by Mills (1990: p.41).

Results

Table 1 shows a list of the variables that were imported and constructed in Microfit in order to assess the existence of cointegration between freight rates and forward crude oil spreads. The variables that are of most importance are: LNFRX (logarithm of UK-USAC freight rates); LNS1M (logarithm of 1-month forward spreads); and LNS2M (logarithm of 2-month forward spreads).

ADF tests are run on the three abovementioned variables. Test results are presented in tables 2a, 3a and 4a. As it can be seen, ADF test results are mixed, initially indicating that the three variables may be stationary. For more than two lags, however, several *t*-statistics are below the 95%-critical values (given in brackets) which make the null hypotheses of non-stationarity impossible to reject.

Tables 2b, 3b and 4b show the ADF test results of the above series after first order differencing (DLNFRX, DLNS1M, and DLNS2M). The results firmly indicate that the differences of all three series are stationary, and there is no evidence of higher degree of integration.

Subsequently, both the ADF and Johansen's FIML methodologies are used to establish whether freight rates are cointegrated with the 1-month and 2-month forward spreads. Johansen's method is more conclusive, with *t*-ratios exceeding 95%-critical values, in most cases. Tests are carried out using all options for Johansen estimation of cointegration available in Microfit, i.e. for 'non-trended variables', 'trended variables with no trend in the data generating process', and 'trended variables with trend in the data generating process'. The cointegrating equations are also tested for 1 to 8 lags in the vector autoregressive (VAR) model.

A subset of the test results is given in tables 5 to 13. Part (a) in each table shows the results of tests on the cointegrating regression based on maximal eigen values of the stochastic matrix; part (b) in each table shows the results of tests on the cointegrating regression based on the trace of the stochastic matrix; finally, part (c) shows the estimated cointegrated vector(s) for the variables in question.

In most cases, freight rates are found to be cointegrated both with the 1-month and the 2-month forward spreads. However, the null hypothesis of non-cointegration cannot be rejected when tests are run assuming 4 and 5 lags in the VAR model.

Conclusion

Test results provide substantial evidence for cointegration between inter-regional tanker freight rates and the respective inter-crude forward spreads. This evidence lends support to the intuitive long-term relationship implied between these variables. Although the first indications are positive in the case of cross-Atlantic freight rates and WTI-Brent spreads, further research is required to establish whether such long-term relationships hold between more tanker routes and more forward spreads between crude oils and oil products from different regions. Such research may be hampered by the lack of low-cost, consistent, frequent and readily available information on tanker freight rates on a wide range of trade routes.

Despite these problems, however, such research would have very practical benefits both for shipowners and for charterers, who wish to manage their freight risk. It would also be beneficial to financial intermediaries providing freight swaps, who can thus have a way of diversifying away residual risk from any mismatched swap positions, much like providers of oil swaps can do very efficiently.

References

Bessler, D.A., and Covey, T. (1991): "Cointegration: Some results on U.S. cattle prices", *The Journal of Futures Markets*, 11(4):461-474.

Bopp, A.E., and Sitzer, S. (1987): "Are petroleum futures prices good predictors of cash value?", *The Journal of Futures Markets*, 7(6):705-719.

Chowdhury, A.R. (1991): "Futures market efficiency: Evidence from cointegration tests", *The Journal of Futures Markets*, 11(5):577-589.

Dickey, D.A., and Fuller, W.A. (1979): "Distribution of the estimators for autoregressive time series with a unit root", *Journal of the American Statistical Association*, 74:427-431.

Edwards, F.R., and Ma, C.W. (1992): *Futures & Options*, McGraw Hill (Series in Finance).

Engle, R.F., and Granger, C.W.J. (1987): "Co-integration and error correction: Representation, estimation, and testing", *Econometrica*, 55(2):251-276.

Fuller, W.A. (1976): *Introduction to Statistical Time Series*, New York: John Wiley.

Garbade, K., and Silber, W. (1983): "Price movements and price discovery in futures and cash markets", *Review of Economics and Statistics*, 289-297.

Garcia, P., Leuthold, R.M., Fortenbery, T.R., and Sarassoro, G.F. (1988): "Pricing efficiency in the live cattle futures market: Further interpretation and measurement", *American Journal of Agricultural Economics*, 70:162-169.

Ghosh, A. (1993): "Cointegration and error correction models: Intertemporal Causality between index and futures prices", *The Journal of Futures Markets*, 13(2):193-198.

Goss, B. (1983): "The semi-strong form efficiency of the London Metal Exchange", *Applied Economics*, 15:681-698.

Goss, B. (1988): "A semi-strong test of the efficiency of the aluminium and copper markets at the LME", *The Journal of Futures Markets*, 8:67-77.

Granger, C.W.J. (1981): "Some properties of time series data and their use in econometric model specification", *Journal of Econometrics*, 16:121-130.

Gupta, S., and Mayer, T. (1981): "A test of the efficiency of futures markets in commodities", *Weltwirtschafltiches Archiv*, 117:661-671.

Hakkio, C.S., and Rush, M. (1989): "Market efficiency and cointegration: An application to the Sterling and Deutschemark exchange markets", *Journal of International Money and Finance*, 8:75-88.

Hamilton, J.D. (1994): *Time Series Analysis*, Princeton University Press.

Hansen, B.E. (1990): "A powerful, simple test for cointegration using Cochrane-Orcutt", University of Rochester, Mimeo.

Johansen, S. (1988): "Statistical analysis of cointegration vectors", *Journal of Economic Dynamics and Control*, 12:231-254.

Johansen, S. (1991): "Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models", *Econometrica*, 59:1551-1580.

Johansen, S., and Juselius, K. (1990): "Maximum likelihood estimation and inference on cointegration – with reference to the demand for money", *Oxford Bulletin of Economics and Statistics*, 52:169-210.

Leuthold, R.M., and Hartman, P.A. (1979): "A semi-strong form evaluation of the efficiency of the hog futures markets", *American Journal of Agricultural Economics*, 61:482-489.

MacKinnon, J.G. (1991): "Critical values for cointegration tests", in *Modelling Long-Run Economic Relationships*, Engle, R.F., and Granger, C.W.J. (eds.), Oxford University Press.

Mills, T.C. (1990): *Time Series Techniques for Economists*, Cambridge University Press.

Mills, T.C. (1993): *The Econometric Modelling of Financial Time Series*, Cambridge University Press.

Park, J.Y., Ouliaris, S., and Choi, B. (1988): "Spurious regressions and tests for cointegration", Cornell University, Mimeo.

Pesaran, M.H., and Pesaran, B. (1991): *Microfit 3.0: An Interactive Econometric Software Package*, Oxford University Press.

Phillips P.C.B., and Ouliaris, S. (1990): "Asymptotic properties for of residual based tests for cointegration", *Econometrica*, 58:165-193.

Shen, C.H., and Wang, L.R. (1990): "Examining the validity of a test of futures market efficiency: A comment", *The Journal of Futures Markets*, 10:195-196.

Stock, J.H. (1990): "A class of tests for integration and cointegration", Harvard University, Mimeo.

Wang, G.H.K, and Yau, J. (1994): "A time series approach to testing for market linkage: Unit root and cointegration tests", *The Journal of Futures Markets*, 14(4):457-474.