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Exchange Rate Uncertainty, Forward Contracts, and International Portfolio Selection

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ABSTRACT

In this paper, ex ante efficient portfolio selection strategies are developed to realize potential gains from international diversification under flexible exchange rates. It is shown that exchange rate uncertainty is a largely nondiversifiable factor adversely affecting the performance of international portfolios. Therefore, it is essential to effectively control exchange rate volatility. For that purpose, two methods of exchange risk reduction are simultaneously employed: multicurrency diversification and hedging via forward exchange contracts. The empirical findings show that international portfolio selection strategies designed to control both estimation and exchange risks almost consistently outperform the U.S. domestic portfolio in out-of-sample periods.

SINCE GRUBEL [11] APPLIED MODERN portfolio theory (MPT) to international investment, various authors, such as Levy and Sarnat [17], Solnik [20], and Lessard [16], have examined the gains from international diversification of investment portfolios. For the purpose of establishing the gains from international diversification, these studies constructed international portfolios using historical risk and return data from a period of fixed or relatively stable exchange rates and showed that internationally diversified portfolios dominated purely domestic portfolios in terms of mean-variance efficiency. From the standpoint of today's investors, however, the previous studies fail to offer operational guidance for international diversification for two important reasons. First, it is now questionable whether the past findings are still relevant under the current flexible exchange rate regime. Second, by being "ex post" in nature, the past studies ignored the issue of estimation risk, or parameter uncertainty, and therefore may have overstated the realizable portion of the potential gains from international diversification.

Fluctuating exchange rates are likely to mitigate the potential gains from international diversification by making investment in foreign securities more risky. As will be shown later, a fluctuating exchange rate contributes to the risk of foreign investment not only through its own variance but also through its "positive" covariances with the local stock market returns. During our sample period of 1980 through 1985, for example, exchange rate volatility is found to account for about fifty percent of the volatility of dollar returns from investment in the stock markets of such major countries as Germany, Japan, and the U.K. Furthermore, the exchange rate changes vis-à-vis the U.S. dollar are found to be

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highly correlated across currencies. This, of course, implies that a large portion of exchange risk would remain nondiversifiable in a multicurrency portfolio.[1]

In addition, fluctuating exchange rates are likely to compound the problem of estimation risk. As is well known, investors must estimate the risk-return characteristics of securities in order to construct ex ante optimal portfolios according to MPT. Gyrating exchange rates will make this task more difficult, possibly leading to suboptimal portfolio selection. Underscoring the problem of estimation risk, the simulation analysis of Jorion [14] suggests that the classical international tangency portfolio constructed using "historical" mean returns and covariance matrix will often fail to outperform the U.S. domestic portfolio in out-of-sample periods. However, Jorion's results also suggest that, when estimation risk is controlled, it is possible by some strategies for the U.S. investor to realize a sufficient portion of the potential gains available from international diversification to warrant making international investment. Eun and Resnick [8] also show that certain ex ante international strategies controlling estimation risk outperform the purely domestic portfolios for most of fifteen national investors over their out-of-sample holding period, but not for the U.S. investor. They point out, however, that the actual gains would have been greater for most national investors in the absence of exchange rate fluctuations.

Considering the adverse effect of fluctuating exchange rates, it is highly desirable to develop an "ex ante" efficient international portfolio strategy that is capable of capturing the potential gains from international diversification as much as possible. Of central importance to such a strategy is the design of the effective mechanism for offsetting exchange rate volatility. In this study, we simultaneously employ two methods of exchange risk reduction, i.e., multicurrency diversification and hedging via forward exchange contracts. Specifically, the main objectives of this study are to

(i) examine the effect of exchange rate changes on the risk of international portfolios,
(ii) investigate how the negative effects of exchange rate volatility can be mitigated in a portfolio context by the judicious use of forward exchange contracts, and
(iii) develop an ex ante efficient international diversification strategy that can effectively control exchange and estimation risks.

In fulfilling these objectives, we take the viewpoint of the U.S. investor using the U.S. dollar as the numeraire currency.

Though much of the exchange risk may remain nondiversifiable in a multicurrency portfolio due to the high correlations among exchange rate changes, U.S. investors can conceivably eliminate much of the exchange risk by selling the "expected" foreign currency proceeds forward on a currency-by-currency basis. Since the forward exchange premium is known to be a nearly unbiased predictor

[1] In an update examining the potential gains from international diversification, Eun and Resnick [7] estimated the potential gains using a decade of data characterized by flexible exchange rates. They found that large potential gains still existed but that fluctuating exchange rates mitigated the gains by making foreign investment more risky.

of the future change of the exchange rate, the U.S. investor might be able to eliminate much of the exchange risk without having to lower the expected dollar returns from foreign investment.[2] From a portfolio standpoint, the size of the hedge position will depend upon the ex ante portfolio weights selected. The effectiveness of the hedge will depend upon the investor's ability to estimate accurately the expected foreign currency proceeds. Both of these factors pertain to the estimation-risk problem of implementing MPT in an international setting. If MPT can be implemented efficaciously using forward contracts, any "residual" exchange risk arising from unexpected foreign currency proceeds (due to misestimates of the expected proceeds) should be small in magnitude and conceivably diversifiable in an international portfolio. Overall, the investor should be able to realize a larger portion of the potential gains from international diversification.

The organization of the paper is as follows. Section I analyzes the effect of fluctuating exchange rates on the international investment opportunity set and discusses the rationale for international diversification using a forward hedge strategy. Section II discusses alternative ex ante portfolio strategies in the presence of estimation risk and extends these strategies to incorporate forward hedging. Section III presents out-of-sample performance results from empirically testing these strategies. Finally, Section IV offers a summary and concluding remarks.

I. Exchange Rate Volatility and the Hedging Strategy

In this section, we examine the effect of fluctuating exchange rates on the risk of foreign stock market investment and compare the hedging strategy with the unhedged strategy. In doing so, we take the viewpoint of the U.S. investor investing in the U.S. and six major foreign stock markets, i.e., Canada (CA), France (FR), Germany (GE), Japan (JP), Switzerland (SW), and the U.K. (UK). It is in the currencies of these countries that the U.S. investor can readily hedge exchange risk via the well-developed forward exchange market.

A. The Effect of Fluctuating Exchange Rates

The dollar rate of return, $\tilde{R}_{i\$}$, from an unhedged investment in the ith foreign market is

$$\tilde{R}_{i\$} = (1 + \tilde{R}_i)(1 + \tilde{e}_i) - 1, \tag{1a}$$

$$\tilde{R}_{i\$} = \tilde{R}_i + \tilde{e}_i + \tilde{R}_i\tilde{e}_i, \tag{1b}$$

where $\tilde{R}_i$ is the local currency rate of return, $\tilde{e}_i$ is the rate of appreciation of the local currency against the dollar, and the symbol "$\sim$" denotes a random variable. Since the cross-product in equation (1b) is small in magnitude, $\tilde{R}_{i\$}$ is well approximated by

$$\tilde{R}_{i\$} \approx \tilde{R}_i + \tilde{e}_i. \tag{2}$$

[2] For the empirical evidence on the forward exchange premium as an unbiased predictor of the future change of the exchange rate, refer to Frenkel [9] and Agmon and Amihud [3].

Based on equation (2), the variance of the dollar rate of return can be approximated as

$$\mathrm{var}(\tilde{R}_{i\$}) \approx \mathrm{var}(\tilde{R}_i) + \mathrm{var}(\tilde{e}_i) + 2\,\mathrm{cov}(\tilde{R}_i, \tilde{e}_i). \tag{3}$$

As can be seen from equation (3), the exchange rate change contributes to the variance of dollar returns through not only its own variance but also its covariance with the local stock market returns.

Table I presents the breakdown of the volatility of dollar returns into different components. Contrary to the conventional belief that the exchange market should be substantially less volatile than the stock market, the dollar exchange rates of such major currencies as the German mark and the Japanese yen exhibit nearly as much volatility as their respective stock markets during the sample period of 1980 through 1985. In the case of Switzerland, the exchange market turns out to be even more volatile than the stock market. For other countries, i.e., France, the U.K., and especially Canada, the stock market remains more volatile relative to the exchange market counterpart. It is also noteworthy that the covariance between the local stock market returns and the exchange rate changes is positive for each of the six foreign countries. In fact, the correlation coefficient between the two variables is significantly different from zero at least at the ten percent level in each country. The exchange rate movements are thus found to reinforce, rather than offset, the stock market movements. Table I also shows that, through its own variance as well as its covariance with the local stock market returns, the exchange rate changes account for a significant fraction of the volatility of dollar returns in each country except Canada. For example, the fraction is 52.35 percent for Japan, 58.49 percent for Germany, 69.99 for Switzerland, and 48.77 percent for the U.K.

The preceding analysis can be extended into a portfolio context. The variance of dollar portfolio returns, $\tilde{R}_{p\$}$, can be written as

$$\mathrm{var}(\tilde{R}_{p\$}) = \textstyle\sum_i X_i^2 \mathrm{var}(\tilde{R}_{i\$}) + \sum_i \sum_{j\neq i} X_i X_j \mathrm{cov}(\tilde{R}_{i\$}, \tilde{R}_{j\$}), \tag{4}$$

where X_i denotes the fraction of wealth invested in the ith market. Noting from equation (2) that

$$\begin{aligned}\mathrm{cov}(\tilde{R}_{i\$}, \tilde{R}_{j\$}) \approx\ & \mathrm{cov}(\tilde{R}_i, \tilde{R}_j) + \mathrm{cov}(\tilde{e}_i, \tilde{e}_j) \\ & + \mathrm{cov}(\tilde{R}_i, \tilde{e}_j) + \mathrm{cov}(\tilde{R}_j, \tilde{e}_i)\end{aligned}$$

and using equation (3), equation (4) can be approximated as

$$\begin{aligned}\mathrm{var}(\tilde{R}_{p\$}) \approx\ & \textstyle\sum_i \sum_j X_i X_j \mathrm{cov}(\tilde{R}_i, \tilde{R}_j) + \sum_i \sum_j X_i X_j \mathrm{cov}(\tilde{e}_i, \tilde{e}_j) \\ & + 2 \textstyle\sum_i \sum_j X_i X_j \mathrm{cov}(\tilde{R}_i, \tilde{e}_j).\end{aligned} \tag{5}$$

It is clear from equation (5) that the overall portfolio risk depends on (a) the covariances among the local stock market returns, (b) the covariances among the exchange rate changes, and (c) the cross-covariances among the local stock market returns and the exchange rate changes. Fluctuating exchange rates contribute to the portfolio risk via the second and third terms of equation (5). If the exchange rate correlations and the stock/exchange market cross-correlations

Table I

Decomposition of the Volatility of Stock Market Returns in U.S. Dollars (Weekly Data: January 1980 through December 1985)[a]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Stock Market	$\text{var}(\tilde{R}_i)$	$\text{var}(\tilde{e}_i)$	$\text{cov}(\tilde{R}_i,\tilde{e}_i)$	$\text{cor}(\tilde{R}_i,\tilde{e}_i)$	$\text{var}(\tilde{R}_{i\$})$	$\frac{(1)}{(5)} \times 100\%$	$\frac{(2)}{(5)} \times 100\%$	$\frac{2 \times (3)}{(5)} \times 100\%$
Canada	7.37	0.37	0.47	0.281*	8.68	84.91	4.26	10.83
France	7.52	3.61	0.52	0.100**	12.17	61.79	29.66	8.55
Germany	3.69	3.46	0.87	0.244*	8.89	41.51	38.92	19.57
Japan	3.86	2.58	0.83	0.264*	8.10	47.65	31.85	20.50
Switzerland	2.35	4.32	0.58	0.180*	7.83	30.01	55.17	14.81
U.K.	5.21	3.28	0.84	0.205*	10.17	51.23	32.25	16.52
U.S.	5.42	—	—	—	5.42	100.00	—	—

[a] The variances and covariances of columns (1), (2), (3), and (5) are stated in terms of squared percentages.

* Correlation coefficient is significantly different from zero at the five percent level.

** Correlation coefficient is significantly different from zero at the ten percent level.

are largely positive (negative), then fluctuating exchange rates will increase (decrease) the portfolio risk.

Table II provides the stock market correlations, the exchange market correlations, and the stock/exchange market cross-correlations calculated using weekly data from the period of January 1980 through December 1985. It can be seen from comparing Panel A with Panel B that the correlations are much higher among the exchange rate changes than among the local stock market returns. In fact, the average correlation is 0.669 for the exchange rate changes, compared with 0.319 for the local stock market returns. This implies that, while the local stock market risk can be diversified away to a large extent, much of the exchange risk is nondiversifiable.[3]

It is noted from Panel C of Table II that the cross-correlations among the stock and exchange markets are relatively low, with an average value of 0.189. Remarkably, however, every entry in panel C is positive. Furthermore, thirty-nine out of forty-two of the entries in Panel C are statistically significantly different from zero at the five percent level.[4] This result implies that the exchange rate changes in a given country reinforce the stock market movements in the same country as well as in the other countries examined. This reinforcement will, as shown by equation (5), further increase the overall portfolio risk.

The effect of exchange rate volatility can be clearly demonstrated by constructing an equally weighted portfolio from the seven stock markets previously mentioned. Doing so results in an overall portfolio risk, $\text{var}(\tilde{R}_{p\$})$, of 4.804 squared percent, using the weekly data from the 1980 through 1985 period. The $\text{var}(\tilde{R}_{p\$})$ decomposition according to equation (5) is shown in Table III. As shown in the table, fluctuating exchange rates account for 32.20 percent of the risk of the equally weighted portfolio through its own covariances and an additional 24.92 percent through its cross-covariances with the stock market returns. In the absence of exchange rate volatility, the portfolio variance would have been 2.060 squared percent, as opposed to 4.804 squared percent.

B. The Hedging Strategy

The preceding analysis shows that exchange risk may be nondiversifiable to a large extent and, as a result, substantially contributes to the overall risk of the portfolio. This observation leads one to consider the use of foreign exchange forward contracts as a tool for exchange risk management.

Assume that the U.S. investor sells the *expected* foreign currency proceeds forward. In dollar terms, it amounts to exchanging the uncertain dollar return $(1 + \text{E}(\tilde{R}_i))(1 + \tilde{e}_i) - 1$ for the certain dollar return $(1 + \text{E}(\tilde{R}_i))(1 + f_i) - 1$, where $\text{E}(\tilde{R}_i)$ is the expected rate of return on the ith foreign stock market in terms of the foreign currency and f_i is the forward exchange premium. The

[3] Adler and Simon [2] present evidence consistent with this statement. They show that, in a pre-1979 period, portfolio diversification did serve to reduce currency risk exposure but that, in a post-1979 period, exposure reduction through diversification was diminished.

[4] Two of the three remaining entries are statistically significant at the ten percent level. The only insignificant entry is the correlation between the French stock market and the Canadian exchange market.

Table II

Correlation Matrices of Seven Major Countries (Weekly Data: January 1980 through December 1985)

	CA	FR	GE	JP	SW	UK	US
A: Stock Market Returns in Local Currencies							
Canada		0.247	0.274	0.267	0.326	0.472	0.722
France			0.132	0.167	0.203	0.266	0.205
Germany				0.363	0.393	0.341	0.300
Japan					0.294	0.390	0.337
Switzerland						0.266	0.297
U.K.							0.429
B: Exchange Rate Changes against Dollar							
Canada		0.508	0.528	0.397	0.517	0.518	0.000
France			0.941	0.626	0.884	0.774	0.000
Germany				0.656	0.937	0.795	0.000
Japan					0.661	0.516	0.000
Switzerland						0.772	0.000
C: Stock/Exchange Markets Cross-Correlations[a]							
Canada	0.281	0.191	0.213	0.223	0.239	0.256	0.000
France	0.039	0.100	0.121	0.122	0.111	0.118	0.000
Germany	0.217	0.210	0.244	0.209	0.226	0.133	0.000
Japan	0.099	0.158	0.209	0.264	0.212	0.193	0.000
Switzerland	0.165	0.189	0.187	0.157	0.180	0.198	0.000
U.K.	0.191	0.155	0.174	0.186	0.199	0.205	0.000
U.S.	0.183	0.205	0.244	0.240	0.276	0.220	0.000

[a] Each entry in Panel C denotes the correlation between the row stock market returns in the local currency and the column exchange rate changes. All nonzero entries are statistically significant at least at the ten percent level, except for the correlation between the French stock market and the Canadian exchange market.

Table III

Decomposition of Portfolio Risk

Component	Absolute Contribution	Relative Contribution
1. $\sum_i \sum_j (1/n)^2 \operatorname{cov}(\tilde{R}_i, \tilde{R}_j)$	2.060	42.88%
2. $\sum_i \sum_j (1/n)^2 \operatorname{cov}(\tilde{e}_i, \tilde{e}_j)$	1.547	32.20%
3. $2 \sum_i \sum_j (1/n)^2 \operatorname{cov}(\tilde{R}_i, \tilde{e}_j)$	1.197	24.92%
	$\operatorname{var}(\tilde{R}_{p\$}) \approx 4.804$	100.00%

unexpected foreign currency proceeds, however, will have to be converted into U.S. dollars at the uncertain future spot exchange rate. The dollar rate of return under the hedging strategy is thus given by[5]

$$\tilde{R}^H_{i\$} = [1 + \mathrm{E}(\tilde{R}_i)](1 + f_i) + [\tilde{R}_i - \mathrm{E}(\tilde{R}_i)](1 + \tilde{e}_i) - 1, \tag{6a}$$

$$\tilde{R}^H_{i\$} = \tilde{R}_i + f_i + \tilde{R}_i\tilde{e}_i + \mathrm{E}(\tilde{R}_i)(f_i - \tilde{e}_i). \tag{6b}$$

[5] The hedging strategy described by equation (6) hedges expected foreign currency proceeds on a unitary basis. Adler and Simon [2] present empirical evidence that each of the foreign stock indices

Because the third and fourth terms of equation (6b) will be small in magnitude, the following approximation results:[6]

$$\tilde{R}^H_{i\$} \approx \tilde{R}_i + f_i. \tag{7}$$

Equation (7) suggests that much of the effect of exchange rate changes on the risk of the foreign stock market investment can be offset by means of the forward exchange contract.[7] Table IV provides a comparison between the hedged and unhedged strategies with regard to the risk-return characteristics of foreign investment. In light of the empirical results presented in Section I, Subsection *A*, it is clear that the hedging strategy results in a lower variance and covariance, i.e.,

$$\mathrm{var}(\tilde{R}^H_{i\$}) < \mathrm{var}(\tilde{R}_{i\$})$$

$$\text{and } \mathrm{cov}(\tilde{R}^H_{i\$}, \tilde{R}^H_{j\$}) < \mathrm{cov}(\tilde{R}_{i\$}, \tilde{R}_{j\$}).$$

Since the forward exchange premium is known to be a nearly unbiased predictor of the future change of the exchange rate, i.e., $f_i \approx \mathrm{E}(\tilde{e}_i)$, this is indeed one of the rare occasions where risk can be reduced without adversely affecting return.

Table IV

Risk and Return from Foreign Stock Market Investment: Hedged versus Unhedged Strategy[a]

	Hedged Strategy	Unhedged Strategy
Expected Return	$\mathrm{E}(\tilde{R}^H_{i\$}) = (1 + \mathrm{E}(\tilde{R}_i))(1 + f_i) - 1$	$\mathrm{E}(\tilde{R}_{i\$}) = (1 + \mathrm{E}(\tilde{R}_i))(1 + \mathrm{E}(\tilde{e}_i)) - 1$
Actual Return	$\tilde{R}^H_{i\$} = (1 + \mathrm{E}(\tilde{R}_i))(1 + f_i) + (\tilde{R}_i - \mathrm{E}(\tilde{R}_i))(1 + \tilde{e}_i) - 1 \approx \tilde{R}_i + f_i$	$\tilde{R}_{i\$} = (1 + \tilde{R}_i)(1 + \tilde{e}_i) - 1 \approx \tilde{R}_i + \tilde{e}_i$
Variance of Returns	$\mathrm{var}(\tilde{R}^H_{i\$}) \approx \mathrm{var}(\tilde{R}_i)$	$\mathrm{var}(\tilde{R}_{i\$}) \approx \mathrm{var}(\tilde{R}_i) + \mathrm{var}(\tilde{e}_i) + 2\,\mathrm{cov}(\tilde{R}_i, \tilde{e}_i)$
Covariance of Returns	$\mathrm{cov}(\tilde{R}^H_{i\$}, \tilde{R}^H_{j\$}) \approx \mathrm{cov}(\tilde{R}_i, \tilde{R}_j)$	$\mathrm{cov}(\tilde{R}_{i\$}, \tilde{R}_{j\$}) \approx \mathrm{cov}(\tilde{R}_i, \tilde{R}_j) + \mathrm{cov}(\tilde{e}_i, \tilde{e}_j) + \mathrm{cov}(\tilde{R}_i, \tilde{e}_j) + \mathrm{cov}(\tilde{R}_j, \tilde{e}_i)$

[a] The forward premium, f_i, is equal to $F_i/S_i - 1$, where F_i and S_i are, respectively, the forward and spot exchange rates in U.S. dollar equivalents.

used in the present study has approximately unitary exposure exclusively to its own currency and to no other. In related work, Eaker and Grant [4] analytically show that, for the case of quadratic utility, the optimal hedge is the expected value of the uncertain exposure.

[6] To make sure that it is appropriate to use equation (7) as an approximation for equation (6b), we calculated the mean-return vector and variance-covariance matrix using both equations. The historical mean return was used for $\mathrm{E}(\tilde{R}_i)$ in equation (6b). As expected, we found that the approximation error resulting from using equation (7) is indeed negligible. Specifically, the magnitude of absolute error relative to the precise value was found to be only about two percent for the mean returns and less than one percent for the variances-covariances, with the exception of a few entries. Thus, omission of $\tilde{R}_i\tilde{e}_i$, which is customary in the literature, together with $\mathrm{E}(\tilde{R}_i)(f_i - \tilde{e}_i)$ was found to be justifiable on empirical grounds. This omission also simplifies the ensuing analysis, which is summarized in Table IV, by preventing proliferation of the variance-covariance terms.

[7] Obviously, equation (7) ignores the existence of residual exchange risk arising from the unexpected foreign currency proceeds. To isolate the effect of residual exchange risk, equation (6b) can be

Although we are going to test the forward hedging strategy in this paper, it is pointed out that investors can hedge exchange risk alternatively via borrowing in the international money market. Suppose a U.S. investor borrows, in terms of foreign currency, the present value of the expected foreign currency proceeds, i.e., $[1 + \mathrm{E}(\tilde{R}_i)]/(1 + r_i)$, where r_i denotes the risk-free interest rate in the foreign country, and then immediately converts this borrowing into dollars and invests at the U.S. risk-free interest rate, $r_\$$. Then, at maturity, the U.S. investor will have to repay the maturity value of the borrowing, i.e., $1 + \mathrm{E}(\tilde{R}_i)$, which can be met by using the expected (foreign currency) proceeds from the foreign stock market investment. As was the case with the forward hedging strategy, any unexpected foreign currency proceeds would remain exposed to exchange risk.

Based on the preceding analysis, it can be shown that the dollar rate of return from the foreign stock market investment with the money market hedging is equal to

$$\tilde{R}^H_{i\$} = [1 + \mathrm{E}(\tilde{R}_i)]\left[\frac{1 + r_\$}{1 + r_i}\right] + [\tilde{R}_i - \tilde{\mathrm{E}}(R_i)](1 + \tilde{e}_i) - 1. \tag{8}$$

Equation (8) is, in fact, the analog of money market hedging to equation (6a). Note that both equations (6a) and (8) consist of a hedged component and an unhedged component, and also that the unhedged component is identical. Furthermore, the apparent difference in the hedged component can be shown to disappear if interest rate parity (IRP) holds, i.e.,

$$\frac{1 + r_\$}{1 + r_i} = 1 + f_i, \tag{9}$$

where f_i is, as previously defined, the forward exchange premium. (That is, $f_i = (F_i - S_i)/S_i$, where F_i (S_i) is the forward (spot) rate.) From equations (6a), (8), and (9), it can be seen that, if IRP holds, the two hedging methods will yield the identical investment results in dollar terms. As is well known, IRP is a pure arbitrage condition that must hold to preclude arbitrage opportunities in the absence of investment barriers. Previous empirical studies, most notably Frenkel and Levich [10], confirmed the empirical validity of IRP.

II. Alternative Ex Ante Strategies

A. Preliminary Discussion

In this section, alternative "ex ante" international diversification strategies, both with and without forward exchange hedging, are presented. The objective is

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rewritten as follows:

$$\tilde{R}^H_{i\$} = \tilde{R}_i + f_i + \mathrm{E}(\tilde{R}_i)f_i + [\tilde{R}_i - \mathrm{E}(\tilde{R}_i)]\tilde{e}_i.$$

Clearly, only the last term of the equation, which must be very small in magnitude, is still subject to exchange risk, and this residual risk can be conceivably diversified away in an international portfolio. To see the effectiveness of our hedging strategy, we constructed an equally weighted hedged portfolio and found its variance to be about 2.06 squared percent. This is, of course, equal to the value that to develop an effective strategy for controlling both estimation risk and exchange rate uncertainty. To lay the foundation for the discussion, the intertemporal stability of two "ex post" portfolios, i.e., the optimal international (tangency) portfolio and the minimum-variance portfolio, is first examined. As is well known, the entire efficient set can be constructed by combining these two portfolios.[8] Using 310 weeks of weekly stock index return data commencing with the first week of January 1980, we construct these two portfolios for a variety of six-month (twenty-six-week) holding periods using the ex post parameter values. Table V presents the portfolio weights for ten (largely) nonoverlapping holding periods. In solving for the tangency portfolio, the risk-free rate was assumed to be zero and the returns were in the U.S. numeraire.

Examination of Table V shows that the composition of the ex post tangency portfolio is highly unstable over time. This point is further confirmed by the very high standard deviations of the intertemporal portfolio weights relative to the average portfolio weights. As was pointed out by Jorion [14], the instability of the tangency portfolio weights is mainly due to the intertemporal instability of the mean-return vector; the variance-covariance matrix of international stock index returns demonstrates greater stability through time. Jobson and Korkie [12, 13] reach the same conclusion in a purely domestic context. Unlike the tangency portfolio, the minimum-variance portfolio is much more stable through time. Table V shows that the minimum-variance portfolio standard deviations of intertemporal portfolio weights for the seven stock indices are often only one tenth of the size of the respective values for the tangency portfolio. This result is due to the fact that the solution of the minimum-variance portfolio does not use the mean-return vector as input; it further confirms the relative intertemporal stability of the variance-covariance matrix. Accurate estimation of the mean-return vector thus proves to be of critical importance to the formulation of efficacious ex ante portfolio strategies.

Recently, Jorion [14, 15] has formalized in an expected-utility-maximization framework a Bayes-Stein approach for estimating the ex ante expected-return vector to use in solving the portfolio problem. This approach will result in a uniform improvement on the ex post classical sample mean because it relies on a more general model that includes the ex post sample mean as a special case. Jorion shows that the optimal portfolio choice should be based on the predictive density function of the vector of future rates of return. With a suitable informative prior on expected returns, the conditional predictive distribution he derives is multivariate normal with expected return

$$\underline{R} = (1 - \hat{w})\underline{Y} + \hat{w}\,\underline{1}\,Y_0, \tag{10}$$

where a bar under a variable symbol denotes a vector, $\underline{Y}$ is the $N \times 1$ ex post sample mean-return vector of the N assets, $\underline{1}$ is the vector of ones, Y_0 denotes the mean return from the ex post minimum-variance portfolio, and $\hat{w}$ represents

the variance of the equally weighted unhedged portfolio would have assumed in the absence of exchange rate volatility. This result implies that our hedging strategy is fully capable of eliminating the adverse effect of fluctuating exchange rates on the portfolio risk.

[8] See Merton [19] for proof.

Table V

Intertemporal Stability of International Portfolios

Holding Periods (Weeks)[a]	Tangency Portfolio							Minimum-Variance Portfolio						
	CA	FR	GE	JP	SW	UK	US	CA	FR	GE	JP	SW	UK	US
1 (1–26)	0.3418	0.0763	−0.1356	1.5900	−1.4024	1.3880	−0.8580	−0.1165	0.1548	0.3417	0.5022	−0.3327	0.1327	0.3179
2 (21–46)	−0.4133	−0.2514	−1.3419	0.4148	0.4119	0.9851	1.1948	−0.2641	0.2872	0.2187	0.2977	0.2043	0.2224	0.0339
3 (49–74)	−0.0436	−0.5737	−1.1133	3.3265	−0.0074	−1.3699	0.7814	0.1686	0.0503	−0.1256	0.5046	0.0511	0.1158	0.2352
4 (97–122)	−6.5169	2.7039	−6.4784	−2.6742	2.2692	6.5914	5.1050	−0.2656	0.1503	−0.0743	0.0768	0.4386	−0.0216	0.6957
5 (145–170)	2.9439	0.3950	1.2933	0.2597	−0.1788	−3.3620	−0.3511	−0.2323	0.1587	−0.0220	0.0033	0.4790	0.3492	0.2642
6 (169–194)	1.4393	0.2070	−0.3202	0.0860	−0.7546	0.1446	0.1979	−0.0061	0.1322	−0.0469	−0.0446	0.5273	0.0403	0.3978
7 (193–218)	−0.5439	0.5255	−0.0078	0.5902	0.7834	0.0476	−0.3950	−0.1704	0.1299	−0.0512	−0.0022	0.5638	0.1275	0.4025
8 (241–266)	0.1923	0.5441	−0.0550	0.5587	−0.6588	−0.0347	0.4534	0.0848	0.1850	−0.2407	0.3526	0.1108	0.0906	0.4168
9 (265–290)	−0.4780	0.2974	0.3957	0.3058	0.3375	−0.4456	0.5870	0.2132	0.0042	−0.1559	0.4339	−0.0623	0.0420	0.5249
10 (285–310)	−1.2205	0.4092	0.8278	−0.3908	1.8520	−1.1438	0.6661	0.4266	−0.0432	−0.0272	0.2090	0.0039	0.0577	0.3731
Average	−0.4299	0.4333	−0.6935	0.4067	0.2652	0.2801	0.7382	−0.0162	0.1209	−0.0183	0.2333	0.1984	0.1157	0.3662
S.D.	2.4427	0.8730	2.1817	1.4998	1.1438	2.5878	1.6566	0.2351	0.0948	0.1735	0.2148	0.2973	0.1056	0.1761

[a] For reference purposes, week number one corresponds to the first week in January 1980.

the estimated shrinkage factor for shrinking the elements of $\underline{Y}$ toward Y_0. The shrinkage factor is estimated by

$$\hat{w} = \frac{(N+2)(T-1)}{(N+2)(T-1) + (\underline{Y} - Y_0\underline{1})'TS^{-1}(T-N-2)(\underline{Y} - Y_0\underline{1})},$$

where T represents the length of the time series of the sample observations and S is the usual $N \times N$ sample variance-covariance matrix. In related work, Jobson and Korkie [12, 13] have derived a variation of equation (10), where the grand mean of the $\underline{Y}$ elements is substituted for Y_0 and the shrinkage factor is estimated differently.

Using equation (10) and an estimate of the inverse of the variance-covariance matrix, the optimal ex ante portfolio can be determined. As previously mentioned, the sample variance-covariance matrix is relatively stable through time. Therefore, in this study, we use the conventional unbiased estimator (see Jobson and Korkie [12]),

$$\hat{\Sigma}^{-1} = \frac{(T-N-2)}{(T-1)} S^{-1}, \tag{11}$$

in estimating the inverse of the true variance-covariance matrix.[9]

B. The Ex Ante Strategies

Altogether, we examine eight ex ante investment strategies from the perspective of the U.S. investor confronted with making the optimal international investment decision in the presence of estimation risk and exchange rate uncertainty. The results from testing these strategies are compared with investment in solely the U.S. stock market. This latter strategy is denoted US. The eight international strategies are divided into four unhedged and four hedged strategies.

If the investor selects an unhedged strategy, realized returns are defined by equation (1). Implementation of the strategy requires obtaining a historical time-series sample of dollar returns, $R_{i\$}$ ($i = 1, \cdots, N$), to calculate the $\underline{Y}$, Y_0, S, and $\hat{w}$ in equations (10) and (11). If the investor selects a hedged strategy, realized returns are defined by equation (6). Equation (7), which approximates equation (6), suggests that, when a hedged strategy is employed, the variability in $\tilde{R}_{i\$}^{H}$ will be primarily due to the variability in the local currency return, $\tilde{R}_i$ ($i = 1, \cdots, N$). This, in turn, suggests that the ex ante hedged expected-return vector be estimated as

$$\mathrm{E}(\underline{\tilde{R}}_{\$}^{H}) = \underline{R} + \underline{f}, \tag{12a}$$

$$\mathrm{E}(\underline{\tilde{R}}_{\$}^{H}) = (1 - \hat{w})\underline{Y} + \hat{w}\underline{1}Y_0 + \underline{f}, \tag{12b}$$

[9] In addition to the expected-return vector stated as equation (10), Jorion [15] also derives the variance-covariance matrix for the conditional predictive multivariate normal distribution. In our empirical testing, we considered strategies using Jorion's derivation as an alternative to $\hat{\Sigma}$ of equation (11) and found, as did Jobson and Korkie [12, 13], that more conventional estimators, such as (11), work as well as if not better than alternative estimators in obtaining good ex ante estimates of the investment weight vector. Hence, we decided to use equation (11) in this paper.

where $\underline{Y}$, Y_0, S, and $\hat{w}$, and thus $\underline{R}$, are calculated from a historical time series of local currency returns, R_i ($i = 1, \cdots, N$). The vector $\underline{f}$, on the other hand, is not estimated from historical data but rather contains as elements the current market-determined forward exchange premiums.

One unhedged strategy would be to construct an equally weighted (EQW) portfolio. This approach can be viewed as a naive diversification strategy in the attempt to capture some of the potential gains from international diversification. Alternatively, it can be viewed as an ad hoc method for controlling estimation risk, where the investor believes that the best ex ante estimate of the expected-return (standard deviation) vector is the grand mean of the ex post sample mean returns (standard deviations) and that the best estimate of the pairwise correlation coefficients is the grand mean from the ex post sample correlation matrix.[10] These inputs into the portfolio problem will result in an equally weighted portfolio being selected as the optimal portfolio. The second unhedged strategy is to identify the weights of the ex post (or historical) tangency portfolio and to invest accordingly. In terms of equation (10), this amounts to setting $\hat{w} = 0$. This method implicitly assumes no estimation risk and is labeled the certainty-equivalence-tangency (CET) portfolio strategy.[11] The third strategy, which is due to the simulation results of Jobson and Korkie [12, 13] in a purely domestic setting, is to arbitrarily set $\hat{w} = 1$ and estimate $\sum^{-1}$ by equation (11). This strategy identifies as the optimal ex ante weights those of the ex post minimum-variance portfolio (MVP). The MVP strategy 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.[12] The fourth strategy we consider is the Bayes-Stein (BST) strategy, which solves for the optimal ex ante tangency portfolio using equations (10) and (11).

[10] Elton and Gruber [5] first developed the grand (overall) mean approach for forecasting the dependence structure of domestic share prices. They found the grand mean estimate to be superior to conventional (full historical) estimation in out-of-sample periods. Eun and Resnick [6] show the grand (global) mean model to be a very poor method for forecasting the pairwise correlation structure of international share prices. They present evidence that the international correlation structure contains a strong country factor that can best be captured by a country mean model or conventional (full historical) estimation. When using national stock index data, as in the present study, conventional estimation of the variance-covariance matrix is consistent with using a country mean model.

[11] It is noted that our CET strategy is consistent with Jobson and Korkie's [12, 13]. Jorion [15], however, uses the estimator S^{-1} instead of equation (11) for estimating the inverse of the variance-covariance matrix. The difference is minimal when T is large and N is small, as it is in the present study.

[12] Interestingly, Adler and Dumas [1] show in the context of worldwide investments (and in the absence of parameter uncertainty) that the MVP computed in nominal returns is the optimal international portfolio choice for an investor with zero risk tolerance. They call this portfolio the investor's hedge portfolio and show that it is almost entirely made up of a nominal bank deposit denominated in the investor's home currency. This portfolio offers the very risk-averse investor the best hedge against home-country inflation (i.e., provides a stable real return) while minimizing exchange rate and stock price uncertainty. In the present study, we assume that the U.S. investor ignores his home-country inflation (or assumes it to be zero) and therefore considers security rates of return denominated in dollars as being real rates of return. Under this assumption, the U.S. bank deposit or Treasury bill is riskless in real terms. In this context and in the presence of parameter uncertainty, a worldwide MVP strategy assumes that the MVP is the best ex ante portfolio for all U.S. investors to combine with investment in the risk-free asset.

Each of the four unhedged strategies has a hedged (H) counterpart. When a hedged strategy is employed, the realized returns are defined by equation (6). Examination of equation (6) shows that $\tilde{R}^H_{i\$}$ ($i \neq$ US) is dependent on how $\tilde{\mathrm{E}}(R_i)$ is estimated. For the EQW(H) strategy, the $\mathrm{E}(\tilde{R}_i)$ values are each estimated as the grand mean of the $\underline{Y}$ elements. This is also done for the MVP(H) strategy, following Jobson and Korkie [12, 13].[13] For the CET(H) strategy, the $\mathrm{E}(\tilde{R}_i)$ values are the respective Y_i elements. In the BST(H) strategy, the $\mathrm{E}(\tilde{R}_i)$ values are the respective elements from the vector $\underline{R}$ in equation (12a).

In the next section, we empirically test the four unhedged and hedged ex ante international diversification strategies and compare their performance results with one another and with the US strategy. It is noted that Jorion [14, 15] and Eun and Resnick [8] have previously examined the unhedged strategies. These works, however, relied on simulation testing or covered only one out-of-sample holding period.[14] The empirical tests in this paper use actual data and multiple out-of-sample holding periods to draw inferences. Consequently, the results of the unhedged strategies are interesting in their own right as the current test results obtained under actual market conditions can be compared with the previous test results. Moreover, it is noted that actual market data were required because the hedged strategies rely on market-determined forward premiums. Hence, any differential investment performance detected from employing a hedged versus unhedged strategy represents a realizable gain from international diversification.[15]

III. Empirical Tests of the Ex Ante Strategies

A. The Data and Test Structure

The primary data used in this study are the Morgan Stanley Capital International Perspective daily stock index values for the U.S. and the six countries previously mentioned, for which forward contracts are readily available. Each of the stock indices is value weighted and is representative of a domestic stock index fund. The data series are provided in both the U.S. and the local currencies for the period from December 31, 1979, through December 10, 1985. From these data, a time series of 310 weekly returns is constructed for each index in both the U.S. and local currency. Using the U.S. and local currency returns, a corresponding time series of exchange rate changes versus the dollar is constructed for each country via solving equation (1) for e_i.

The weekly stock index return and exchange rate change data are used to test the performance of the ex ante investment strategies developed in Section II. In

[13] It is noted that the name "MVP(H) strategy" is actually a misnomer since the ex ante expected returns for all N securities will not be the same after the respective forward premiums are added according to equation (12). 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.

[14] To be more precise, the work of Jorion [14] is a simulation analysis using actual data.

[15] Madura and Reiff [18] performed an ex post test of hedged portfolio returns. They document large potential gains versus an unhedged strategy. However, since their study assumed parameter certainty, it is not known to what extent the potential gains are realizable in out-of-sample periods. Moreover, they examine only a single time period.

conducting the tests, it is assumed that the investor has a twenty-six-week (six-month) investment holding period. For the strategies that require estimation of the "optimal" ex ante investment-weight vector, it is assumed that the investor has knowledge of the 156 weekly returns prior to the inception date of the holding period. The holding-period returns are calculated by starting with a one-day lag beyond the close of the estimation period so that investment is not being made at ex post values. For the hedging strategies, the six-month forward premiums are calculated as of the inception date of the holding period from the applicable spot and 180-day forward exchange rates obtained from *The Wall Street Journal*. The six-month forward premiums are then converted to weekly premiums to calculate the ex ante expected-return vector and the actual holding-period returns.

In total, the performance results for each strategy are examined for thirty-three out-of-sample (overlapping) holding periods using the 310 weeks of data. The sample periods are structured as follows. For the first holding period covering weeks 157 through 182, the estimation period covers weeks 1 through 156. For the second holding period of weeks 161 through 186, the estimation period covers weeks 5 through 160. Each subsequent pair of estimation and holding periods is shifted forward in time by four weeks.

B. Test Results

Table VI presents the performance results from employing the various ex ante strategies in the thirty-three out-of-sample holding periods. For each strategy, the table shows the average portfolio mean return and standard deviation stated in percentage per week. The table also shows the average Sharpe (SHP) measure of portfolio performance, i.e., reward-to-variability ratio. In conducting the tests, the weekly risk-free rate was assumed to be zero.

From Table VI, first consider the performance of the unhedged strategies. The three international strategies that attempt to control estimation risk, i.e., EQW, MVP, and BST, clearly outperform the US strategy in terms of the average SHP value. Each of these three strategies registered an average SHP value of approximately 0.200, which is about twice as high as that of the US strategy (0.104). The CET strategy, which ignores the problem of estimation risk, however, failed to outperform the US strategy. On average, the CET strategy realized a somewhat higher mean return than the US but at a substantially high risk level, resulting in the lowest SHP value (0.084) among all strategies considered.[16] The performance results of the unhedged strategies indicate that, as long as the estimation risk is adequately controlled, investors can actually benefit from international diversification.

The international diversification strategies designed to control exchange risk as well as estimation risk, i.e., EQW(H), MVP(H), and BST(H), performed extremely well. As can be seen from Table VI, each of the three strategies realized an average SHP value in excess of 0.400. This is about twice the size of the

[16] This result is consistent with the previous findings of Jorion [14, 15] and Eun and Resnick [8]. This result is also consistent with the purely domestic simulation results of Jobson and Korkie [12, 13].

Table VI

Out-of-Sample Performance Results of the Ex Ante Investment Strategies[a]

Strategy	Mean (%)	S.D. (%)	SHP
1. EQW	0.315	1.515	0.214
2. CET	0.198	3.862	0.084
3. MVP	0.336	1.545	0.210
4. BST	0.293	1.810	0.188
5. EQW(H)	0.393	1.054	0.423
6. CET(H)	0.466	1.266	0.399
7. MVP(H)	0.500	1.202	0.429
8. BST(H)	0.491	1.203	0.424
9. US	0.189	1.744	0.104

[a] For each ex ante investment strategy, the table shows the averages of the resulting mean portfolio returns, the portfolio standard derivations, and the reward-to-variability ratios (SHP) for the thirty-three out-of-sample test periods.

unhedged counterpart and about four times the size of the US strategy. This result clearly shows that, when both estimation and exchange risks are controlled, investors can actually reap very substantial gains from international diversification.

Surprisingly, the CET(H) strategy, which makes no attempt to control estimation risk, performed nearly as well, with an average SHP of 0.399. The strong performance of the CET(H) strategy may, in fact, reflect not only the benefit of exchange risk hedging but also a reduction in the estimation risk "incidentally" achieved by the exchange risk hedging policy. Under the CET strategy, the expected return on the stock market is estimated as the historical sample mean of the dollar returns ($\bar{R}_{i\$}$), which is approximately equal to the sum of the sample mean of local currency stock market returns ($\bar{R}_i$) and the sample mean of exchange rate changes ($\bar{e}_i$). Under the CET(H) strategy, on the other hand, the expected return is estimated using the current market-determined forward exchange premium (f_i) instead of the historical sample mean of exchange rate changes. To the extent that the current forward exchange premium provides a more accurate estimate of the expected change in the exchange rate, which is likely to be the case in an efficient exchange market, the CET(H), which controls exchange risk, also controls estimation risk to a degree.[17]

The average performance results presented in Table VI indicate that hedging exchange risk is beneficial, but they do not allow for clear discrimination among the various strategies. Table VII facilitates discrimination by presenting a dominance analysis of the performance results.[18] A number in the table denotes the

[17] This explanation does indeed appear to be correct. As a test, we modified the (unhedged) CET strategy where in one case the expected returns were estimated as $\bar{R}_i + f_i$ and in the other merely as $\bar{R}_i$, i.e., a martingale assumption with respect to the expected exchange rate change. The forward premium model resulted in an average SHP of 0.146, and the martingale model yielded 0.147, both higher than the CET strategy's average SHP value of 0.084. This implies that the forward premium or "no-change" extrapolation provides a more accurate estimate of the expected change in the exchange rate than the historical sample mean of exchange rate changes.

[18] In this study, a strategy is said to dominate another strategy if the former has a higher SHP value than the latter in at least seventeen out of thirty-three holding periods.

Table VII

Dominance Analysis of the Out-of-Sample Performance of the Ex Ante Investment Strategies[a]

	EQW	CET	MVP	BST	EQW(H)	CET(H)	MVP(H)	BST(H)	US	Total
EQW		23	14	16	6	5	5	5	24	98
CET	10		11	8	3	2	3	2	16	55
MVP	19	22		16	5	7	4	6	23	102
BST	17	25	17		4	5	4	4	20	96
EQW(H)	27	30	28	29		15	11	11	31	182
CET(H)	28	31	26	28	18		15	14	27	187
MVP(H)	28	30	29	29	22	18		17	32	205
BST(H)	28	31	27	29	22	19	16		30	202
US	9	17	10	13	2	6	1	3		61

[a] A number in the table represents the number of times, out of thirty-three 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. To facilitate multilateral comparison, the sum of these numbers is provided for each strategy in the "Total" column.

number of times out of the thirty-three holding periods that the row strategy had a larger SHP value than the strategy at the top of the table. Examination of the table shows that the CET strategy was the worst-performing strategy; it did not dominate any of the others. By comparison, the US strategy had a larger SHP than the CET strategy in seventeen of the thirty-three out-of-sample holding periods, but it did not dominate any other international strategies. Table VII also reveals that all of the hedging strategies clearly dominate any of the unhedged strategies. Among the hedging strategies, the MVP(H) and BST(H) emerge as the best-performing strategies, whereas the EQW(H) performs most poorly. It is noted that each of the former strategies outperformed the latter in twenty-two out of thirty-three periods. It is also noted that these two strategies outperformed the US strategies in over ninety percent of the holding periods.

It is clear from the performance results presented in Tables VI and VII that, even in the presence of exchange rate uncertainty, the U.S. investor can realize a substantial gain from international diversification, as long as estimation risk is controlled by any method (EQW, MVP, or BST). Furthermore, the U.S. investor can substantially increase the gains from international diversification by employing a hedging strategy controlling both estimation and exchange risks, especially by the BST(H) or MVP(H) strategy.

IV. Summary and Conclusion

It was shown in this paper that fluctuating exchange rates make foreign investment more risky and, at the same time, aggravate estimation risk, thereby diminishing the gains from international diversification. The purpose of this paper was to develop an ex ante international portfolio selection strategy that can effectively control both exchange and estimation risks and capture the gains from international diversification as much as possible.

Our analysis showed that exchange risk is nondiversifiable to a large extent due to the high correlations among the changes in the exchange rates and, as a result, substantially contributes to the overall risk of the international portfolio. We thus proposed to simultaneously use two methods of exchange risk reduction, i.e., multicurrency diversification and the forward exchange contract on a currency-by-currency basis. Since the size of the forward contract is dependent upon the ex ante portfolio weights selected, alternative ex ante portfolio strategies controlling estimation risk are extended to incorporate forward hedging.

Performance results of the alternative strategies in the out-of-sample periods reveal that the U.S. investor can actually capture a substantial gain from international diversification if estimation risk is controlled by any method considered, i.e., EQW, MVP, or BST. The CET strategy, which ignores estimation risk, produced out-of-sample performance that is inferior to the US strategy. More importantly, the U.S. investor can substantially increase the gains from international diversification by using a hedging strategy. All of the hedging strategies, designed to control both estimation and exchange risks, were found to outperform any of the unhedged strategies by far. It was noted that MVP(H), the best-performing strategy, registered an average SHP value that is more than four times the size of the corresponding value for the US strategy, and it had the higher SHP value in thirty-two out of thirty-three out-of-sample periods.

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