Testing Index Futures Market Efficiency Using Price Differences: A Critical Analysis

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INTRODUCTION

In a recent issue of this journal, Saunders and Mahajan (1988) (hereafter SM) suggest an alternative approach for analyzing pricing efficiency of stock index futures contracts that is based not on the levels of cash and futures prices, but on their first differences. The approach is *a priori* attractive since it does not price futures contracts as forward contracts and hence obviates the need to explicitly assume deterministic interest rates or dividend payouts beyond the next period. On the basis of their empirical results, SM conclude that they cannot reject the hypothesis that index futures pricing is "efficient." This conclusion is in apparent contrast with the evidence on substantial forward pricing formula "mispricing" and the simulated profitability of arbitrage-related trading rules reported *inter alia* by Merrick (1988, 1989), Mackinlay and Ramaswamy (1988), and Yadav and Pope (1990).

This article examines the tests proposed by SM in greater detail. First, it is clarified that the failure to reject "efficiency" using the SM tests does not necessarily preclude the existence of arbitrage profits from hold to expiration or other trading rules. Second, the validity of the SM slope test is questioned, given that in the absence of perfectly elastic arbitrage the futures contract exhibits at least some mispricing relative to the cash index. Finally, it is shown that the SM intercept test is misspecified and that its power is so low that under normal circumstances it almost never rejects efficiency. The arguments are illustrated with evidence based on data relating to the UK FTSE100 stock index futures contract traded on the London International Financial Futures Exchange (LIFFE).

The financial support of the Centre for the Study of Futures Markets, Graduate School of Business, University of Columbia, is gratefully acknowledged. The helpful comments of the two anonymous referees are also acknowledged. Any remaining errors are, of course, the authors' responsibility.

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The Journal of Futures Markets, Vol. 11, No. 2, 239–252 (1991)

CCC 0270-7314/91/020239-14$04.00

THE SM TESTS—BASIC FEATURES

SM show that under their stated assumptions it is reasonable to write

$$E(R_t^F)\left[\prod_{w=t}^{T} e^{-E(r_{w,w+1})}\right] = E(R_t^I) \tag{1}$$

In the above equation, $r_{w,w+1}$ is the one-period risk-free rate at time w; T is the value of the time parameter at futures maturity; and R_t^F and R_t^I are the period t futures "return" and cash return respectively, defined in terms of the t period futures price $F_{t,T}$, the t period cash index price I_t, and the t period dividend d_t as[1]:

$$E(R_t^F) = \frac{\{E(F_{t,T}) - F_{t-1,T}\}}{I_{t-1}}$$

$$E(R_t^I) = \frac{\{E(I_t) - I_{t-1} + d_t\}}{I_{t-1}}$$

SM convert the *ex ante* eq. (1) into *ex post* form by assuming that (i) actual realized values can be taken as surrogates for expected values and (ii) the best proxy for the product of expected one period interest rates can be taken to be the interest rate observed at t for an instrument maturing at T.

SM suggest that if pricing mechanisms are efficient, the following regression eq. (2) should have OLS estimated coefficients of $a = 0$ and $b = 1$.

$$R_t^F e^{-r_{t,T}(T-t)} = a + bR_t^I + u_t \tag{2}$$

where

$$E(u_t) = 0$$

and

$$\mathrm{Cov}(R_t^I, u_t) = 0$$

It is important to highlight the following observations made by SM in regard to eq. (2):

(i) SM state that "... the prevalence of a significant intercept parameter would support the hypothesis that the arbitrage relationship was systematically violated" (SM, p. 214). They actually find that the null hypothesis $a = 0$ is "... unambiguously accepted ... " and infer that "... no systematic excess returns are possible by maintaining a position in any index futures contract implying that the market is in equilibrium and pricing efficiently" (SM, p. 220).

(ii) SM also state that "... finding that the slope parameter was significantly different from one would support the hypothesis that the arbitrage relationship was consistently violated unsystematically for short periods of time" (SM, p. 214). They find that the null hypothesis $b = 1$ is rejected for the early contracts and not rejected for the later contracts and conclude that "... systematic and significant arbitrage opportunities have disappeared ... " (SM p. 226).

It should be noted also that:

(i) SM explicitly recognize that "the *ex post* empirical counterpart to .... (their) .... normative equilibrium equation (1) .... is identical to that derivable

[1]The reason for dividing by I_{t-1} is to avoid potential problems related to heteroskedascity.

under the assumptions that forward prices are not different from futures prices and that future dividends are certain . . . . " (SM, p. 213).

(ii) Regression eq. (2) requires SM to assume that cash returns are independent of the error term. They do not consider the alternative possibility of a reverse regression of (time adjusted) cash returns on futures returns (also consistent with eq. (1)) which requires the assumption that futures returns are independent of the error term.

(iii) The normative equilibrium eq. (1) ignores the one day interest r_o. If this is included (but time variation in this factor is ignored), then eq. (1) can be written as:

$$E(R_t^F)\left[\prod_{w=t}^{T} e^{-E(r_{w,w+1})}\right] = E(R_t^I) - r_o$$

THE SM TESTS—A CRITIQUE

SM "Efficiency" and Profitability of Trading Rules

The claim made by SM is that their results support the "efficiency" of the index futures market and hence conflict with previous studies (SM, p. 211). However, it is important to realize that failure to reject "efficiency" as implicitly defined by SM does not necessarily preclude the existence of riskless arbitrage profits from hold to expiration or other trading rules.

First, it is relevant to highlight the difference between the implicit definition of the term "efficiency" used by SM and that used by earlier studies on index futures markets.[2] Studies on index futures markets based on the levels of futures prices (like Merrick (1988, 1989), Mackinlay and Ramaswamy (1988), Yadav and Pope (1990)) attempt to identify opportunities for riskless excess returns using trading rules which exploit the known change in cash futures basis between the day of the trade and the expiration day. The relevant measure of efficiency in these studies is implicitly or explicitly the number of cases in which the deviation of actual prices from non-arbitrageable prices exceeds transactions cost-based thresholds. These studies adopted a perspective which is consistent with, or at least subsumes, Jensen's (1978) trading rule orientation to testing efficiency. On the other hand, transactions costs are not directly relevant in the SM notion of efficiency. The SM tests imply a definition of efficiency equivalent to the unbiased realization, on average, of expectations of changes in futures prices, conditional upon changes in cash prices (where expectations are based on infinitely elastic arbitrage). In that sense, it is comparable with the formulation of Fama (1970, 1976), and not to Jensen's trading rule approach to testing efficiency.

Second, what is relevant from the SM viewpoint is whether the OLS regression of eq. (2) indicates bias. Inferences based only on the regression line can obviously mask significant features of the data—in particular the systematic patterns in mispricing returns (i.e., the regression residuals). For example, Merrick (1988) (for U.S. data) and Yadav and Pope (1990) (for U.K. data) report that the returns on one-day hedges are significant and positive (negative) if such hedges are established when mispricing is initially positive (negative) even though the average returns on one-day hedges are zero. However, the only information which the SM regression line

[2]For an excellent review of the different conceptual definitions of market efficiency, see Ball (1989).

can provide in this context is on the *average* returns on one-day hedges. The SM tests thus appear capable of overlooking systematic and potentially exploitable mispricing (inefficiency) because of their focus on the overall regression line rather than on individual observations.

Finally, it should be realized also that inferences from the SM tests are based only on changes in cash and futures prices and not on the levels of these prices. These inferences are not affected if all the prices used in the computations display the same bias, however large. Such a scenario is conceivable if expiration day observations are not included in the data.[3] Under such circumstances the SM tests would not be capable of providing information about levels of mispricing and the implied profitability of arbitrage-related trading rules.

Validity of the SM Tests

The validity of the SM tests is questioned here, given that in the absence of perfectly elastic arbitrage, futures prices, in general, exhibit some mispricing.

Let $F_{t,T}^*$, $F_{t-1,T}^*$ be theoretical futures prices in the SM framework, i.e., prices generated when the expectations contained in eq. (1) are exactly realized in every period. This is feasible if intermarket arbitrage is perfectly elastic so that deviations from equilibrium due to noise are continually and instantaneously arbitraged away.[4] Let $W_{t,T}, W_{t-1,T}$ be the corresponding futures "mispricing," i.e., $(F_{t,T} - F_{t,T}^*)$, $(F_{t-1,T} - F_{t-1,T}^*)$. Then following Merrick (1988) the scaled change in futures mispricing or mispricing "return" R_t^X can be written as:

$$\begin{aligned} R_t^X &= \frac{W_{t,T} - W_{t-1,T}}{I_{t-1}} \\ &= \frac{F_{t,T} - F_{t,T}^*}{I_{t-1}} - \frac{F_{t-1,T} - F_{t-1,T}^*}{I_{t-1}} \\ &= \frac{F_{t,T} - F_{t-1,T}}{I_{t-1}} - \frac{F_{t,T}^* - F_{t-1,T}^*}{I_{t-1}} \\ &= R_t^F - R_t^{F*} \end{aligned}$$

where R_t^{F*} is the "theoretical" futures return given by:

$$R_t^{F*} e^{-r_{t,T}(T-t)} = R_t^I - r_o$$

Hence[5]

$$(R_t^F e^{-r_{t,T}(T-t)} - R_t^I) = R_t^X e^{-r_{t,T}(T-t)} - r_o \tag{3}$$

[3]In any case, expiration day observations are usually not included in studies of pricing efficiency in view of expiration day distortions documented *inter alia* by Stoll and Whaley (1987). Furthermore, it is sometimes difficult to include expiration day/time observations as, e.g., in the U.K. where futures contracts mature at *11:20 am*.

[4]Since daily cash and futures return in an SM framework are interrelated in exactly the same way as they would be if the forward pricing formula was valid, and since cash and futures prices are necessarily identical on expiration day, $F_{t,T}^*$ and $F_{t-1,T}^*$ would also be the forward pricing formula futures prices.

[5]An investor, e.g., a market maker, wanting to hedge a predetermined long (short) cash market position over one period, would on the basis of infinitely elastic arbitrage and perfect knowledge of future absolute dividend inflows, construct a one-period hedge portfolio by selling (buying) $\exp\{-r_{t,T}(T-t)\}$ futures contracts for every unit of the cash index held. The mispricing return thus has a direct economic interpretation in terms of the abnormal return earned on such a one day hedge portfolio.

In the presence of stochastic changes in futures mispricing, the estimated values of the OLS coefficients in the SM regression (2) are:

$$\hat{b} = 1 + b_{xc} \tag{4a}$$

$$\hat{a} = \text{Mean}\,(R_t^X e^{-r_{t,T}(T-t)}) - b_{xc}\,\text{Mean}\,(R_t^I) - r_0 \tag{4b}$$

where

$$b_{xc} = \frac{\text{Cov}(R_t^X e^{-r_{t,T}(T-t)}, R_t^I)}{\text{Var}\,(R_t^I)} \tag{4c}$$

i.e., b_{xc} is the OLS estimate of the slope of the regression line of (time adjusted) mispricing returns on cash returns.

The SM Slope Test. The existence of mispriced futures has several important implications for the SM slope test.

First, an OLS regression of eq. (2) estimates $\hat{a}$ and $\hat{b}$ so as to minimize the variance of $\{R_t^F e^{-r_{t,T}(T-t)} - \hat{a} - \hat{b}R_t^I\}$. In other words, a risk minimizing hedge is being constructed for an investor who is buying *spot* to hedge a fixed quantity commitment in the *futures* market. In this context, most of the issues raised by Merrick (1988) are valid, *mutatis mutandis*. In particular, the estimated slope $\hat{b}$ has two components. The first is the equilibrium component arising from eq. (1). The second is an adjustment factor equal to the slope between the changes in futures mispricing and the contemporaneous change in cash index prices. This adjustment factor is zero only when period t cash returns are uncorrelated with period t changes in mispricing.

Neither the forward pricing formula nor the theory underlying the SM tests can tell anything about the size and sign of this slope adjustment factor. Guidance, in this respect, can only come from a *dynamic* model which specifically incorporates inelastic intermarket arbitrage, such as the model of Garbade and Silber (1983). More generally, if futures prices and cash equivalent futures prices are modeled in an error correction model framework with a co-integrating parameter of unity,[6] the scaled mispricing variable X_t follows an autoregressive process of the form[7]:

$$X_t = \alpha + \sum_{k=1}^{p} \psi_k X_{t-k} + e_t \tag{5}$$

where

$$X_t = W_{t,T}/I_t$$
$$|\psi_1| < |$$
$$p \geq 1$$

This implies that mispricing tends to regress toward its equilibrium value of zero and is consistent with the evidence of mispricing reversals documented by Merrick (1988) and Yadav and Pope (1990). Mispricing reversals (or arbitrage related restoration of equilibrium) means that long futures/short cash hedges begun with overpriced (underpriced) futures can be predicted *ex ante* to earn less (more) than the riskless return. In other words, conditional upon information about mispricing in period $(t-1)$, the *ex ante expected* (time-adjusted) futures return in period t will be equal not just to the cash index return in period t (as provided in eq. (1)) but will include a component reflecting the correction of mispricing in period $(t-1)$ and,

[6]See Engle and Granger (1987) for details of models with cointegrated variables.
[7]The Garbade and Silber (1983) model is a special case of such an error correcting model.

possibly, earlier periods. Hence, if efficiency is considered relative to a pricing model which incorporates inelastic intermarket arbitrage, the slope adjustment factor b_{xc} in eq. (4a), (4b), and (4c) need not necessarily be equal to zero. In particular, it depends on whether *on average* as mispricing changes from period to period in accordance with eq. (5), cash prices move further toward futures prices than futures prices move toward cash prices; i.e., it depends specifically on the relative roles of the cash market and the futures markets in price discovery. As such, with mispriced futures, the hypothesis $b = 1$ does not necessarily reflect an unbiased realization of expectations and is hence not necessarily a valid null hypothesis.

Secondly, it is also relevant to observe that:

$$\hat{b} = \rho_{fc}\frac{\sigma_f}{\sigma_c} \tag{6}$$

where ρ_{fc} is the correlation between (time adjusted) futures returns and cash returns; and σ_f and σ_c are the respective futures and cash standard deviations.

If the arbitrage link is perfect, the futures contract is a perfect substitute for the cash index, mispricing is identically zero, and hence

$$\rho_{fc} = 1,\ \sigma_f = \sigma_c, \text{ and } b = 1$$

With mispriced futures $0 < \rho_{fc} < 1$ and $\hat{b}$ can be equal to unity (as hypothesized by SM) only if $\sigma_f > \sigma_c$, i.e., only if the perfect equivalence of cash and futures markets (or the perfect arbitrage link) is destroyed by futures prices systematically overshooting cash equivalent prices.

There is evidence to show that futures prices exhibit greater volatility than cash prices (see e.g., Yadav and Pope (1990) and Mackinlay and Ramaswamy (1988)). Hence, the SM "acceptance" of the null hypothesis $\hat{b} = 1$ is consistent with this excess volatility of futures relative to cash, and instead of indicating efficiency, supports, on the contrary, the rejection of the hypothesis of a perfect arbitrage link.

Finally, it is also important to note that in moving from eq. (1) to eq. (2), SM assume that cash returns are independent of the error term and that the error term is not autocorrelated. In frictionless markets, the error term in eq. (2) should represent the effect of randomly arriving new information, which though incorporated (instantaneously) into cash prices, is not yet reflected in futures prices, since futures prices are still "catching up." In other words, eq. (2) is based on price discovery taking place entirely in the cash market. In fact, it is often argued that because of lower transaction costs, mature futures markets tend to play the more active role in price discovery (Hill, Jain, and Wood, 1988). Merrick (1987) reports evidence consistent with this argument. This alternative possibility of futures returns being independent of the error term is also equally consistent with eq. (1) and implies a reverse regression of the form

$$R_t^I = a^1 + b^1 R_t^F e^{-r_{t,T}(T-t)} + u_t^1 \tag{7}$$

The OLS estimates of b^1 are:

$$\hat{b}^1 = \rho_{fc}\frac{\sigma_c}{\sigma_f} \tag{8}$$

Thus if $\hat{b} = 1$ (the SM null hypothesis) and $\rho_{fc} \neq 1$, then $\hat{b}^1$ will *definitely* be less than unity. With mispriced futures one of $\hat{b}$ or $\hat{b}^1$ will *always* be different from unity. By itself, $\hat{b}$ does not provide a meaningful picture of the extent of integration between the markets. Information on $\hat{b}^1$ (or equivalently, the R^2 of the regression based on eq. (2) or ρ_{fc}) is required also.

To summarize, with mispriced futures, SM eq. (1) does not necessarily reflect an unbiased realization of expectations. Furthermore, even starting from SM eq. (1), it is not possible to cogently argue for either $\hat{b}$ or $\hat{b}^1$ to be *the* measure to assess "efficiency" unless it is assumed that one market is completely irrelevant from the viewpoint of price discovery. Not only that, at least one of $\hat{b}$ or $\hat{b}^1$ is always different from unity. As such, the SM slope test (or its variant based on the reverse regression eq. (7)) cannot result in a clear statement about "efficiency."

The SM Intercept Test. The SM null hypothesis $\hat{a} = 0$ is rejected at the $\alpha\%$ level when

$$\left|\frac{\hat{a}}{SE(\hat{a})}\right| > t_{\alpha} \tag{9}$$

If n observations are used in the SM regression (2), then since $[\text{Mean}(R_t^I)]^2 \ll \text{Var}(R_t^I)$ it follows that

$$SE(\hat{a}) = \frac{\sigma_u}{\sqrt{n}}$$

where σ_u is the standard error of regression (2).
Condition (9) can hence be rewritten as

$$\frac{\sqrt{n}}{\sigma_u t_\alpha}\left|\text{Mean}\,(R_t^X e^{-r_{t,T}(T-t)}) - b_{xc}\,\text{Mean}(R_t^I) - r_o\right| > 1$$

which implies that

$$\left|\frac{\sqrt{n}}{\sigma_u t_\alpha}\text{Mean}(R_t^X e^{-r_{t,T}(T-t)})\right| + \left|\frac{\sqrt{n}}{\sigma_u t_\alpha} b_{xc}\,\text{Mean}(R_t^I)\right| + \left|\frac{\sqrt{n}\, r_o}{\sigma_u t_\alpha}\right| > 1 \tag{10}$$

Note that under the null hypothesis σ_u can be approximated by the standard deviation of forward pricing formula mispricing returns.[8] Yadav and Pope (1990), using four years of daily U.K. data, estimate this standard deviation to be about 0.5%. The estimate made by Hill, Jain, and Wood (1988) using three years of daily U.S. data is very similar.

Under the SM null hypothesis, b_{xc} should be zero. In any case, it is likely to be small enough to make the second term in eq. (10) much smaller than the third term. With daily data, r_o, the one-period interest, also will be less than 0.05%. Hence, with daily data, and at the 5% significance level, the second and third terms are important in relation to unity only when $n \geq 400$.

If there are no missing values in the time series of cash and futures returns, with n observations the first term in eq. (10) will be approximately[9]

$$\frac{|X_n - X_1|}{\sigma_u t_\alpha/\sqrt{n}}$$

[8]It will actually be slightly less depending on the extent to which b_{xc} is different from zero.

[9]In the general case (i.e., with possible missing values), the results of Yadav and Pope (1990) show that with the strong tendency for mispricing reversals, the mean of mispricing returns has been much smaller than the one-day interest rate in the U.K. Though not specifically reported, the results of Merrick (1988) point to a similar conclusion for daily U.S. data.

With daily data and transaction costs of about 1% to 2%, this can be important in relation to unity only when $n \leq 20$.

Thus, considering the "normal" levels of transaction costs in the U.S. and the U.K. markets, and the implied "normal" variation in mispricing, the SM intercept test using daily data could reject the null hypothesis only when the number of observations used is below about 20 or exceeds about 400. With the use of about three to 12 months of daily data, it is unlikely to ever reject "efficiency."

It should be noted also that ignoring the one-day interest factor (as SM have done) results in a serious misspecification of the SM null hypothesis relating to the intercept since, with reasonably large sample sizes and reasonably SM "efficient" markets, the third term rapidly becomes the dominant term in eq. (10). For example, if one considers three months' daily data, interest rates of about 10% and highly SM "efficient" markets (i.e., $b_{xc} = 0$ and mispricing returns averaging zero), then the null hypothesis will be rejected incorrectly whenever the transaction costs are low enough to make the standard deviation of mispricing returns below about 0.1%.

Eq. (4b) also shows that, with mispriced futures, the value of the OLS intercept depends on the *ex post* cash index returns. Thus, even if the markets are "efficient" enough to result in zero average mispricing returns, the *ex ante* expected value of the intercept depends on the expected market returns. The null hypothesis is to that extent misspecified, though b_{xc} is likely to be small enough to make the effect of this factor much smaller than the effect of ignoring the one-day interest factor.

To summarize, with mispriced futures the SM intercept test is misspecified to the extent that the "null" value of the intercept depends on average market returns and, more importantly, on the average one-day interest factor. Futhermore, the power of the test is so low that under normal circumstances it almost never rejects "efficiency."

EMPIRICAL RESULTS

This section illustrates the arguments of the previous section with empirical evidence based on the FTSE100 index futures contract traded on the London International Financial Futures Exchange (LIFFE). The empirical analysis includes 1012 trading days over 16 different contracts spanning the period July 1, 1984 to June 30, 1988. The first 9 contracts expiring up to September 1986 constitute evidence for the pre-Big Bang (i.e., pre-market deregulation)[10] period, while the last 7 contracts constitute evidence for the deregulated post-Big Bang period. The analysis is based on the near contract, shifting to the next contract on expiration day.

"Time and Sales" data on FTSE100 index futures is from LIFFE. The data includes all bid and ask quotes and all transaction prices relating to the FTSE100 index futures contract over the period of study. The data is used to infer the mid-market quotes valid at 10:00 am, 11:00 am, 12:00 noon, 1:00 pm, 2:00 pm, 3:00 pm, 3:30 pm, and 4:00 pm[11] each day. Data on the FTSE100 index are from the International Stock Exchange (formerly the London Stock Exchange). This includes opening, 3:30 pm, and closing values of the index over the entire period of study. Hourly data on the FTSE100 index are from the *Financial Times.* This data is available only from February 18, 1986, onward, and hence the aggregated results of analyzing hourly data are reported only for contracts expiring after the Big Bang. Information

[10]Market deregulation took place from October 27, 1986.

[11]Prior to April 28, 1986, LIFFE index futures traded only up to 3:30 pm each day. Thus, 4:00 pm values are used only after April 28, 1986.

on the constituents of the index, and how these constituents changed over the sample period, are from the International Stock Exchange. The daily dividend entitlement on the FTSE100 index is calculated as in Yadav and Pope (1990). Daily series for one- and three-month Treasury Bill rates are from *Datastream,* and used to infer a linear term structure over the relevant period.

The results of regressions based on eq. (2) or eq. (7) are likely to be dependent on the time period over which first differences in cash and futures prices are measured. Table I is based on weekly intervals (coincident 3:30 pm prices Thursday to Thursday), Table II on daily intervals (coincident 3:30 pm prices each day), and Table III on hourly intervals (using coincident prices at 10:00 am, 11:00 am, 12:00 noon, 1:00 pm, 2:00 pm, 3:00 pm, and 4:00 pm each day).[12] However, all computations for weekly and daily price intervals are repeated with coincident prices at 10:00 am, 11:00 am, 12:00 noon, 1:00 pm, 2:00 pm, 3:00 pm, and 4:00 pm[13] and all computations for weekly intervals are repeated with different days of the week. The results of these computations are qualitatively identical to the results reported.

In all cases of daily intervals, Friday to Monday, and other holiday gapped returns are not used in the regressions. In all cases of weekly intervals, returns over weeks which included holidays are not used. For hourly price differences, 4:00 pm to 10:00 am returns are not used.[14]

In almost all cases, OLS regressions reveal that the residuals are autocorrelated and that the residuals could be best modeled as AR(1) processes. Hence, the regression results reported are based on GLS estimation, with the assumption that residuals are an AR(1) process. The actual computation uses the Beach and Mackinnon (1978) maximum likelihood procedure to estimate coefficients and standard errors. In *all* cases, the autocorrelation of the transformed residuals is insignificantly low, and the Durbin Watson Statistic for the transformed residuals is within satisfactory limits.

The essential features of the results reported in Table I (weekly data), Table II (daily data), and Table III (hourly data) are:

1. Neither the hypothesis $a = 0$ nor the hypothesis $a^1 = 0$ can be rejected at the 5% level.[15]
2. For weekly and daily data: (a) in the pre-Big Bang period, the hypothesis $b = 1$ is conclusively rejected but the hypothesis $b^1 = 1$ cannot be rejected[16]; and (b) in the post-Big Bang period, the hypothesis $b = 1$ cannot be rejected, but the hypothesis $b^1 = 1$ is conclusively rejected.[17]
3. With hourly data, both the hypotheses $b = 1$ and $b^1 = 1$ are conclusively rejected.[18] Both b and b^1 are significantly below unity, but this arises because of the

[12]Four o'clock pm values not used before April 28, 1986.

[13]LIFFE index futures open at 9:05 am and close at 4:05 pm (3:30 pm before April 28, 1986). Cash index values are available, at best hourly. Results based on closing and opening prices are not reported in view of this misalignment.

[14]Three o'clock pm to 10:00 am returns are not used before April 28, 1986.

[15]Both a and a^1 are insignificant for both subperiods with weekly data, for 15 out of 16 contracts with daily data and for all contracts with hourly data.

[16]b is significantly below unity (at 5% level) for weekly data and for 8 of 9 contracts with daily data. On the other hand, b^1 is neither significantly different from unity with weekly data, nor for any of the 9 contracts using daily data.

[17]b is neither significantly different from unity (at 5% level) for weekly data nor for 5 of 7 contracts using daily data. On the other hand, b^1 is significantly different from unity at 5% level for weekly data, and for 6 of 7 contracts with daily data.

[18]b is significantly below unity for 6 of 7 contracts and b^1 is significantly below unit for each of the 7 contracts.

Table I
WEEKLY DATA

Contracts Expiring	$a \times 10^3$	t-stat $H_o: a = 0$	b	t-stat $H_o: b = 1$	$a^1 \times 10^3$	t-stat $H_o: a^1 = 0$	b^1	t-stat $H_o: b^1 = 1$
Pre-Big Bang	−0.69	−1.41	0.915	−3.37*	0.96	1.92	1.023	0.92
Post-Big Bang	−0.16	−0.16	1.010	0.19	0.87	1.00	0.877	−2.85*

*Significant at the 1% level.

Table II
DAILY DATA

Contracts Expiring	$a \times 10^3$	t-stat $H_o: a = 0$	b	t-stat $H_o: b = 1$	$a^1 \times 10^3$	t-stat $H_o: a^1 = 0$	b^1	t-stat $H_o: b^1 = 1$
September '84	0.73	1.28	0.921	−1.26	−0.06	−0.09	0.926	−1.16
December '84	0.44	1.23	0.819	−3.54*	−0.49	−1.26	1.057	0.87
March '85	0.47	1.35	0.913	−2.03*	−0.31	−0.82	0.991	−0.19
June '85	0.17	0.55	0.871	−2.65*	−0.41	−1.13	0.974	−0.46
September '85	−0.02	−0.08	0.840	−2.78*	0.14	0.35	0.967	−0.50
December '85	1.02	4.24*	0.840	−3.36*	−0.77	−2.47†	1.020	0.33
March '86	0.81	1.72	0.855	−2.53†	−0.27	−0.54	0.979	−0.32
June '86	0.08	0.14	0.884	−2.01†	−0.11	−0.18	0.942	−0.94
September '86	−0.44	−1.02	0.888	−2.38†	0.29	0.64	0.993	−0.14
December '86	0.08	0.23	0.949	−0.74	0.01	0.05	0.855	−2.35*
March '87	0.23	0.61	0.853	−2.88*	0.35	0.96	0.988	−0.22
June '87	0.21	0.33	0.984	−0.28	0.15	0.26	0.886	−2.24†
September '87	−0.02	−0.05	1.043	0.93	0.07	0.17	0.886	−2.92*
December '87	−0.00	−0.01	1.024	0.66	−0.04	0.07	0.927	−2.25†
March '88	−0.17	−0.46	1.093	1.93	0.28	0.78	0.822	−4.80*
June '88	−0.26	−0.61	1.147	2.31†	0.42	1.20	0.785	−4.93*
Pre-Big Bang	0.33	2.57†	0.890	−6.43*	−0.21	−1.56	0.974	−1.39
Post-Big Bang	−0.04	−0.27	1.014	0.80	0.18	1.18	0.904	−6.23*

*Significant at the 1% level.
†Significant at the 5% level.

Table III
HOURLY DATA

Contracts Expiring	$a \times 10^3$	t-stat $H_o: a = 0$	b	t-stat $H_o: b = 1$	$a^1 \times 10^3$	t-stat $H_o: a^1 = 0$	b^1	t-stat $H_o: b^1 = 1$
March '86	0.23	1.35	0.782	−2.48*	0.00	0.02	0.449	−10.11*
June '86	0.03	0.27	0.710	−5.26*	−0.18	−1.58	0.393	−17.26*
September '86	0.08	0.66	0.580	−7.42*	−0.15	−1.28	0.362	−16.22*
December '86	−0.00	−0.02	0.822	−3.32*	0.04	0.69	0.479	−16.13*
March '87	−0.03	−0.41	0.881	−3.46*	−0.07	0.98	0.705	−10.24*
June '87	−0.07	−0.90	0.784	−5.61*	0.05	0.64	0.668	−9.72*
September '87	−0.16	−2.02	0.929	−2.12†	0.06	0.80	0.723	−10.02*
December '87	0.00	0.00	0.832	−3.42*	−0.09	−0.34	0.544	−14.25*
March '88	−0.06	−0.64	1.131	3.13*	−0.01	−0.11	0.596	−18.06*
June '88	−0.05	−0.71	1.020	0.53	0.00	0.08	0.675	−12.63*
Post-Big Bang	−0.06	−1.05	0.864	−7.82*	−0.01	0.25	0.580	−35.75*

*Significant at the 1% level.
†Significant at the 5% level.

relatively lower overall correlation between cash returns and (time-adjusted) futures returns.[19] Futhermore, for every contract, the implied correlation between futures returns and mispricing returns is consistently greater in magnitude than the implied correlation between cash returns and mispricing returns. Futures returns are significantly more volatile than cash returns, but because of the lower correlation between them, b remains below unity.

The above results clearly illustrate the arguments of the previous section. The hypothesis $a = 0$ is almost never rejected. And whenever the hypothesis $b = 1$ is not rejected, the hypothesis $b^1 = 1$ is conclusively rejected. As pointed out in the previous section, whenever $b = 1$ the volatility of futures returns is greater than that of cash returns, contrary to the hypothesis of a perfect arbitrage link between the two markets. Note that even for U.S. markets, over the period that SM are unable to reject the hypothesis $b = 1$, Merrick (1988) reports significantly high correlation between mispricing returns and futures returns. This implies that over SM's sample period b^1 is significantly less than unity.

CONCLUSIONS

This study examines the nature and validity of the tests for pricing efficiency proposed by Saunders and Mahajan (1988). First, it points out that the failure to reject "efficiency" using the SM tests does not necessarily preclude the existence of arbitrage profits from hold to expiration or other trading rules. Second, it questions the validity of the SM slope test, given that in the absence of perfectly elastic arbitrage the futures contract will, in general, exhibit at least some mispricing relative to the cash index. Third, it argues that the SM intercept test is seriously misspecified. Finally, it shows that the power of the SM intercept test is so low that under normal circumstances it almost never rejects "efficiency." The arguments presented in this article are illustrated with empirical results from the London markets.

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[19]The overall correlation drops from above 0.9 with weekly/daily returns to about 0.7 with hourly returns.

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