Tests of Random Walk of Hedge Ratios and Measures of Hedging Effectiveness for Stock Indexes and Foreign Currencies

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INTRODUCTION

Hedging theory in futures markets is developed in Working (1953, 1962), Johnson (1960), Stein (1961), and more recently, Rutledge (1972), Ederington (1979), and Franckle (1980). According to the portfolio theory approach to hedging, the hedge ratio and the measure of hedging effectiveness correspond to the regression coefficient, B, and the coefficient of determination, R^2, obtained from regressing the spot price changes on futures price changes. The coefficients B and R^2 are extensively examined.[1] However, previous studies of hedging performance of futures markets are subject to criticism because they are based on the assumption that the regression coefficient, which corresponds to the hedge ratio, is stable over the whole sample period. Indeed, Grammatikos and Saunders (1983), find that the hedge ratios for five major foreign currency futures are unstable over time. This article further explores the nonstationarity of the hedge ratio and the measure of the hedging effectiveness.

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[1]Hedge ratios and measures of hedging effectiveness are estimated for GNMA futures by Ederington (1979), Hill, Liro, and Schneeweis (1983); for foreign currency futures by Hill and Schneeweis (1982), Grammatikos and Saunders (1983) and Grammatikos (1986); for T-bond futures by Hill and Schneeweis (1984); for CD futures by Overdalh and Sterleaf (1986); for T-bill futures by Ederington (1979), Franckle (1980), and Howard and D'Antonio (1984); and for stock market index futures by Figlewski (1984, 1985), and Junkus and Lee (1985).

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The random walk hypothesis is tested with two models. One is based on the traditional methodology of Dickey and Fuller (1979, 1981) and the other follows the approach of Lo and MacKinlay (1988), known as the variance-ratio test. The empirical results confirm the random walk hypothesis for two stock index futures: Standard and Poor's 500 and New York Stock Exchange; and for four foreign currency futures: British Pound, German Mark, Japanese Yen, and Swiss Franc. The findings imply that hedgers cannot consistently place optimal hedges and that dynamic hedging techniques must be considered.

HYPOTHESIS OF RANDOM WALK

The main purpose of the article is to detect patterns in the instability of the coefficients B and R-squared, postulating that they vary randomly over time. Specifically, it is claimed that the hedge ratio and the measure of hedging effectiveness follow a random walk process.

The concept of a random walk is much more precise in financial analysis than the notion of instability. Authors such as Grammatikos and Saunders (1983) use the term "unstable hedge ratios" to mean that these ratios are not constant over time. In mathematical economic analysis the notion of instability is given a more precise meaning. Numerous definitions, theorems and applications of stability and instability are presented in Brock and Malliaris (1989). Intuitively, one can say that the sequence of hedge ratios $B_0, B_1, B_2, B_3, \ldots$ is unstable if the absolute deviations of these hedge ratios from the equilibrium hedge ratio become large after a certain time period. Clearly, it is difficult to test this notion of instability for at least two reasons: First, one needs a very long sequence and secondly, a precise meaning of "equilibrium hedge ratio" needs to be established.

Attention is devoted here to the nonconstant behavior of hedge ratios and coefficients of hedging effectiveness in terms of random walk, a notion familiar to financial analysts. Random walk may eventually lead to instability but that instability need not necessarily imply random walk. One reason for studying the random walk behavior is the methodological clarification it provides of the time series behavior of the hedge ratio and coefficient of hedging effectiveness.

There are additional reasons for interest in random walk. First, in an efficient market, changes of spot prices over time are random and reflect the arrival of new information. In other words, price changes on any particular day are uncorrelated with past historical price changes. Empirical research in futures markets suggests that futures price changes also follow a random walk, reflecting efficiency in futures markets as well.[2] The hedge ratio is the ratio of dollar amounts invested in a spot asset and a futures contract. It is reasonable to assume that the behavior of this ratio reflects the behavior of these prices. Therefore, given that prices follow a random walk process, one can also expect the hedge ratio to vary randomly over time.

Second, the random walk behavior of the hedge ratio may be explained by the theories of speculation and the effects of such speculation on price changes on both cash and futures markets. There are, in general, two theories about the effects of speculation on price variability. One theory claims that speculation increases price variability because speculators tend to buy as prices are rising and tend to sell as

[2]Empirical evidence of the random walk hypothesis for security prices is reported, among others, by Fama (1965), and Fama and Blume (1966); and, for futures markets by Fama (1976), Cornell (1977), and others.

prices are falling, generating a bandwagon effect which contributes to larger swings in price volatility. The opposing theory argues that speculation reduces price variability and has been defended by Milton Friedman (1953) who argues that only unprofitable speculation can have a destabilizing effect on prices. These theories are reviewed extensively by Tirole (1989). Simply put, this article assumes that the stability or instability of speculation, with similar or dissimilar intensity in cash and futures markets, may cause hedge ratios and coefficients of hedging effectiveness to follow random walks.

Third, the random walk behavior of the hedge ratio may be caused by differences in the microstructure of cash and futures markets. In this article, spot prices are determined in dealership markets with futures prices formulated in open outcry auction markets. There is an increasing literature that emphasizes the role of different trading mechanisms with special emphasis given to the role of "noise" and "feedback" traders on price formulation and the time series properties of such prices. A representative article in this literature is Cutler, Poterba, and Summers (1990). It seems reasonable to postulate that such differences in the microstructure of cash and futures markets and dissimilarities in trading mechanisms and types of traders may cause hedge ratios to vary over time.

DATA

The data correspond to weekly spot prices and futures prices for the nearby contracts (0–3 months) for the following instruments: (i) Stock Indexes: Standard and Poor's 500 Index, and New York Stock Exchange Index; (ii) Foreign Currencies: British Pound, German Mark, Japanese Yen, and Swiss Franc.

The time periods under study extend from March 4, 1980 through December 27, 1988 for the foreign currency instruments and, from January 1, 1984 through December 27, 1988 for the stock index instruments. The futures prices are Tuesday closing prices (Monday or Wednesday closing prices are used when a Tuesday closing price is missing) obtained from the Wall Street Journal.

METHODOLOGY AND EMPIRICAL RESULTS

First, hedge ratios and measures of hedging effectiveness are generated by means of a moving window regression procedure. Second, the hypothesis that the hedge ratio and the measure of hedging effectiveness follow a random walk process is tested by means of two models. The models are based on the Dickey and Fuller methodology and the variance-ratio approach of Lo and MacKinlay.

Moving Window Regression Procedure

Estimates of the hedge ratio and the measure of hedging effectiveness are obtained by running OLS regressions of the change of the spot price on the change of the corresponding futures price; that is:

$$S_t - S_{t-k} = A + B(F_t - F_{t-k}) + \epsilon_t \tag{1}$$

where:

S_t, S_{t-k} = spot prices at time t and $t - k$, respectively.
F_t, F_{t-k} = futures prices at time t and $t - k$, respectively.
k = the length of hedging horizon measured in weeks.

In Eq. (1), the regression coefficient, B, and the coefficient of determination, R^2, correspond to the hedge ratio and the measure of hedging effectiveness, respectively. Since the behavior of the hedge ratio, over time, is of interest, it is assumed that for each contract the hedging horizon, k, is two-weeks.[3] The regressions are run using changes in cash and futures prices.[4]

B's and R^2's are generated using an overlapping or moving window regression procedure[5] in two steps. First, the hedge ratios and measures of hedging effectiveness are initially estimated for a one-year period: March 1980–February 1981, for foreign currencies, and January 1984–December 1984 for stock indexes. They are, subsequently, reestimated every quarter by adding a new quarter of spot and futures data and deleting the initial quarter's data and keeping a one-year estimation period. In this way, by regressing the change of the spot price on the change of the futures price, (for a two-week hedging horizon) moving B's and R^2's are estimated for each quarter.[6]

RANDOM WALK TESTS

The data used in testing for random walk correspond to the hedge ratios and measures of hedging effectiveness obtained from the moving window regressions.

Dickey and Fuller Tests of Random Walk

To test for random walk using the Dickey and Fuller methodology the following regressions are run:

$$\begin{aligned} \text{Full: } Y_t &= b_0 + b_1 Y_{t-1} + b_2 T + \epsilon_t \\ \text{Reduced: } Y_t - Y_{t-1} &= b_2 T + \epsilon_t \end{aligned} \tag{2}$$

where:

Y_t, Y_{t-1} = hedge ratio or measure of hedging effectiveness.
T = time trend.
ϵ_t = residual term at time t.

The null hypothesis that the hedge ratio and the measure of hedging effectiveness follow random walks, corresponds to H_0: $(b_0, b_1) = (0, 1)$ and is tested with an F-test based on a distribution suggested by Dickey and Fuller (1981). The results, presented in Table I for the hedge ratios and in Table II for the measures of hedging effectiveness, show that one cannot reject the null hypothesis at the 1% or 5% levels of significance. That is, the results of the Dickey and Fuller tests presented in

[3]The two-week hedging horizon is the most commonly found assumption in the futures hedging literature. See, i.e., Grammatikos and Saunders (1983).

[4]Price changes are used, among others, by Ederington (1979), Franckle (1980), Dale (1981), and Grammatikos and Saunders (1983). Other researchers, such as McCabe and Franckle (1983), Hammer (1988), use percentage changes or natural logarithm of prices. Some tests using percentage price changes were conducted (not reported here) which do not change the results.

[5]The same procedure is used by Grammatikos and Saunders (1983).

[6]The hedge ratios and measures of hedging effectiveness obtained from this procedure exhibit major deviations from the average long-term B's and R^2's. The average long-term hedge ratios and measure of hedging effectiveness are estimated by running the OLS regression (1) for the full time periods. These results indicate that the hedge ratio and the measure of hedging effectiveness are unstable over time, which confirms earlier results found in the literature. The average long-term B's and R^2's and the B's and R^2's estimated from the moving window regression procedure are not reported here for the sake of space but they are available from the authors upon request.

these two tables indicate that the hedge ratios and the measures of hedging effectiveness follow random walk processes.

Variance Ratio Tests of Random Walk

The regression models postulated in Eq. (2) assume that the disturbances ϵ_t are independent and identically distributed gaussian random variables. However, there is mounting evidence that financial time series posses time-varying volatilities and deviate from normality. Lo and MacKinlay (1988) have developed a test-statistic for random walk which is sensitive to correlated price changes but which is otherwise robust with respect to many forms of heteroskedasticity and nonnormality of the random disturbances. This new test of random walk is known as the variance-ratio test. This article adopts the Lo and MacKinlay approach to reinforce the results of the Dickey and Fuller test and to provide further empirical evidence that the hedge ratios and the measures of hedging effectiveness are governed by a random walk behavior.

The intuition behind the variance ratio test is the following: If the natural logarithm of a time series denoted Y_t, is a pure random walk of the form

$$Y_t = \mu + Y_{t-1} + \epsilon_t$$

then, the variance of its k-differences grows linearly with the difference k. For example, the variance of monthly sampled series must be four times as large as the variance of a weekly sampled series. That is, if the series follows a random walk, it must be the case that the variance of the k-differences is k times the variance of the first-difference:

$$VAR(Y_t - Y_{t-k}) = kVAR(Y_t - Y_{t-1}).$$

Therefore, under the random walk hypothesis, the ratio of $(1/k)$ times the variance of the k-differences over the variance of the first-differences is expected to be equal to one. In other words, a test of random walk is equivalent to testing the null hypothesis:

$$H_0{:}(1/k)VAR(Y_t - Y_{t-k})/VAR(Y_t - Y_{t-1}) = 1.$$

The results of the variance ratio tests shown in Table III and IV indicate that one cannot reject the null hypothesis. In fact, the variance ratios are not statistically different from one at the 5% level of significance. Thus, the results of the variance ratio tests reinforce those reported by the Dickey and Fuller methodology and indicate the robustness of the random walk hypothesis for the hedge ratios and the measures of hedging effectiveness.

A slightly different interpretation of the variance ratio test is given by Cochrane (1988) who argues that a series can be decomposed into fluctuations that are partly temporary and partly permanent. The random walk carries the permanent component of a change and the stationary series carries the temporary part of a change. In this case, the $(1/k)VAR(Y_t - Y_{t-k})$ should settle down to the variance of the shock of the random walk or permanent component. Therefore, the variance ratio corresponds to an estimate of the measure of the random component of the series. Following Cochrane's argument, the large variance ratios reported in Table III and IV seem to indicate that hedge ratios and measures of hedging effectiveness contain a large permanent or random walk component and a small temporary component.

Table I
TEST OF RANDOM WALK OF THE HEDGE RATIO
Model: Full: $Y_t = b_0 + b_1 Y_{t-1} + b_2 T + \epsilon_t$ **Reduced:** $Y_t - Y_{t-1} = b_2 T + \epsilon_t$

$$H_0: (b_0, b_1) = (0, 1) \qquad F = \frac{(SSE_R - SSE_F)/2}{SSE_F/(n-3)}$$

Futures Contract	Model	Coefficients of Independent Variables (t values and std. errors in parenthesis) b_0	b_1	b_2	R^2 (adj.) (F) (pr.)	SSE	F	F critical[c] 5%, 1%
British Pound	Full	0.34421 (3.561) (0.0966)	0.62142 (5.262) (0.11809)	0.00064 (0.402) (0.00159)	0.5586 (19.98) (0.0001)	0.13089	6.665[b]	5.18
	Reduced			0.00022 (0.289) (0.00075)	0.0028 (0.084) (0.774)	0.19320		7.18
German Mark	Full	0.26772 (2.40) (0.11137)	0.71606 (5.64) (0.12688)	0.00028 (0.320) (0.00088)	0.6398 (27.642) (0.0001)	0.03328	3.664[a]	5.18
	Reduced			0.0000004 (0.001) (0.00035)	0.0001 (0.00) (0.9991)	0.04199		7.18
Japanese Yen	Full	0.14813 (1.50) (0.09888)	0.81930 (7.62) (0.10757)	0.00064 (0.33) (0.00191)	0.6556 (29.55) (0.0001)	0.25216	1.425[a]	5.18

	Reduced			0.000056 (0.063) (0.00090)	0.0001 (0.004) (0.9505)	0.27782		7.18
Swiss Franc	Full	0.24742 (2.22) (0.11124)	0.70227 (5.28) (0.13291)	0.001592 (1.50) (0.00106)	0.6887 (34.19) (0.0001)	0.04604	2.512[a]	5.18
	Reduced			0.000105 (0.263) (0.000398)	0.0023 (0.069) (0.7946)	0.05430		5.18
S&P 500	Full	0.271952 (1.80) (0.15142)	0.64774 (3.67) (0.17650)	0.002106 (0.90) (0.002353)	0.3832 (7.21) (0.0050)	0.076685	2.269[a]	5.18
	Reduced			0.000434 (0.39) (0.001125)	0.0074 (0.15) (0.7035)	0.096020		7.18
NYSE	Full	0.229945 (1.74) (0.13204)	0.671400 (3.98) (0.16857)	0.004161 (1.05) (0.003976)	0.5377 (12.63) (0.0004)	0.178330	1.920[a]	5.18
	Reduced			0.000174 (0.103) (0.001689)	0.0005 (0.011) (0.92)	0.216376		7.18

[a]The null hypothesis cannot be rejected at the 5% confidence level.
[b]The null hypothesis cannot be rejected at the 1% confidence level.
[c]*F*-critical obtained from Table IV of Dickey and Fuller (1981).

Table II
TEST OF RANDOM WALK OF THE MEASURE OF HEDGING EFFECTIVENESS

Model: Full: $Y_t = b_0 + b_1 Y_{t-1} + b_2 T + \epsilon_t$ Reduced: $Y_t - Y_{t-1} = b_2 T + \epsilon_t$

H_0: $(b_0, b_1) = (0, 1)$ $F = \dfrac{(SSE_R - SSE_F)/2}{SSE_F/(n-3)}$

Futures Contract	Model	Coefficients of Independent Variables (t values and std. errors in parenthesis)			R^2 (adj.) (F) (pr.)	SSE	F	F critical[c] 5%, 1%
		b_0	b_1	b_2				
British Pound	Full	0.36964 (3.55) (0.10406)	0.60958 (4.90) (0.12441)	−0.00087 (−0.52) (0.00169)	0.4435 (12.95) (0.0001)	0.17095	6.716[b]	5.18
	Reduced			−0.00019 (−0.226) (0.00086)	0.0017 (0.051) (0.8225)	0.25296		7.18
German Mark	Full	0.26518 (2.85) (0.09322)	0.73544 (6.98) (0.10541)	−0.00110 (−1.65) (0.00067)	0.6164 (25.10) (0.0001)	0.02589	7.122[b]	5.18
	Reduced			−0.00024 (−0.719) (0.00034)	0.0170 (0.518) (0.4774)	0.03906		7.18
Japanese Yen	Full	0.24210 (2.24) (0.10796)	0.72008 (5.83) (0.12344)	0.00119 (1.75) (0.00068)	0.7739 (47.93) (0.0001)	0.01707	2.583[a]	5.18

	Reduced			0.00005 (0.208) (0.00024)	0.0014 (0.043) (0.8364)	0.2022		7.18
Swiss Franc	Full	0.33621 (2.64) (0.12756)	0.61320 (4.03) (0.152028)	0.001204 (1.15) (0.001047)	0.5827 (21.95) (0.0001)	0.04135	3.680[a]	5.18
	Reduced			0.000048 (0.123) (0.000390)	0.0005 (0.015) (0.9031)	0.05222		7.18
S&P 500	Full	0.362901 (2.58) (0.140466)	0.447433 (2.24) (0.19939)	0.007037 (2.31) (0.003046)	0.5504 (13.24) (0.0003)	0.081003	3.958[a]	5.18
	Reduced			0.00850 (0.69) (0.00124)	0.023 (0.47) (0.50)	0.116630		7.18
NYSE	Full	0.250761 (1.80) (0.139585)	0.635419 (3.45) (0.184028)	0.003848 (1.53) (0.002521)	0.4813 (10.28) (0.0011)	0.77059	2.134[a]	5.18
	Reduced			0.000848 (0.76) (0.001121)	0.028 (0.57) (0.4580)	0.095328		7.18

[a]The null hypothesis cannot be rejected at the 5% confidence level.
[b]The null hypothesis cannot be rejected at the 1% confidence level.
[c]*F*-critical obtained from Table IV of Dickey and Fuller (1981).

Table III
VARIANCE RATIO TEST OF RANDOM WALK HYPOTHESIS OF THE HEDGE RATIO[a]

Foreign Currency		k (quarters) 1	2	3	4	5	6	7	8
British Pound	σ_k^2	0.009440	0.006844	0.008301	0.007653	0.007367	0.006999	0.006442	0.006033
	σ_k^2/σ_1^2	1.0000	0.7250	0.8793	0.8107	0.7804	0.7414	0.6842	0.6391
	Z_k		−1.506	−0.443	−0.554	−0.549	−0.573	−0.638	−0.668
German Mark	σ_k^2	0.001558	0.001944	0.001823	0.001694	0.001535	0.001365	0.001281	0.001125
	σ_k^2/σ_1^2	1.0000	1.2478	1.1701	1.0873	0.9852	0.8761	0.8222	0.7221
	Z_k		1.357	0.625	0.256	−0.037	−0.275	−0.357	−0.515
Japanese Yen	σ_k^2	0.021903	0.020844	0.025015	0.030200	0.029728	0.031345	0.031014	0.030229
	σ_k^2/σ_1^2	1.0000	0.9517	1.1421	1.3788	1.3573	1.4311	1.4160	1.3801
	Z_k		−0.265	0.522	1.109	0.893	0.955	0.836	0.704
Swiss Franc	σ_k^2	0.002235	0.002663	0.003149	0.003344	0.003012	0.002568	0.002201	0.001942
	σ_k^2/σ_1^2	1.0000	1.1915	1.4089	1.4962	1.3477	1.1490	0.9848	0.8689
	Z_k		1.049	1.502	1.453	0.869	0.330	−0.031	−0.243
S&P 500	σ_k^2	0.007440	0.006796	0.006847	0.007722	0.006765	0.006025	0.005098	0.004458
	σ_k^2/σ_1^2	1.0000	0.9134	0.9203	1.0379	0.9093	0.8098	0.6852	0.5992
	Z_k		−0.387	−0.239	0.091	−0.185	−0.344	−0.516	−0.606
NYSE	σ_k^2	0.014981	0.016598	0.017452	0.018396	0.015934	0.013222	0.011540	0.011628
	σ_k^2/σ_1^2	1.0000	1.1079	1.1649	1.2280	1.0636	0.8826	0.7703	0.7762
	Z_k		0.483	0.495	0.545	1.298	−0.212	−0.377	−0.338

[a] σ_k^2 corresponds to $1/k$ times the variance of the k-differences, that is, $\sigma_k^2 = (1/k)\ \mathrm{VAR}\ (Y_t - Y_{t-k})$; σ_k^2/σ_1^2 is the variance ratio, and Z_k is the normal Z-statistics with $Z_{crit} = 1.96$ for a two-tailed test at the 5 percent of significance level.

Table IV
VARIANCE RATIO TEST OF RANDOM WALK HYPOTHESIS OF THE MEASURE OF HEDGING EFFECTIVENESS[a]

Foreign Currency		k (quarters) 1	2	3	4	5	6	7	8
British	σ_k^2	0.013937	0.011529	0.011872	0.013629	0.012063	0.010886	0.010201	0.009716
Pound	σ_k^2/σ_1^2	1.0000	0.8272	0.8518	0.9779	0.8655	0.7811	0.7319	0.6971
	Z_k		−0.962	−0.554	−0.066	−0.342	−0.493	−0.548	−0.570
German	σ_k^2	0.001673	0.002183	0.002444	0.002228	0.001928	0.001861	0.001855	0.001931
Mark	σ_k^2/σ_1^2	1.0000	1.3048	1.4608	1.3317	1.1524	1.1124	1.1088	1.1542
	Z_k		1.697	1.721	0.987	0.387	0.253	0.222	0.290
Japanese	σ_k^2	0.000816	0.001048	0.001276	0.001373	0.001365	0.001213	0.001051	0.000868
Yen	σ_k^2/σ_1^2	1.0000	1.2843	1.5637	1.6826	1.6728	1.4865	1.2880	1.0637
	Z_k		1.583	2.105	2.031	1.710	1.096	0.588	0.120
Swiss	σ_k^2	0.002417	0.001358	0.001682	0.001587	0.001336	0.001528	0.001453	0.001551
Franc	σ_k^2/σ_1^2	1.0000	0.5619	0.6959	0.6566	0.5528	0.6322	0.6012	0.6417
	Z_k		−2.439	−1.136	−1.022	−1.136	−0.8280	−0.815	−0.674
S&P 500	σ_k^2	0.009756	0.005874	0.005990	0.006180	0.005572	0.005345	0.005652	0.006282
	σ_k^2/σ_1^2	1.0000	0.6021	0.6140	0.6335	0.5711	0.5479	0.5793	0.6439
	Z_k		−1.823	−1.187	−0.898	−0.897	−0.838	−0.707	−0.552
NYSE	σ_k^2	0.008596	0.010899	0.012479	0.012484	0.010790	0.009658	0.008448	0.00784
	σ_k^2/σ_1^2	1.0000	1.2679	1.4517	1.4523	1.2552	1.1235	0.9828	0.9160
	Z_k		1.2277	1.389	1.108	0.534	0.229	−0.029	−0.130

[a] σ_k^2 corresponds to $1/k$ times the variance of the k-differences, that is, $\sigma_k^2 = (1/k)\ VAR\ (Y_t - Y_{t-k})$; σ_k^2/σ_1^2 is the variance ratio, and Z_k is the normal Z-statistics with $Z_{crit} = 1.96$ for a two-tailed test at the 5 percent of significance level.

DISCUSSION OF RESULTS

The empirical tests confirm the hypothesis that the hedge ratios and the measures of hedging effectiveness follow a random walk. One way of interpreting these results is to think in terms of market efficiency. In this sense, the findings reinforce previous research confirming market efficiency in both spot and futures markets. The major implication of this random walk hypothesis is that hedgers cannot consistently place perfect hedges and need to continuously readjust their hedges. This can be done by using appropriate computational methods that take into account the variable nature of the hedge ratio and the measure of hedging effectiveness. A few of these methods are briefly summarized below.

Cechetti, Cumby, and Figlewski (1986) apply the Autoregressive Conditional Heteroskedasticity (ARCH) method to hedging in futures markets. Their approach maximizes the expected logarithmic utility of an investor and gives estimates of optimal hedges. Another methodology which measures hedging effectiveness and which avoids many of the estimation problems caused by nonstationarity in expected returns, is developed in McCabe and Solberg (forthcoming). This technique is based on conditional probability distributions, and the results reported by the authors indicate that varying assumptions about conditional expectations can greatly alter the effectiveness measures. Anderson and Danthine (1982) propose a multiperiod model of hedging which allows for the futures position to be revised within the cash market holding period. Finally, Herbst, Kare, and Coples (1989) estimate optimal hedge ratios by using the ARIMA methodology of Box and Jenkins. Their approach successfully solves the problem of autoregressive disturbances.

The findings of this research imply that the already complex relationships among hedge ratios, measures of hedging effectiveness, volume of trade and open interest require further empirical research. Individual investors, institutional investors, and corporations seeking to reduce or eliminate risk are aware that the hedging process is complicated. It is possible that dynamic hedging is more costly than traditional hedging because the continuous readjustment of the hedge might increase transaction costs. However, the opposite effect is also possible. Herbst, Kare, and Coples (1989) report that their hedge ratios are lower than those rendered by the traditional OLS regression technique which implies a reduction in the required margin deposit and in commissions incurred by hedgers.

Bibliography

Anderson, Ronald W., and Danthine, Jean-Pierre. (1982): "The Time Pattern of Hedging and the Volatility of Futures Prices," *Review of Economic Studies,* 50:249–265.

Brock, W. A., and Malliaris, A. G. (1989): *Differential Equations, Stability and Chaos in Dynamic Economics,* North Holland Publishing Company, Amsterdam and New York.

Cechetti, Stephen, Cumby, Robert, and Figlewski, Stephen. (1986): "Estimation of the Optimal Futures Hedge," WP Series Graduate School of Business, New York University.

Cochrane, John H. (1988): "How Big Is the Random Walk in GNP?," *Journal of Political Economy,* 96:833–920.

Cornell, B. (1977): "Spot Rates, Forward Rates and Exchanges Market Efficiency," *Journal of Financial Economics,* 5:55–65.

Cutler, D., Poterba, J., and Summers, L. (1990): "Speculative Dynamics and the Role of Feedback Traders," *American Economic Review: Papers and Proceedings,* 80:63–68.

Dale, C. (1981): "The Hedging Effectiveness of Currency Futures Markets," *The Journal of Futures Markets,* 1:77–88.

Dickey, D. A., and Fuller, W. A. (1979): "Distribution of the Estimators of the Autoregressive Time Series With A Unit Root," *Journal of the American Statistical Association,* 74:427–431.

Dickey, D. A., and Fuller, W. A. (1981): "Likelihood Ratio Statistics for Autoregressive Time Series With A Unit Root," *Econometrica,* 49:1057–1072.

Ederington, L. H. (1979): "The Hedging Performance of the New Futures Markets," *Journal of Finance,* 34:157–170.

Fama, E. (1976): "Forward Rates as Predictors of Futures Spot Rates," *Journal of Financial Economics,* 3:361–377.

Fama, E. (1965): "The Behavior of Stock Market Prices," *Journal of Business,* 38:38–105.

Fama, E., and Blume, M. (1966): "Filter Rules and Stock-Market Trading," *Journal of Business,* 39:226–241.

Figlewski, Stephen. (1985): "Hedging With Stock Index Futures: Theory and Application In a New Market," *The Journal of Futures Markets,* 5:183–199.

Figlewski, Stephen. (1984): "Hedging Performance and Basis Risk in Stock Index Futures," *The Journal of Finance,* 39:657–669.

Franckle, Charles T. (1980): "The Hedging Performance of the New Futures Markets: Comments," *The Journal of Finance,* 35:1273–1279.

Friedman, M. (1953): "Essays in Positive Economics," Chicago: University of Chicago Press.

Grammatikos, Theoharry. (1986): "Intervalling Effects, and the Hedging Performance of Foreign Currency Futures," *Journal of Financial Research,* 5:95–104.

Grammatikos, T., and Saunders, Anthony. (1983): "Stability and the Hedging Performance of Foreign Currency Futures," *Journal of Futures Markets,* 3:295–305.

Hammer, Jerry A. (1988): "Hedging and Risk Aversion in the Foreign Currency Market," *Journal of Futures Markets,* 8:657–686.

Herbst, A. F., Kare, D. D., and Coples, S. C. (1989): "Hedging Effectiveness and Minimum Risk Hedge Ratios in the Presence of Autocorrelation: Foreign Currency Futures," *The Journal of Futures Markets,* 9:185–197.

Hill, Joanne, and Schneeweis, Thomas. (1982): "The Hedging Effectiveness of Foreign Currency Futures," *Journal of Financial Research,* 5:95–104.

Hill, Joanne, and Schneeweis, Thomas. (1984): "Reducing Volatility with Financial Futures," *Financial Analysts Journal,* 40:34–40.

Hill, Joanne, Liro, Joseph, and Schneeweis, Thomas. (1983): "Hedging Performance of GNMA Futures Under Rising and Falling Interest Rates," *Journal of Futures Markets,* 3:403–413.

Howard, Charles T., and D'Antonio, Louis J. (1984): "A Risk-Return Measure of Hedging Effectiveness," *Journal of Financial and Quantitative Analysis,* 19:101–112.

Johnson, L. (1960): "The Theory of Hedging and Speculation in Commodity Futures," *Review of Economic Studies,* 27:139–151.

Junkus, Joan C., and Lee, Cheng F. (1985): "Use of Three Stock Index Futures in Hedging Decisions," *Journal of Futures Markets,* 5:201–222.

Lo, A., and MacKinlay, A. C. (1988): "Stock Market Prices Do Not Follow Random Walks: Evidence From A Simple Specification Test," *Review of Financial Studies,* 1:41–66.

McCabe, George M., and Solberg, Donald P. (1988): "Hedging in the Treasury Bill Futures Markets When the Hedged Instrument and the Deliverable Instrument Are Not Matched," Working paper University of Nebraska, forthcoming in *Journal of Financial Management.*

McCabe, George M., and Franckle, Charles T. (1983): "The Effectiveness of Rolling the Hedge Forward in the Treasury Bill Futures Market," *Journal of Financial Management,* 12:21–29.

Overdahl, James A., and Starleaf, Dennis R. (1986): "The Hedging Performance of the CD Futures Markets," *Journal of Futures Markets,* 6:71–81.

Rutledge, D. J. S. (1972): "Hedgers' Demand for Futures Contracts: A Theoretical Framework With Applications to the United States Soy-Bean Complex," *Food Research Institute Studies,* 11:237–256.

Stein, J. L. (1961): "The Simultaneous Determination of Spot and Futures Prices," *American Economic Review,* 51:1012–1025.

Tirole, Jean. (1989): "Theories of Speculation," in Bhattacharya S. and G. M. Constantinides, Ed, *Financial Markets and Incomplete Information,* Rowman and Littlefield Publishers, Inc., Totowa, N. J.

Working, H. (1953): "Futures Trading and Hedging," *American Economic Review,* 43: 314–343.

Working, H. (1962): "New Concepts Concerning Futures Markets and Prices," *American Economic Review,* 52:431–459.