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Universal Currency Hedging for International Equity Portfolios under Parameter Uncertainty

Glen A. Larsen, Jr. and Bruce G. Resnick

This study empirically tests whether Black's universal hedge ratio or regression hedge ratios work better than a simple unitary hedging strategy for hedging the exchange rate exposure in international equity portfolios in the presence of parameter uncertainty. When the ex ante universal hedge ratio or regression hedge ratios are estimated from historical data, it is quite possible that the performance results will be inferior to using a simple unitary hedge ratio. Two techniques for controlling estimation risk are used: a MVP technique due to Jobson and Korkie [16, 17]; and a Bayes-Stein (BST) technique derived by Jorion [19, 20].

The results indicate that when exchange risk is hedged using a unitary hedge ratio, an arbitrary universal hedge ratio of .77, or a uniquely determined universal hedge ratio, the average performance results are about the same, but inferior to unhedged international investment under all parameter estimation techniques. Moreover, the results are inferior to solely US investment. Even worse results obtain when regression hedge ratios are employed. In contrast, the Eun/Resnick [9] unitary hedging strategy performs very well under all parameter estimation techniques, yielding correspondingly superior average performance to all other hedging strategies and unhedged investment.

I. INTRODUCTION

International diversification of investment portfolios has for the last several years received widespread attention at both the academic and practitioner levels.[1] Recent ex ante portfolio selection studies, including Jorion [19, 20] and Eun and Resnick [9, 10], have shown i) that it is important to control parameter uncertainty in order to capture the potential gains from international diversification, and ii) that hedging foreign exchange risk can increase the gains from international stock portfolio diversification. In other words, investors can substantially benefit from international equity diversification when they properly control foreign exchange and parameter uncertainties. When neither of these uncertainties are controlled, however, investors may not be able to realize enough of the potential benefits to justify international investment. Instead, they should invest domestically.

Glen A. Larsen, Jr. , School of Business, Indiana University, Indianapolis, IN 46202 and **Bruce G. Resnick**, Babcock Graduate School of Management, Wake Forest University, Winston-Salem, NC 27109.

Much of the empirical work of hedging exchange rate exposure in portfolios of financial assets has used a unitary hedge ratio. A unitary hedging strategy is in accord with the empirical findings of Adler and Simon [3] and the theoretical work of Eaker and Grant [8]. Recently, Black [5, 6] proposed a *universal* hedge ratio that is less than unity for equity portfolios and is the same for all currencies and all national investors. Glen and Jorion [14] perform an ex post comparison of portfolios hedged with an optimal combination of forward contracts versus a unitary hedging strategy and portfolios hedged using Black's universal hedge ratio. The optimally hedged portfolios yielded better but not a statistically significant improvement in performance.[2]

Adler and Prasad [2] criticize Black's assumptions as being unrealistic. As an alternative, they propose the minimum variance hedge ratios that result from regressing the world market portfolio or any national stock market portfolio on third currencies. Jensen's inequality guarantees that the hedge ratios will be the same for each national investor regardless of the numeraire currency. In an ex post study, Adler and Jorion [1] show that this latter point holds empirically.

Whether Black's universal hedge ratio or the regression hedge ratios work better than a simple unitary hedging strategy in the presence of parameter uncertainty is an unanswered question. It may very well be that when the ex ante universal hedge ratio or regression hedge ratios are estimated from historical data that the performance results are inferior to using a simple unitary hedge ratio. Alternatively, in the case of Black's universal hedge ratio, it may be possible to control for estimation error in the data, using the same techniques that have proved successful in estimating the parameter inputs for the portfolio problem, so that superior hedging performance in comparison to simple unitary hedging is achieved. The proposed research will address these issues.

II. THE ALTERNATIVE HEDGING STRATEGIES

A. Unhedged Investment

The dollar rate of return, $R_{i\$,t+1}$, for U.S. dollar investors investing in the i^{th} foreign market over the holding period from time t to $t+1$ is given by

$$R_{i\$,t+1} = (1 + R_{i,t+1})(1 + e_{i,t+1}) - 1 = R_{i,t+1} + e_{i,t+1} + R_{i,t}e_{i,t+1}, \qquad (1)$$

where $R_{i,t+1}$ is the local currency rate of return on the i^{th} market, $e_{i,t+1} = (S_{i,t+1} - S_{i,t})/S_{i,t}$ is the rate of appreciation of the local currency against the dollar, and S_i is the spot exchange rate expressed in American terms.

B. Hedged Investment

Glen and Jorion [14] present the following expression for a U.S. dollar investor who hedges the return from investing in the i^{th} foreign market:

$$R^{H}_{i\$,t+1} = R_{i\$,t+1} - hf^{1}_{i,t+1}, \tag{2}$$

where h is the hedge ratio and $f^{1}_{i,t+1} = (S_{i,t+1} - F_{i,t})/S_{i,t}$ is the normalized "return" on a long position in a forward contract with price $F_{i,t}$ (in American terms) that spans the holding period. The hedge ratio can take on any value. When h = 0, the foreign investment is unhedged as in equation (1). When h = 1, a unitary hedge ratio is employed.

C. Black's Universal Hedge Ratio

Black [6] derives a *universal* hedge ratio in which each investor, regardless of nationality, takes the same position when hedging the exchange risk from investing in the foreign equities of all countries. The necessary assumptions are that all investors have the same risk tolerance and that the national wealth of each country is equal to the country's stock market capitalization. Under these assumptions, the hedge ratio for all investors is:

$$h = (\mu_m - \sigma^2_m) / (\mu_m - 0.5\, \sigma^2_e), \tag{3}$$

where from a given numeraire currency m_m equals the weighted average over all currencies of the market's mean excess return, s_m^2 equals the weighted average over all currencies of the market's variance, and s_e^2 equals the weighted average over all pairs of currencies of the variance of the exchange rate.

Black [5] provides an example of how to calculate the universal hedge ratio. The example numbers he uses results in a hedge ratio of .77. He notes that parameter estimates calculated from long time series are best for estimating the hedge ratio because short-run historical values vary too much to be useful. In this regard, one frequently encounters the value of .77 in the literature as *the number to use* for the universal hedge ratio.

D. Regression Hedge Ratios

Adler and Prasad [2] criticize Black's assumptions as being unrealistic. As an alternative, they propose the minimum variance hedge ratios that result from regressing the world market portfolio or any national stock market portfolio on third currencies. Jensen's inequality guarantees that the hedge ratios will be the same for each national investor regardless of the numeraire currency. Regression equation (4) produces the hedge ratios for a U.S. dollar investor holding investment portfolio *i*:

$$R_{i\$,t+1} = \alpha_{i\$} + \Sigma_j\, h_{j\$}\, f^{2}_{j,t+1} + \varepsilon_{i\$,t+1}, \tag{4}$$

where $h_{j\$}$ is the regression hedge ratio (coefficient) of the j^{th} currency in the U.S. dollar regression, $f^2_{j,t+1} = (S_{j,t+1} - F_{j,t})/F_{j,t}$ is a variation of the normalized "return" on a long position in a forward contract that spans the holding period, and $e_{i\$,t+1}$ is the regression error term. In practice, hedge ratios should be calculated using one-month returns for as many currencies as there are forward contracts.

When universal regression hedge ratios are employed, the counterpart to equation (2) is:

$$R^{H}_{i\$,t+1} = R_{i\$,t+1} - \Sigma_j\, h_{j\$}\, f^{1}_{j,t+1}. \tag{5}$$

It is evident from hedging equation (5) that the U.S. dollar investor hedges the exchange rate uncertainty in more currencies than just the currency denominating national portfolio *i*. In fact, national portfolio *i* may be denominated in a currency in which forward contracts are not typically traded. Consequently, when hedging the investor will utilize cross-hedges to hedge the exchange rate uncertainty.

E. Eun/Resnick Unitary Hedge Ratio

Substituting equation (1) into equation (2) when $h = 1$ results in

$$R^{H}_{i\$,t+1} = R_{i,t+1} + e_{i,t+1} + R_{i,t+1}\, e_{i,t+1} - f^{1}_{i,t+1}, \tag{6a}$$

$$R^{H}_{i\$,t+1} = R_{i,t+1} + R_{i,t+1}\, e_{i,t+1} + f^{3}_{i,t+1}, \tag{6b}$$

where $f^3_{i,t+1} = (F_{i,t} - S_{i,t})/S_{i,t}$ is the forward exchange premium. Because the second term in equation (6b) will be small in magnitude, the following approximation results:

$$R^{H}_{i\$,t+1} \approx R_{i,t+1} + f^{3}_{i,t+1}. \tag{7}$$

Equation (7) is the unitary hedging strategy derived by Eun and Resnick [9]. The difference between constructing optimal hedged portfolios using equation (7) versus equation (2), when $h = 1$, is that the optimal portfolio weights will be determined using local currency returns modified by the forward premium in the former and U.S. dollar returns in the latter. Consequently, *different* "optimal" portfolio weights will obtain for the two unitary hedging strategies. This will be discussed in more depth in the next section.

III. EX-ANTE PORTFOLIO CONSTRUCTION

In this study, the ex ante international portfolio construction techniques developed by Jobson and Korkie [16, 17] and Jorion [19, 20], and extended by Eun and Resnick [9, 10, 11], are employed. This literature has established that the expected return vector is the critical input for successfully implementing modern portfolio theory, i.e., identifying the ex ante "optimal" investment weights. Conventional estimation of the variance-covariance matrix works well.

Let us examine the unhedged strategies first, using the expected return equation:

$$E(\underline{R}) = (1 - \hat{w})\,\underline{Y} + \hat{w}\,\underline{1}\,Y_0, \tag{8}$$

where a bar under a variable symbol denotes a vector, $\underline{Y}$ is the $N \times 1$ ex post (historical) sample mean-return vector of the N assets, $\underline{1}$ is a vector of ones, Y_0 denotes the mean return from the ex post minimum-variance portfolio, and $\hat{w}$ represents the estimated shrinkage factor for shrinking the elements of $\underline{Y}$ toward Y_0.

Equation (8) is a Bayes-Stein expression derived by Jorion for estimating the ex ante expected-return vector to use in solving the portfolio problem. It is, however, general enough to encompass other models. If $\hat{w} = 0$, the resulting vector of estimated expected returns contains the ex post classical sample means. These estimates result in identifying the weights of the ex post (or historical) tangency portfolio as the ex ante "optimal" investment weights. This method implicitly assumes there is no estimation risk in the classical sample estimates and it is labeled the certainty-equivalence-tangency (CET) portfolio technique. A second method, which is due to the simulation results of Jobson and Korkie [16, 17], is to arbitrarily set $\hat{w} = 1$. This technique identifies the optimal ex ante investment weights as those of the ex post minimum-variance portfolio (MVP). The MVP technique implicitly assumes that there is no useful asset-specific information in $\underline{Y}$ because it is not required as input to solve the portfolio problem.

A third technique is the Bayes-Stein method developed by Jorion, which uniquely estimates the shrinkage factor according to the equation:

$$\hat{w} = \frac{(N+2)(L-1)}{(N+2)(L-1) + (\underline{Y} - Y_0\underline{1})'\, LV^{-1}(L - N - 2)(\underline{Y} - Y_0\underline{1})}\ , \qquad (9)$$

where L represents the length of the time series of the sample observations and V is the usual N x N sample variance-covariance matrix. Using Jorion=s $\hat{w}$ in equation (8), the Bayes-Stein (BST) optimal ex ante tangency portfolio can be determined. When using a uniquely determined $\hat{w}$, equation (8) can potentially result in a uniform improvement on the ex post classical sample mean or Y_0 as estimates of the expected return because it relies on a more general model that includes them as special cases.

If the investor selects an unhedged investment, for example, realized returns are appropriately defined by equation (1). To implement either the CET, MVP or the BST parameter estimation technique requires obtaining a historical time series sample of *U.S. dollar* returns, $R_{i\$,t+1}$ $(i=1,..., N)$ to calculate the $\underline{Y}$, Y_0, V, and $\hat{w}$ necessary to calculate the expected return vector specified by equation (8).

If the investor selects a hedged investment where realized returns are defined by equation (2) or equation (5), the expected return vector is calculated the same as for unhedged investment. However, if the Eun/Resnick (E/R) unitary hedging strategy is used, realized returns will be defined by equation (6b) (which is the same as equation (2) when h = 1). Equation (7), which is an approximation of equation (6b), suggests that the variability in $R^H_{i\$,t+1}$ will be primarily due to the variability in the local currency return, $R_{i,t+1}$ $(i=1,...,N)$. This, in turn, suggests that for the ex ante E/R unitary forward hedging strategy, the expected-return vector can be estimated as:

$$E(\underline{R}^H_\$) = \underline{R} + \underline{f}^3, \qquad (10a)$$

$$E(\underline{R}^H_\$) = (1 - \hat{w})\underline{Y} + \hat{w}\underline{1}Y_0 + \underline{f}^3, \qquad (10b)$$

where $\underline{Y}$, Y_0, V, and $\hat{w}$, and thus $\underline{R}$, are calculated from a historical time series of *local* currency returns, $R_{i,t+1}$ $(i=1,...,N)$. The vector $\underline{f}^3$ contains as elements the market-determined forward exchange premiums.[3]

In the next section, we test six ex ante international diversification strategies:

i) unhedged investment,
ii) hedged investment where $h = 1$,
iii) hedged investment where the Black universal hedge ratio is arbitrarily equals .77,
iv) hedged investment where the Black universal hedge ratio is uniquely estimated,
v) hedged investment where the universal regression hedge ratios are uniquely estimated, and
vi) the Eun/Resnick unitary hedging strategy.

For each of the six strategies, the investment weights are calculated using the three-parameter estimation techniques: CET, MVP, and BST. Additionally, for strategy iv, Black's universal hedge ratio is estimated using the corresponding parameter estimation technique. For example, if the ex ante optimal investment weight vector is estimated using the BST parameter estimation method, the hedge ratio was also estimated using the BST parameter estimation technique. The performance results are compared with one another, with domestic index fund investment (US), and with international index fund investment represented by the MSCI World Index (MSCI).

IV. EMPIRICAL RESULTS

A. The Data and Test Structure

We use the Morgan Stanley *Capital International Perspective* Stock Index monthly return data for the United States (US) and six foreign countries: Canada (CN), France (FR), Germany (GR), Japan (JP), Switzerland (SW), and the United Kingdom (UK). It is in the currencies of these countries that the U.S. dollar investor can readily hedge exchange risk via the well-developed forward exchange market. We have 222 months of return data that span the time period 1978.07 through 1996.12. In conducting the tests, it is assumed that the investor has a 12-month buy-and-hold investment horizon period that corresponds to the period covered by the 12-month forward position. The forward premiums, $\hat{f}_{i,t+1}$, are calculated as of the inception date of the holding period from spot and 12-month forward exchange rates obtained from various volumes of the Chicago Mercantile Exchange (CME) *Statistical Yearbook* and from private correspondence with the Statistics Department of the CME. The

12-month forward premiums are converted to their monthly equivalent to calculate the ex ante expected-return vector and the holding period returns. One-month Eurodollar rates were also obtained from the CME *Statistical Yearbooks* and directly from the CME.

In total, the performance results for each strategy are examined for 76 overlapping out-of-sample test periods. For each test, 60 corresponding monthly returns for each of the seven stock indices are used to estimate the input parameters to solve the ex ante optimal investment weights for each investment strategy. The sample periods are structured as follows. For the first holding period covering months 61 through 72, the estimation period covers months 1 through 60. For the second holding period covering months 63 through 74, the estimation period covers months 3 through 62. Each subsequent pair of estimation and holding periods is shifted forward in time by two months. The performance of each strategy over the holding period is measured by the Sharpe (1966) reward-to-variability measure of portfolio performance.[5]

B. Average Performance Results

Table I presents the average performance results from the 76 out-of-sample tests from employing the alternative ex ante international portfolio selection strategies. The results presented in the table show the average portfolio mean return and standard deviation stated in percentage per month and the average Sharpe (SHP) measure of portfolio performance. For comparison purposes, investment solely in the US portfolio yielded an average return of 1.29% per month, an average standard deviation of return of 3.84% per month, and an average Sharpe ratio of .42. The corresponding numbers for the MSCI World Index are 1.29%, 3.92%, and .40. These results are indicative of a strong U.S. equity market over much of the sample period.

Examination of Table 1 indicates that unhedged international portfolio investment that does not control for parameter uncertainty (the CET strategy) fails to provide superior performance to investment solely in the US portfolio. When parameter uncertainty is controlled by the BST method, the results are comparable to US investment. The MVP estimation technique, however, yields superior average performance to solely US investment. These results are consistent with the previous findings of Jorion [19] and Eun and Resnick [9, 10, 11], although in the present study the US portfolio exhibits sample-specific strength.

When exchange risk is hedged using a hedge ratio of unity, .77, or a uniquely determined universal hedge ratio, the average performance results are inferior to unhedged international investment under all parameter estimation techniques and, also, inferior to solely US investment. These hedging strategies yield comparable results to investment in the MSCI index under the MVP method. The results are poorest when regression hedge ratios are employed.[5] In contrast, the E/R unitary hedging strategy performs very well under all parameter estimation techniques, yielding correspondingly superior average performance to all other hedging strategies and unhedged investment. These results suggest that there is considerable estimation error in the $e_{i,t+1}$ and $R_{i,t+1}$ $e_{i,t+1}$ terms of $R_{iS,t+1}$ that cannot successfully be controlled by any parameter estimation technique. Thus, it is better to estimate the optimal investment weight vector using expected return equation (9b), where only the local currency return is subject to estimation error from using historical data.

Table 1

Average Performance Results of the Ex Ante Investment Strategies[a]

Ex Ante Strategy		Unhedged	Unitary Hedge Ratio	Hedge Ratio equals .77	Black Hedge Ratio	Regression Hedge Ratio	E/R Unitary Hedge Ratio
CET	MN(%)	1.18	1.04	1.07	1.01	0.93	1.21
	SD(%)	4.27	4.27	4.27	4.27	4.27	3.95
	SHP	.35	.32	.32	.32	.32	.43
MVP	MN(%)	1.26	1.12	1.15	1.14	0.86	1.24
	SD(%)	3.69	3.69	3.69	3.69	3.69	3.81
	SHP	.43	.40	.40	.40	.34	.46
BST	MN(%)	1.23	1.11	1.14	1.13	0.93	1.25
	SD(%)	3.74	3.74	3.74	3.74	3.74	3.81
	SHP	.42	.39	.39	.39	.37	.46

[a]In each cell, the three numbers represent the average of 76 out-of-sample values.

Table 2 presents the minimum, maximum, and average values of the Black universal hedge ratios from the 76 test periods for each of the three-parameter estimation techniques. The standard deviations are also presented. The table implies that there is considerable variability in the universal hedge ratio estimate from one time period to the next, regardless of attempts to control parameter uncertainty of the inputs by either the MVP or the BST estimation technique. Consequently, a constant estimate of unity or .77 for the universal hedge ratio works as well as attempts to uniquely estimate the universal hedge ratio using inputs calculated from a short time series of data.

Table 2
Analysis of Ex Ante Black Hedge Ratios

Estimation Technique	Minimum	Maximum	Average	Standard Deviation
CET	-16.53	19.06	1.07	4.11
MVP	.43	.92	.76	.11
BST	.15	.91	.74	.15

Table 3 presents the average values and standard deviations from the 76 estimates of the regression hedge ratios. The table shows that there is substantial variability in the regression hedge ratios. In fact, the variability is generally much larger than the variability in the estimates of the Black universal hedge ratio when using the MVP or BST estimation techniques. This variability accounts for the poor performance of the regression hedge ratio strategy in comparison to the other hedging strategies.

C. Dominance Analysis

The average performance results presented in Table 1 indicate that hedging exchange rate risk via the E/R unitary hedging strategy is beneficial for the U.S. investor in comparison to solely investing in the U.S. market or to unhedged international investment. Table 1 does not allow for clear discrimination among the various strategies, however. Tables 4 and 5 facilitate discrimination by presenting a dominance analysis of the performance results.[6] The two tables are constructed in a similar format. Using Table 4 as an example, a number in the table denotes the number of times out of the 76 out-of-sample holding periods that the row strategy had a larger SHP value than the strategy at the top of the table. As will be noted from examination of the tables, the dominance analysis results are essentially consistent with the conclusions drawn from the SHP analysis.[7]

Table 3
Analysis of Ex Ante Regression Hedge Ratios[a]

Stock Market	Intercept	$/CD	$/FF	$/DM	$/JY	$/SF	$/BP
Canada	.0080 (.0050)	1.9137 (.7764)	.5377 (.7295)	-.7392 (.6857)	.0953 (.2191)	-.2015 (.2634)	.1660 (.1189)
France	.0121 (.0069)	-.0130 (.3913)	1.7016 (.8027)	-.4526 (.9207)	.2014 (.2429)	-.8492 (.6272)	.2836 (.2561)
Germany	.0118 (.0078)	-.0530 (.4508)	.5516 (1.2137)	1.0636 (1.2674)	.0268 (.3631)	-1.0412 (.6821)	.1842 (.3568)
Japan	.0110 (.0112)	.3129 (.6932)	-.5649 (1.1093)	.0900 (1.4994)	1.5213 (.2409)	-.1674 (.5800)	.1279 (.3885)
Switzerland	.0133 (.0060)	.1384 (.4590)	1.0386 (.5896)	-.7697 (.5604)	-.0044 (.2631)	.2390 (.7462)	.1687 (.2745)
United Kingdom	.0111 (.0068)	.4797 (.7534)	1.2488 (1.3720)	-1.2448 (1.2173)	.1009 (.2301)	-.5342 (.5530)	1.1512 (.2815)
United States	.0116 (.0030)	.5930 (.4586)	.9167 (1.0391)	-.6726 (.9157)	.0103 (.1086)	-.3835 (.2624)	.0431 (.1842)

[a]The standard deviations of the 76 regression coefficient estimates are in parentheses.

Table 4 presents a dominance analysis comparing all investment strategies under each parameter estimation technique versus unhedged investment, U.S. index fund investment, and investment in the MSCI World Index. The first panel examines only the unhedged investment strategies. The panel indicates that unhedged investment dominates US investment and investment in the hypothetical MSCI World Index fund when estimation is done by the BST technique.

The remaining five panels of Table 4 show that, in general, all hedging strategies other than the E/R unitary strategy perform very poorly in comparison to unhedged international investment or investment in the US portfolio. Only the E/R unitary hedging strategy dominates US investment when parameter estimation is done by the MVP method.[8]

Table 5 compares the E/R unitary hedging strategy with the other four hedging strategies. The table shows that the E/R strategy dominates all other hedging strategies when parameter estimates are made by either the MVP or the BST estimation technique.

Table 4
Dominance Analysis of the Out-of-Sample Performance of the Ex Ante Investment Strategies versus Unhedged Investment[a]

		Unhedged				
		US	MSCI	CET	MVP	BST
Unhedged	US	0	41	40	40	35
	MSCI	35	0	50	32	36
	CET	36	26	0	26	22
	MVP	36	44	50	0	43
	BST	41	40	54	33	0
Unitary Hedge Ratio	CET	31	27	36	22	25
	MVP	34	35	41	32	33
	BST	33	39	42	33	32
Hedge Ratio = 0.77	CET	32	27	36	25	24
	MVP	35	36	42	32	34
	BST	34	40	43	35	32
Black Hedge Ratio	CET	40	33	41	30	30
	MVP	34	37	42	32	35
	BST	34	39	42	36	32
Regression Hedge	CET	27	31	32	23	24
	MVP	31	35	35	30	27
	BST	35	36	41	30	31
E/R Unitary Hedge	CET	31	40	44	36	35
	MVP	39	39	42	38	37
	BST	37	39	44	40	37

[a]A number in the table represents the number of times, out of 76 ex ante test periods, that the left-hand-side strategy had a larger out-of-sample reward-to-variability ratio than the strategy at the top.

V. SUMMARY AND CONCLUSION

The purpose of this study was to empirically test whether Black's [5, 6] universal hedge ratio or regression hedge ratios work better than a simple unitary hedging strategy for hedging the exchange rate exposure in international equity portfolios in the presence of parameter uncertainty. It is possible that when the ex ante universal hedge ratio or regression hedge ratios are estimated from historical data that the performance results are inferior to using a simple unitary hedge ratio. Two techniques for controlling estimation risk are used: a MVP technique due to Jobson and Korkie [17, 18]; and a Bayes-Stein (BST) technique derived by Jorion [19, 20].

Table 5

Dominance Analysis of the Out-of-Sample Ex Ante Performance of the E/R Unitary Hedging Strategy versus the Other Hedging Strategies[a]

		Unitary Hedge Ratio			Hedge Ratio equals .77			Black Hedge Ratio		
		CET	MVP	BST	CET	MVP	BST	CET	MVP	BST
E/R Unitary Hedge Ratio	CET	51	40	37	46	38	35	42	39	36
	MVP	52	45	47	50	43	44	45	44	43
	BST	55	46	49	53	44	43	43	45	43

		Regression Hedge Ratio			E/R Unitary Hedge Ratio		
		CET	MVP	BST	CET	MVP	BST
E/R Unitary Hedge Ratio	CET	54	44	46	0	34	25
	MVP	54	50	51	42	0	36
	BST	58	49	50	46	39	0

[a]A number in the table represents the number of times, out of 76 ex ante test periods, that the left-hand-side strategy had a larger out-of-sample reward-to-variability ratio than the strategy at the top.

The results indicate that when exchange risk is hedged using a unitary hedge ratio, an arbitrary universal hedge ratio of .77, or a uniquely determined universal hedge ratio, the average performance results are about the same, but inferior to unhedged international investment under all parameter estimation techniques. Moreover, the results are inferior to solely US investment or investment in the MSCI World Index. The results are even worse when regression hedge ratios are employed. In contrast, the Eun/Resnick [9] unitary hedging strategy performs very well under all parameter estimation techniques, yielding correspondingly superior average performance to all other hedging strategies and unhedged investment.

Additional analysis implies that there is considerable variability in the universal hedge ratio estimate from one time period to the next, regardless of attempts to control parameter uncertainty of the inputs by either the MVP or BST estimation technique. Consequently, a constant estimate of unity or .77 for the universal hedge ratio works as well as attempts to uniquely estimate the universal hedge ratio using inputs calculated from a short time series of data. Moreover, the variability in the regression hedge ratios is generally much larger than the variability in the estimates of the Black universal hedge ratio. This accounts for the poor performance of the regression hedge ratio strategy.

NOTES

1. Grubel [15] originally extended the concept of modern portfolio analysis, pioneered by Markowitz [25] and Tobin [31], to global markets. He argued that international portfolio diversification is the source of an entirely different world welfare gain, distinguishable from both the gains from trade and the productivity gains from international factor movements. This insight provided the stimulus for a series of ex post studies, such as Levy and Sarnat [24], Solnik [29], and Lessard [23], which collectively established a convincing case for international portfolio diversification.
2. Other recent studies on hedging strategies include Thomas [30], Celebuski, Hill and Kilgannon [7], and Kaplanis and Schaefer [22].
3. It is noted that the “MVP technique” is actually a misnomer for the E/R unitary hedging strategy since the ex ante expected returns for all *N* securities will *not* be the same after the forward premiums are added according to equation (9b). Consequently, the expected-return vector is required as input into the portfolio problem to find the ex ante solution weights. The name, however, is retained for simplicity.
4. In calculating the ex ante optimal investment weights for each strategy and the resulting Sharpe measures, the monthly risk free rate is assumed to be zero. A positive risk free locates the tangency portfolio higher up on the efficient frontier where fewer assets are likely to make up the optimal

portfolio. Thus, as Jorion [19] notes, a positive risk free rate would accentuate any undesirable characteristics of the tangency portfolio. Using an assumed zero rate leads to a conservative measure of the effect of estimation risk on all assets. Eun and Resnick [9, 10, 11] also assume a zero risk free rate.

5. The reader will notice from Table 1 that for each parameter estimation technique, the standard deviation of return is the same for all hedging strategies (except the E/R unitary hedging strategy) as it is for the corresponding unhedged strategy. The reason for this can be seen by comparing return equations (1), (2), and (5). Examination shows that (2) and (5) involve subtracting a constant term for equation (1), which will not affect the variance. Thus, the portfolio standard deviations will be the same since the "optimal" portfolio weights have been calculated from the same expected return vector and variance-covariance matrix.
6. In this study, a strategy is said to dominate another strategy if the former strategy has a larger SHP measure than the latter in at least 39 out of the 76 out-of-sample holding periods.
7. Jobson and Korkie [18] have developed a z-statistic for determining if the Sharpe performance measure of a portfolio is statistically significantly different from that of another portfolio. Unfortunately, their test is not very powerful in small samples, such as the 12 monthly observations used in this study. They concluded from testing the z-statistic that the "...results emphasize the dubious practice of evaluating differences in investment performance with the Sharpe...statistic with small samples...". Nevertheless, we calculated the Jobson and Korkie z-statistic for each portfolio pair for all 76 out-of-sample tests. The results (which are available to interested readers directly from the authors) support the dominance analysis findings.
8. The reader might be concerned that hedging does not appear to be particularly worthwhile in comparison to unhedged international investment or solely US investment. That conclusion would be drawn erroneously from sample data specific to the present study, however. By comparison, Eun and Resnick [9] show that (when using the E/R unitary hedging strategy) the CET hedging strategy has an average Sharpe ratio of .399 versus .084 for the CET unhedged strategy; .429 for the MVP hedging strategy versus .210 for the MVP unhedged strategy; and, .424 for the BST hedging strategy versus .188 for the BST unhedged. Moreover, out of 33 ex ante test periods the MVP hedging strategy has a larger Sharpe ratio than the US strategy, and the unhedged CET, MVP and BST strategies, respectively, in 32, 30, 29 and 29 test periods; the

BST hedging strategy has a larger Sharpe ratio in 30, 31, 27 and 29 test periods. Additionally, Eun and Resnick [11] show that (when using the E/R unitary hedging strategy) the CET hedging strategy has an average Sharpe ratio of .54 versus .42 for the CET unhedged strategy; .57 for the MVP hedging strategy versus .45 for the MVP unhedged strategy; and, .57 for the BST hedging strategy versus .43 for the BST unhedged strategy. Out of 100 ex ante test periods the MVP hedging strategy has a larger Sharpe ratio than the US strategy, and the unhedged CET, MVP and BST strategies in 70, 63, 60 and 61 test periods, respectively; the BST hedged strategy has a larger Sharpe ratio in 60, 61, 60 and 62 test periods. These test results clearly make a case for hedging exchange rate uncertainty using the E/R unitary hedging strategy.

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