The effectiveness of global currency hedging after the Asian crisis

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Abstract Global equity portfolio managers employ a variety of approaches to currency hedging either hedging all of their currency risk, hedging only a portion of their currency risk, or simply not hedging at all. This paper considers a hypothetical US-based global portfolio invested in Europe, Asia, Latin America, and the US and looks at how various passive hedging strategies would have performed over the post-Asian crisis period from 1999 to 2006, while also looking at individual currency hedges in isolation over a longer time period (from 1984 to 2006). Although it is well known that currency hedging reduces the volatility of dollar returns, some recent studies have argued that hedging is less important in emerging markets due to the negative correlation between currency returns and local equity returns. The Sharpe ratio of this hypothetical global portfolio is examined to determine which currency hedging approach did the best on a risk-adjusted basis from 1999 to 2006. Five hypothetical global portfolios are considered. The benchmark portfolio is market-capitalisation weighted, while the others are more European weighted, equal weighted among regions of the world, and with large investments in emerging markets, like Asia and Latin America. As in other studies, it is found that currency hedging reduces portfolio risk and improves the performance of most portfolios on a risk-adjusted basis for managers with exposures to single foreign countries. For global investment managers with exposure to many countries and using simple, yet very common hedging techniques, currency hedging did not improve the risk-adjusted returns of the portfolio in most cases compared to a policy of no currency hedging. This was primarily due to the consistent depreciation of the US dollar versus most currencies in the world during this period of time. Even though it did not improve the risk-adjusted returns of the portfolio, currency hedging reduced the overall volatility of the portfolio marginally compared to the unhedged case. As expected, the hedging return volatility matched more closely with the local equity return volatility. The only global portfolio for which hedging improved the risk-adjusted returns was for the global portfolio that was heavily invested in South American equities. The results of this paper also indicate that using a hedging strategy that employs only three optimally weighted currencies performed equally well when compared with a strategy using all currencies to hedge the global portfolio.
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Introduction

The purpose of this study is to investigate the historical performance of simple, yet very common forms of currency hedging in a global portfolio for the period after the Asian and Russian crises, which so dramatically shook the international financial markets in 1997 and 1998. The approach of this paper is to create a hypothetical global portfolio that has significant investment exposure to emerging markets, particularly in Asia and Latin America. For this global portfolio, three popular hedging techniques that find wide application among practitioners when immunising a global portfolio are explored. First, a hedge ratio of 1 is considered, which implies that the global portfolio manager hedges each currency in proportion to the weight of his portfolio in that currency. Secondly, a historically constructed *optimal hedge ratio* is constructed by using historical data on foreign exchange rates and the equity indices of each country to derive the optimal in-sample hedging weights. These weights are then used to produce in-sample tests of this strategy. Thirdly, a strategy of hedging with only a subset of the entire currencies in the global portfolio is exercised. In gauging their relative effectiveness, all three strategies are compared against the default of no currency hedging.

The purpose and appeal of the first strategy lies in its relative simplicity and ease of implementation, which makes it quite common among global portfolio managers. The second strategy — accounting for basis risk, and correlations among currencies and equity indices — is critically linked to the desire to find a more optimal approach to hedging. The purpose of the third strategy is motivated by practical considerations, mainly the global portfolio manager's intention to minimise both time and transaction costs. By using only a representative set of currencies to hedge, the global manager has fewer transactions to monitor and also saves on both transactions costs and potential forward premia. Although more complicated hedging techniques could be considered, this is not the main focus of the paper. The main focus is to analyse very simple, yet common techniques of hedging used by portfolio managers to determine how well they compared against a policy of no hedging in the years 1999–2006.

The remainder of the paper is structured as follows. The next section reviews some of the previous literature on the subject of currency hedging. The following section discusses the data sources used in the analysis. The next section examines the currency hedging issue for each individual country in isolation, ignoring the cross-correlation effects between countries. The penultimate section examines the issue from the perspective of a global portfolio manager, considering the cross-correlations of equity indices and currencies. It also considers specific global portfolios with different weightings attached to each country. The final section concludes.

Previous research

Previous studies generally support the idea of currency hedging in a global portfolio. Evidence in favour of hedging the currency risk of a global bond portfolio is presented in Thomas (1989).[1] Thomas (1988) finds that international equity portfolios benefit from currency hedging. Perold and Schulman (1988) claim that even after accounting for transaction costs due to hedging, currency hedging appears to be the dominant strategy for a global portfolio manager. They suggest using a hedge ratio of one, which is a compromise between the difficulty of finding the optimal hedge ratio and the losses from being imperfectly hedged. They also assume that in the long run the expected returns from currency hedging are zero. Cantaluppi (1994) finds that currency hedging is beneficial; however, he discourages the approach of separating the hedging and investment decisions. He makes the point that the covariance between the two must be

taken into account. Glen and Jorion (1993) find that hedging significantly improves the performance of portfolios containing bonds. They also propose certain dynamic hedging strategies that would significantly improve portfolio performance. Black (1989) also finds it beneficial to hedge currency risk and goes even further by defining the universal hedging formula. In fact, in his empirical work he finds that the universal hedging percentage ranges from 30 to 77 per cent. Kawaller (1989) states that 'A policy of not hedging is patently inappropriate.' He speaks primarily about corporations with foreign businesses. Solnik (1974) makes the case that currency hedging certainly leads to greater risk reduction in an international portfolio; however, that even an unhedged portfolio itself is also quite effective as opposed to a purely domestic investment. Gastineau (1995) suggests a 50 per cent hedged benchmark in order to improve long-range performance. He claims that it fits somewhere in between Black's universal hedging range, but it is chosen quite arbitrarily. Jorion (1994) finds that currency hedging is useful, but that *overlay strategies* tend to be sub-optimal because the correlations among the underlying assets and currencies are not taken into account. Arnott and Henriksson (1989) also support the view of currency hedging in a global portfolio. Adler and Jorion (1992) support currency hedging and search for alternative ways to find universal currency hedges.

Evidence against currency hedging over longer horizons, such as eight years, is presented in Froot (1993). He argues that because exchange rates are mean-reverting, over the long run, currency hedging only adds to the cost of managing the portfolio. But if portfolio managers are concerned with short-term results, then currency hedging will continue to be important. Winston and Bailey (1996) find that currency hedging *per se* may be too costly and that investors can hedge using other assets. A study by Hauser *et al*. (1994) finds that hedging currency risks in emerging equity portfolios might not be beneficial. In fact, they conclude that 'the hedging of currency risk is an inferior policy because of the negative correlations between the exchange rate and stock returns when measured in the local currencies of emerging markets.'

A treatment on reducing the transaction costs of international currency hedging is presented in Sorenson *et al*. (1993). They use mean–variance optimisation with a subset of the basket of currencies traded to hedge currency risks. The resulting portfolio returns exhibit lower volatility as compared to the unhedged case and do not require significant transactions in many currencies.

Finally, several authors have considered a strategy of dynamic hedging using GARCH-style models which attempt to account for time-varying volatilities (Yang and Allen, 2005). In their work, they compared the performance of a standard ordinary least squares (OLS) regression to estimate the hedge ratios, a VAR model, an error-correction model, and a multivariate GARCH model in hedging the Australian dollar. They find that the hedging performance of the more complicated GARCH-style models improves over long horizons at reducing the risk of the hedged portfolio over the other methods. They also find that this, however, comes at the cost of lower average returns. A drawback to this paper is that the results could be very specific to the Australian currency market and the time period of study.

Data

The majority of data for this study were obtained from Bloomberg. Some forward currency data were obtained from Goldman Sachs. The Bloomberg tickers and indices used are described in Table 1. The spot currency data were transformed in the number of dollars that can be purchased with one unit of foreign currency (ie $S_{\$/.}$). The

Table 1 Data sources

Country	Equity index	BB ticker	Currency name	BB currency ticker	BB futures tickers	Source
1. Australia	S&P/ASX 100 Index	AS25	Dollar	AUD	AD1	BB Future
2. Brazil	Brazil Bovespa Index	IBOV	Cruzeiro Real	BZL	BR1	BB Future
3. Britain	FTSE All Share	ASX	Pound Sterling	GBP	BP1	BB Future
4. Canada	S&P/TSX Comp	SPTSX	Dollar	CAD	CD1	BB Future
5. Denmark	KAX Copenhagen	KAX	Krone	DKK	DKK3M	BB Forward
6. Europe	DJ Euro Stoxx 50 Index	SX5E	Euro	EUR	EC1	BB Future
7. Hong Kong	Hang Seng index	HIS	Dollar	HKD	HKD3M	BB Forward
8. India	Mumbai Indian stock Index	SENSEX	Rupee	INR	INR3GS	GS Forward
9. Japan	Nikkei 225	NKY	Yen	JPY	JY1	BB Future
10. Mexico	Mexican Bolsa	MEXBOL	Peso	MXN	PE1	BB Future
11. New Zealand	New Zealand All Ordinary Index	NZSE	Dollar	NZD	ZX1	BB Future
12. Norway	OSE All Share	OSEAX	Krone	NOK	NOK3M	BB Forward
13. Singapore	Straight Times Index	STI	Dollar	SGD	SGD3M	BB Forward
14. South Africa	FTSE JSE Africa All Share	JALSH	Rand	ZAR	ZAR3M	BB Forward
15. South Korea	Korean Composite	KOSPI	Won	KRW	KRW3GS	GS Forward
16. Sweden	Stockholm All Share	SAX	Krona	SEK	SEK3M	BB Forward
17. Switzerland	Swiss Market Index	SMI	Franc	CHF	SF1	BB Future
18. Taiwan	Taiwan Thaiex Index	TWSE	Dollar	TWD	TWD3GS	GS Forward
19. Thailand	Thailand Stock Exchange	BGK	Baht	THB	THB3M	BB Forward

Note: Data obtained from Bloomberg and Goldman Sachs.

futures data were taken from the Bloomberg continuous futures contract series when available. This series is constructed by Bloomberg so that as a futures contract is maturing, it creates a continuous series by rolling the contract over into the new contract. When the series history for these futures was limited, Bloomberg forward currency data was used. In some cases, this was unavailable through Bloomberg and Goldman Sachs kindly supplied the forward currency data for India, South Korea, Taiwan, and Thailand. These series are indicated by a 'GS' at the end of their name. The stock indices are in local currency and usually chosen to be the most indicative of that particular country's equity market.

Table 2 presents the summary statistics for each country's equity index, spot currency returns, and forward currency returns for the entire time period for which data are available. For example, looking at Brazil, the Brazilian spot currency (BRL) had a −48.72 per cent annualised return from February 1992 to August 2006. It had an annualised standard deviation (SD) of 35.33 per cent. Moreover, it had a maximum monthly appreciation of 18.49 per cent and a minimum monthly depreciation of −41.06 per cent. Over this period, there were 175

Table 2 Summary statistics of equity, spot currency, and futures currency data

Country	BB ticker	Mean	SD	Max	Min	nobs	Begin date	End date
Australia	AUD	−0.88	10.05	9.26	−12.42	319.00	1980:02	2006:08
	AS25	8.54	12.29	8.05	−10.56	171.00	1992:06	2006:08
	AD1	0.92	9.83	7.18	−9.59	227.00	1987:10	2006:08
Brazil	BRL	−48.72	35.33	18.49	−41.06	175.00	1992:02	2006:08
	IBOV	122.29	83.74	100.00	−50.00	200.00	1990:01	2006:08
	BR1	−5.44	18.84	17.42	−38.08	129.00	1995:12	2006:08
Britain	GBP	−0.10	10.53	14.55	−12.31	319.00	1980:02	2006:08
	ASX	10.69	15.78	13.86	−26.60	319.00	1980:02	2006:08
	BP1	1.87	9.98	7.25	−11.79	243.00	1986:06	2006:08
Canada	CAD	0.32	5.24	4.65	−4.58	319.00	1980:02	2006:08
	SPTSX	8.05	16.04	14.27	−22.63	319.00	1980:02	2006:08
	CD1	1.46	5.73	4.93	−4.93	239.00	1986:10	2006:08
Denmark	DKK	0.34	10.89	8.53	−9.72	319.00	1980:02	2006:08
	KAX	13.63	16.44	11.97	−13.87	128.00	1996:01	2006:08
	DKK3M	1.44	10.03	7.75	−9.98	212.00	1989:01	2006:08
Europe	EUR	1.66	9.49	8.00	−5.08	92.00	1999:01	2006:08
	SX5E	9.11	18.56	14.27	−21.48	236.00	1987:01	2006:08
	EC1	2.08	9.45	8.03	−5.05	99.00	1998:06	2006:08
Hong Kong	HKD	−1.66	3.63	4.40	−9.57	319.00	1980:02	2006:08
	HSI	15.61	29.47	30.28	−43.20	319.00	1980:02	2006:08
	HKD3M	0.04	0.82	1.41	−1.23	212.00	1989:01	2006:08
India	INR	−6.41	6.09	4.93	−18.04	319.00	1980:02	2006:08
	SENSEX	21.38	29.49	51.36	−22.68	319.00	1980:02	2006:08
	INR3GS	−0.73	4.49	3.25	−4.57	84.00	1999:09	2006:08
Japan	JPY	3.39	12.01	17.66	−9.26	319.00	1980:02	2006:08
	NKY	5.21	19.62	20.07	−19.23	319.00	1980:02	2006:08
	JY1	2.58	12.00	17.33	−9.70	243.00	1986:06	2006:08
Mexico	MXN	−18.50	30.28	100.00	−50.20	319.00	1980:02	2006:08
	MEXBOL	44.86	39.78	43.67	−43.19	317.00	1980:02	2006:08
	PE1	−4.09	10.81	8.64	−10.21	136.00	1995:05	2006:08
New Zealand	NZD	−0.84	11.60	19.73	−22.00	319.00	1980:02	2006:08
	NZSE	6.38	14.89	13.63	−13.90	173.00	1992:04	2006:08
	ZX1	0.10	11.39	7.73	−7.63	111.00	1997:06	2006:08
Norway	NOK	−0.47	10.10	8.16	−11.26	319.00	1980:02	2006:08
	OSEAX	16.03	20.21	11.92	−22.89	128.00	1996:01	2006:08
	NOK3M	0.78	9.99	6.64	−9.77	212.00	1989:01	2006:08
Singapore	SGD	1.20	4.97	5.96	−5.25	307.00	1981:02	2006:08
	STI	9.43	25.54	28.20	−40.70	259.00	1985:02	2006:08
	SGD3M	1.32	5.28	6.70	−5.86	212.00	1989:01	2006:08
South Africa	ZAR	−7.04	14.82	15.08	−21.98	319.00	1980:02	2006:08
	JALSH	15.88	21.32	14.11	−29.63	134.00	1995:07	2006:08
	ZAR3M	−5.34	13.11	9.62	−14.44	212.00	1989:01	2006:08
South Korea	KRW	−0.86	9.84	18.03	−27.81	304.00	1981:05	2006:08
	KOSPI	13.75	29.40	50.77	−27.25	319.00	1980:02	2006:08
	KRW3GS	3.30	7.71	6.91	−6.29	84.00	1999:09	2006:08
Sweden	SEK	−1.49	10.80	7.70	−15.80	319.00	1980:02	2006:08
	SAX	17.30	21.81	27.15	−20.85	319.00	1980:02	2006:08
	SEK3M	−0.31	10.81	7.72	−15.44	212.00	1989:01	2006:08

Table 2 Continued

Country	BB ticker	Mean	SD	Max	Min	nobs	Begin date	End date
Switzerland	CHF	1.79	11.97	11.03	−10.01	319.00	1980:02	2006:08
	SMI	10.87	17.26	13.97	−18.93	217.00	1988:08	2006:08
	SF1	2.47	11.51	9.78	−9.67	244.00	1986:05	2006:08
Taiwan	TWD	0.92	5.18	7.05	−7.22	274.00	1983:11	2006:08
	TWSE	16.13	37.11	50.14	−38.95	319.00	1980:02	2006:08
	TWD3GS	−0.20	5.15	4.08	−3.80	84.00	1999:09	2006:08
Thailand	THB	−1.79	10.34	25.00	−22.20	307.00	1981:02	2006:08
	BGK	10.18	34.85	32.88	−29.98	228.00	1987:08	2006:08
	THB3M	−2.56	14.98	26.85	−16.62	128.00	1996:01	2006:08
United States	USD	NA	NA	NA	NA	319.00	NA	NA
	SPX	10.32	14.93	13.18	−21.76	319.00	1980:02	2006:08
	USDF	NA	NA	NA	NA	319.00	NA	NA

Note: Mean represents the annualised monthly mean returns. SD is the annualised standard deviation of monthly returns, Max and Min refer to the maximum and minimum returns in any given month over the investment horizon. nobs refers to the number of observations used to calculate the associated statistics. All data were obtained from Bloomberg, except symbols with a 'GS' in them. Those were obtained from Goldman Sachs.

monthly observations (nobs = 175). The Brazilian equity market (IBOV) had a 122.29 per cent annualised return from January 1990 to August 2006. It had an annualised SD of 83.74 per cent. It had a maximum monthly return of 100 per cent and a minimum monthly return of −50 per cent. There were 200 monthly observations used to construct these statistics.

For most of the currencies, the spot currency and the forward/future currency over the entire time period are strongly correlated.[2] For almost all of the currencies, the spot-forward monthly return correlations are higher than 0.97. Some currencies stand out as deviants. The mildest case is India, where the correlation is 0.92. A slightly more severe case is Mexico, where the correlation is 0.80. Mexico's large devaluations in 1982 and 1994 are also very apparent from the data. South Africa stands out in the sense that its forward rates are consistently lower than its spot rates.[3] The most severe case is Hong Kong, with a correlation of 0.41. This may be a result of the Asian crisis, when forward rates moved substantially away from spot rates. In the period between 1997 and 1998, one can see from Figure 1 that the Hong Kong Dollar three-month forward rate fluctuated quite a bit around the relatively flat spot rate. Hong Kong was one of the few Asian fixed-rate countries to effectively defend its currency during the Asian crisis. The huge devaluation of the Thai Baht also stands out, a near 50 per cent devaluation during the Asian crisis (see Figure 1).

For a global portfolio manager, hedging effectiveness will also depend on the correlations between the returns of the currency futures, currency spot rates, and equity markets of various countries. All the results of this paper use monthly returns.[4]

The average correlation across all currencies is 0.249.[5] Thus, there seems to be quite a bit of currency diversification from just holding a global basket of currencies. Holding a global currency basket actually reduces the aggregate currency risk through the power of diversification. In some extreme cases, such as MEX-EUR, the correlation is actually negative (−0.23), such that when the Mexican peso depreciates, the Euro might actually be appreciating. For a global portfolio manager, this reduces his effective exchange rate risk. In fact, it might

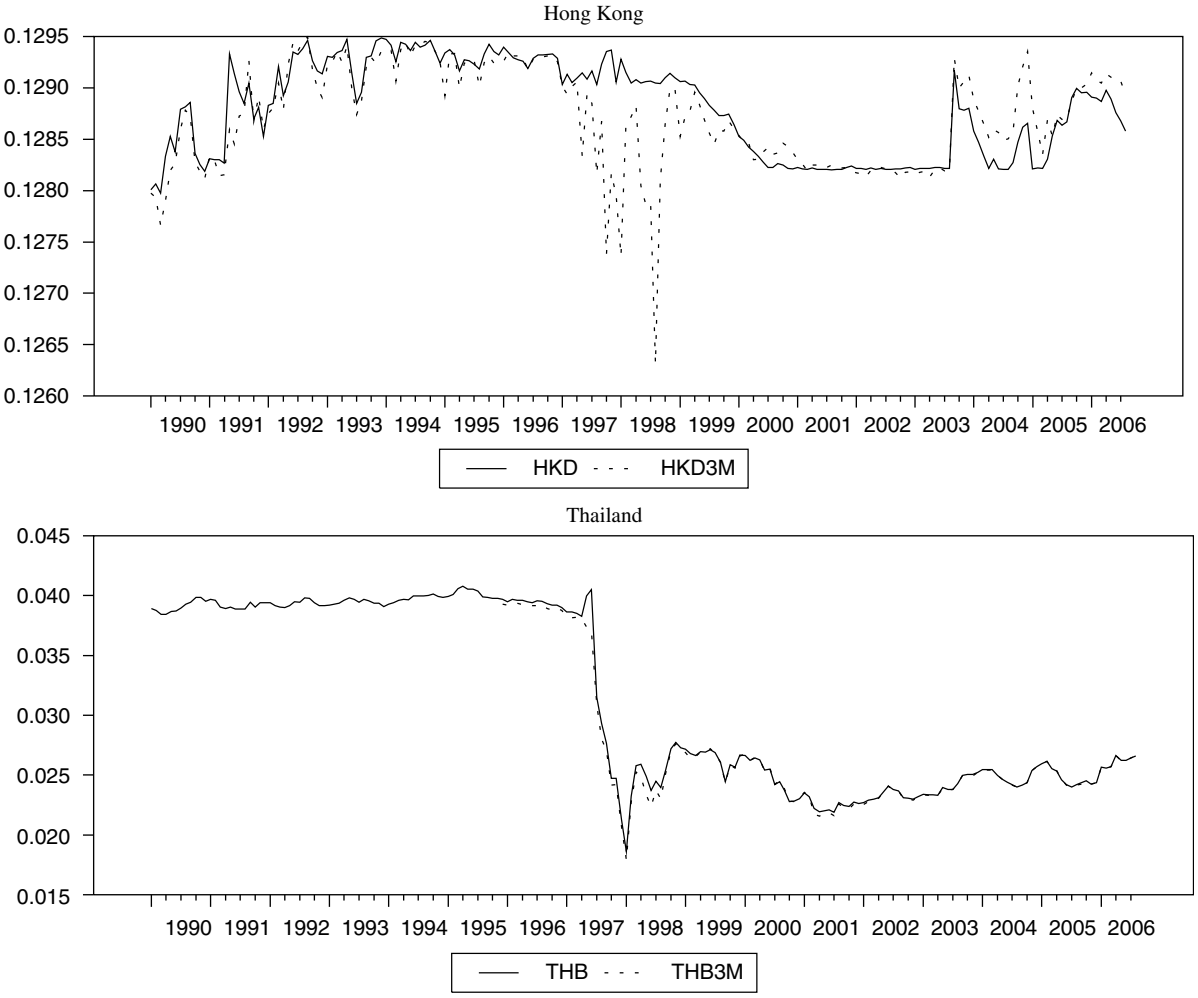

Figure 1 Hong Kong Dollar and Thailand Baht spot and forward rates versus the USD

make the investment manager consider more seriously a hedge ratio of less than 1.[6]

It may also be insightful to examine the correlations between the equity indices of each country and the spot currencies. This will be another form of diversification. It has been documented that in emerging markets during the period 1986–91, currency hedging was less effective due to the negative correlation between equity market returns and currency movements (Hauser *et al.*, 1994).

For many countries, the underlying equity index is negatively correlated with the return in the spot currency. For example, in Brazil, the monthly return of the BRL has a −0.5 correlation with the IBOV. Thus, on an average, when the IBOV has a positive monthly return, the BRL actually depreciates against the dollar. A similar phenomena can be seen in other countries such as Great Britain, Denmark, Europe, India, Norway, Sweden, and Switzerland.

Finally, an examination of the correlations among equity indices in the investment manager's global portfolio reveals that investments limited to Western countries limits the amount of diversification of a USD-based portfolio. The real diversification benefits come from countries such as Brazil, India, Mexico, South Korea, Taiwan, and Thailand. The average cross-correlation of these equity markets with the US equity market is 0.219.

Currency hedging in a single currency

There are a variety of instruments that an investment manager can use to hedge the foreign currency risk of a single investment in a foreign country. In this paper, only futures and forwards contracts are used for hedging.

Methodology

In this section, the words futures and forward contract are used interchangeably throughout. All the hedging techniques used in this paper are passive hedging techniques; thus, it is assumed that the investment manager has no *exchange rate forecasting model*. The hypothetical global portfolio's base currency is US dollars.

Let $R_{i,\$}$ be the returns of an equity investment in country i in terms of USD, let R_i represent the returns of the equity investment in country i in the local currency, let s equal the percentage change in the exchange rate over the investment horizon, that is $s=(S_{t+1}-S_t)/S_t$, where S is the spot exchange rate expressed as dollars that can be purchased with one unit of foreign currency. Thus, when $s>0$, the domestic currency (eg USD) has depreciated, and vice versa. We can represent the returns in USD as:

$$\begin{aligned} 1+R_{i,\$} &= \frac{S_{i,t+1}}{S_{i,t}}(1+R_i) \\ &= (1+s_i)(1+R_i) \\ &= (1+R_i)+s_i(1+R_i) \end{aligned} \tag{1}$$

Thus,

$$R_{i,\$} = R_i + s_i(1+R_i) \tag{2}$$

This says that the return to the global portfolio manager in USD is equal to the foreign equity market return in local currency (R_i) plus the exchange rate return adjusted for the foreign market return in local currency [$s_i(1+R_i)$]. Let $R_{i,F}$ represent the return of the futures contract over the investment horizon for currency i versus the dollar, and let $R^H_{i,\$}$ represent the returns in USD for an investment manager who uses currency futures to hedge his foreign exchange exposure to an investment in country i. The hedged returns can be represented as:

$$R^H_{i,\$} = R_{i,\$} - hR_{i,F} \tag{3}$$

where h is the hedge ratio used by the investment manager.[7] This equation says that the hedged return to the investment manager is equal to the unhedged USD return minus the return from the futures position.

The global portfolio manager has no currency views whatsoever and would like to minimise the return differential between the hedged USD return and the local currency return. In other words, the investment manager would like to eliminate all of the exchange rate risk and be left with only the equity return of the country that he believed would perform well. Thus, the investment manager would like to minimise

$$\min_h \quad \left(R^H_{i,\$} - R_i\right) \tag{4}$$

The investment manager can choose any value of h he wishes. A very common method of hedging currency risk with futures contracts is to *dollar hedge* or to use a value of h equal to 1.

Rather than by considering the pure deviation of returns of the hedged portfolio and the portfolio returns in the local currency, optimal currency hedging is usually performed by minimising the variance of Equation (4). The variance of the expression is

$$\begin{aligned} &\mathrm{Var}(R^H_{i,\$} - R_i) \\ &\quad = \mathrm{Var}(R_{i,\$} - hR_{i,F} - R_i) \\ &\quad = \mathrm{Var}(s_i(1+R_i) - hR_{i,F}) \end{aligned} \tag{5}$$

where Var represents the variance function.[8]

In order to find the optimal hedge ratio that minimises this variance, an OLS estimation is performed on historical data.[9] That is, the following equation is estimated:

$$s_i(1 + R_i) = \alpha + \beta R_{i,F} + \varepsilon \quad (6)$$

where the estimate of β, $\hat{\beta}$ will be the estimate of h.

Empirical analysis

Table 3 shows the estimates of the optimal hedge ratio for various countries using various future contracts for a one-month investment horizon.

The first column of this table is the estimate of the constant, which in all cases is equal to 0. The second column contains the β of the regression or the *optimal hedge ratio.* The $\bar{R}^2$ describes how well the model fits the data (a value of 1 is preferred). For most of the currencies, a hedge ratio near 1 is the most optimal. For some currencies, however, hedge ratios less than/greater than one are preferred. For Hong Kong, a hedge ratio of 0.23 is optimal given the data. This might be distorted by the Asian crisis and the Hong Kong Monetary Authority's attempt to maintain the peg. For Mexico, the optimal hedge ratio is 0.61. In this case, further investigation may be warranted as well due to the pegged rates and devaluations. For Brazil, the optimal hedge ratio is 1.15.

The final step in this analysis is to compare the in-sample performance of these hedging strategies.[10] Four hedging approaches are examined. The first method is simply to not hedge the currency risk ($h = 0$). The second method is to hedge using a hedge ratio of 0.5 ($h = 0.5$); the third method uses a hedge ratio of 1 ($h = 1$); and the fourth method uses the optimal hedge ratio ($h = h^*$). The results are presented in Table 4.

Let us focus on some of the results in Table 4. First, for every foreign investment, some form of currency hedging *reduces* the volatility of USD returns. Secondly, for the majority of currencies (13 out of 19) the Sharpe ratio (SR)[11] of the portfolio is increased by hedging. The six countries whose SR decreases are Britain, Europe, Japan, Singapore, South Korea, and Switzerland. Thirdly, the average SR increases by 0.019 (from 0.283 to 0.302) from $h = 0$ to $h = 0.5$. It increases further to

Table 3 Optimal single currency hedge ratios

Currency	α	β	$\bar{R}^2$	nobs
AUD	0.00	0.98	0.98	171.00
BRL	0.00	1.15	0.94	129.00
GBP	−0.00	0.99	0.98	243.00
CAD	0.00	0.96	0.97	239.00
DKK	−0.00	1.01	1.00	128.00
EUR	−0.00	0.98	0.99	92.00
HKD	0.00	0.23	0.17	212.00
INR	−0.00	0.74	0.83	84.00
JPY	0.00	0.98	0.97	243.00
MXN	−0.00	0.61	0.62	136.00
NZD	0.00	0.97	0.97	111.00
NOK	−0.00	1.00	0.99	128.00
SGD	0.00	0.95	0.95	212.00
ZAR	−0.00	0.99	0.99	134.00
KRW	0.00	0.98	0.97	84.00
SEK	−0.00	1.05	0.99	212.00
CHF	−0.00	0.98	0.98	217.00
TWD	0.00	0.81	0.92	84.00
THB	0.00	1.02	0.91	128.00
USD	NA	NA	NA	NA

Note: Optimal hedge ratios were estimated over the sample period for each spot-forward currency pair. The estimate of β is the hedge ratio.

0.311 with full hedging, it increases to 0.308 using the optimal hedge ratio. In our specific case, the average SD of portfolio returns decreases from 25 to 22.1 per cent from no hedging, compared to a hedge ratio of 1, while the average mean return actually increases from 10.56 to 10.71 per cent. This could very well be a time period-specific bias.

Overall, the results indicate that, for the time period examined, the best approach for a global manager who has invested in a single foreign country is to use a hedge ratio of 1. The next section examines the hedging results of a global portfolio manager who has invested in many countries simultaneously.

Currency hedging for a global portfolio

With a multi-currency global portfolio, the investment manager has several options. Perhaps the most obvious method is to hedge each currency individually. Given the high correlation among some currencies, the manager, however, may not need to hedge all currencies. Also, given the less than perfect correlation among currencies, the manager may not need to hedge as much of an exposure as a currency-by-currency approach would entail.

In this section, two basic strategies for multiple-currency hedging are investigated. One method considers hedging each currency in isolation, and the other method takes the correlation among currencies into account.

Methodology

Using a logic similar to the one for hedging single currency exposures, let us denote the USD return of a global portfolio as, $R_\$$. This is equal to:

$$R_\$ = \sum_{i=1}^{N} w_i[R_i + s_i(1 + R_i)] \tag{7}$$

where N is the number of countries that the global portfolio is invested in, R_i is the local equity return in country i, w_i is the weight of the global portfolio in country i, and s_i is the change in the exchange rate over the investment horizon for currency i with respect to the US dollar. This global portfolio can also include USD investments. In this case, s_i would equal 0. The hedged USD return of a global portfolio is given by

$$R_\$^H = \sum_{i=1}^{N} w_i[R_i + s_i(1 + R_i)] - \sum_{j=1}^{N} h_j R_{j,F} \tag{8}$$

where w_i is the portfolio's weight in country i, N is the number of currencies used to hedge the global portfolio, h_j is the hedge ratio for currency j, and $R_{j,F}$, is the futures return over the investment period for currency j.

This expression can be simplied further as follows:

$$R_\$^H = \sum_{i=1}^{N} w_i R_i + \sum_{i=1}^{N} w_i s_i(1 + R_i) - \sum_{j=1}^{N} h_j R_{j,F} \tag{9}$$

$$R_\$^H - \underbrace{\sum_{i=1}^{N} w_i R_i}_{R} = \sum_{i=1}^{N} w_i s_i(1 + R_i) - \sum_{j=1}^{N} h_j R_{j,F} \tag{10}$$

$$R_\$^H - R = \sum_{i=1}^{N} w_i s_i(1 + R_i) - \sum_{j=1}^{N} h_j R_{j,F} \tag{11}$$

The goal of the global portfolio manager is to find the value of the hedge that minimises the variance of this expression. It will also depend on the weights of the equity investments in each foreign country. Thus, the set of optimal hedge ratios will depend critically on the composition of the global portfolio.

Table 4 Single currency hedging performance

	h=0			*h*=0.5			*h*=1			*h*=*h**				
Country	**Mean**	**SD**	**SR**	**Mean**	**SD**	**SR**	**Mean**	**SD**	**SR**	**Mean**	**SD**	**SR**	**Begin Date**	**End Date**
Australia	9.416	17.770	0.320	9.144	14.456	0.374	8.873	12.238	0.421	8.882	12.288	0.420	1992:06	2006:08
Brazil	22.584	44.589	0.424	25.305	38.760	0.558	28.027	34.554	0.705	28.847	33.702	0.747	1995:12	2006:08
Britain	9.306	16.696	0.290	8.373	15.615	0.250	7.440	16.083	0.185	7.455	16.063	0.186	1986:06	2006:08
Canada	9.842	17.825	0.302	9.113	16.242	0.287	8.384	15.044	0.261	8.445	15.128	0.264	1986:10	2006:08
Denmark	13.180	16.294	0.583	13.171	15.687	0.606	13.163	16.382	0.581	13.163	16.407	0.580	1996:01	2006:08
Europe	4.932	20.034	0.090	4.147	19.244	0.053	3.362	19.625	0.012	3.398	19.582	0.014	1999:01	2006:08
Hong Kong	14.158	26.735	0.369	14.138	26.577	0.371	14.119	26.425	0.372	14.149	26.663	0.370	1989:01	2006:08
India	14.813	25.627	0.459	15.176	24.493	0.495	15.540	23.519	0.531	15.354	23.997	0.513	1999:09	2006:08
Japan	4.865	24.914	0.016	3.574	22.480	−0.040	2.284	21.494	−0.101	2.335	21.503	−0.099	1986:06	2006:08
Mexico	20.344	30.049	0.551	22.390	27.875	0.668	24.436	26.638	0.775	22.859	27.503	0.694	1995:05	2006:08
New Zealand	3.591	20.318	0.008	3.543	16.668	0.007	3.496	14.412	0.005	3.499	14.494	0.005	1997:06	2006:08
Norway	16.447	21.982	0.580	16.177	20.489	0.610	15.908	20.074	0.610	15.909	20.074	0.610	1996:01	2006:08
Singapore	10.610	25.980	0.243	9.950	24.771	0.229	9.291	23.794	0.210	9.353	23.875	0.212	1989:01	2006:08
South Africa	11.020	26.428	0.275	13.401	22.393	0.431	15.781	20.644	0.584	15.753	20.649	0.582	1995:07	2006:08
South Korea	13.047	31.506	0.318	11.397	29.901	0.280	9.746	28.727	0.234	9.828	28.774	0.237	1999:09	2006:08
Sweden	11.251	22.547	0.309	11.406	21.400	0.332	11.561	21.586	0.337	11.577	21.680	0.336	1989:01	2006:08
Switzerland	12.183	17.286	0.453	11.226	16.479	0.417	10.268	17.483	0.339	10.306	17.412	0.342	1988:08	2006:08
Taiwan	0.670	29.178	−0.079	0.771	27.982	−0.079	0.872	26.980	−0.078	0.834	27.338	−0.079	1999:09	2006:08
Thailand	−1.579	40.061	−0.130	−0.302	36.185	−0.109	0.976	33.556	−0.079	1.032	33.474	−0.078	1996:01	2006:08
United States	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Average	10.562	25.043	0.283	10.637	23.037	0.302	10.712	22.066	0.311	10.683	22.137	0.308	NA	NA

Note: The Single Currency hedging performance is computed over the sample period where all relevant variables exist. The hedging techniques range from *h*=0 (no hedging), *h*=0.5 (a hedge ratio of 0.5), *h*=1 (a hedge ratio of 1), and *h*=*h** (the optimal in-sample single currency hedge ratio). The mean is the annualised mean of the monthly average returns, the SD is the annualised standard deviation of monthly returns, and SR is the Sharpe ratio constructed as the average of the monthly returns of the portfolio minus the monthly return of the one-month Treasury bill divided by the volatility of this term.

Three methods are employed to hedge the global portfolio. In the first method, the investment manager simply assesses his global investment position in each country and hedges the entire position using a hedge ratio of 1.

In the second method, the investment manager minimises the variance of the right-hand side of Equation (11). This may lead to hedging all or some of the currencies according to the weightings that minimise variance. The hedging parameters are actually chosen by running the following linear regression on the historical monthly data:

$$\sum_{i=1}^{N} w_i s_i (1 + R_i) = \alpha + \beta_1 R_{1,F} + \beta_2 R_{2,F} + \cdots + \beta_N R_{N,F} + \varepsilon \qquad (12)$$

where there is a β_i estimate for each currency i, which in turn will be the estimate of h_i, the hedging weight for currency i.

The third method is to use an optimal representative hedge, which attempts to find three currencies that can be used to hedge the entire portfolio. To choose the three currencies for each global portfolio, a step-wise linear regression is estimated on all combinations of the three currencies available.[12] The three best currencies are chosen for the currency hedging using the estimates of β on the subset of currencies as the optimal hedge ratios.[13]

The concept of the optimal representative hedge may be beneficial for global portfolio managers for several reasons. At a very transparent level, this may save on administrative hassle (ie one does not have to hedge in every country one invests in), allows one to avoid countries whose FX markets are very illiquid or inefficient, and may save on transaction costs by avoiding illiquid markets.

Empirical analysis

The global portfolios are analysed from 1999 to 2006, partly due to focusing on the situation after the Asian crisis and also due to data availability. The forwards and futures for most emerging market countries could only be obtained starting in 1999 (see second section on data), and also the Euro did not exist prior to 1999. In order to determine the various benefits from hedging a global portfolio during the period from 1999 to 2006, several global portfolios are constructed. The global portfolio weights are listed in Table 5. A Benchmark portfolio and four other portfolios are considered. The Benchmark portfolio is invested in each country's equity market according to each country's relative stock market capitalisation as of the end of 1999.[14] The other portfolios are tilted towards specific regions of the world: Asia, Europe, South America, and one portfolio is equally weighted among regions of the world. The Benchmark portfolio is itself significantly weighted towards US equities. Asian equities comprise 16.88 per cent, Europe is 31.22 per cent, and South America is a mere 1.1 per cent of the portfolio.

For each portfolio, the optimal unconstrained currency hedging weights using in-sample data are presented in Table 6. For each portfolio, the three best currencies for hedging are listed in Table 7 along with the weights of these currencies that would most accurately hedge the currency exposure. The $\bar{R}^2$ is also shown to give the reader an idea of how well the three currencies tracked the global currency exposure of the portfolio.

The final step in this analysis is to compare the in-sample performance of various hedging strategies for a global portfolio manager.[15] Five approaches are examined. The first method is simply to not hedge the currency risk (Unhedged). The second method is to hedge using a hedge ratio of 1 for all countries in which the fund manager has invested in proportion to the weighting of that country in the global portfolio (Hedged ($h = 1$)). The third method uses only the three best currencies from the

Table 5 Weights of various countries for various global portfolios

Country	Benchmark	Asia tilt	Europe tilt	South America tilt	Equal weight
Australia	1.15	1.59	1.00	0.00	0.00
Brazil	0.51	0.51	0.51	41.66	11.59
Britain	8.99	1.00	25.89	0.00	7.19
Canada	2.04	1.00	1.00	1.00	1.04
Denmark	0.37	0.37	1.07	0.37	0.30
Europe	17.76	1.00	50.99	1.00	14.22
Hong Kong	1.10	15.00	1.00	1.10	1.63
India	0.43	10.00	0.43	0.43	0.64
Japan	12.87	15.00	1.22	1.00	19.04
Mexico	0.59	0.59	0.59	48.34	13.41
New Zealand	0.07	0.07	0.07	0.07	0.00
Norway	0.17	0.17	0.73	0.17	0.14
Singapore	0.50	10.00	0.50	0.50	0.74
South Africa	0.55	0.55	0.55	0.40	0.00
South Korea	0.71	15.00	0.71	0.71	1.05
Sweden	1.26	1.00	3.63	1.00	1.01
Switzerland	2.67	1.00	7.69	1.00	2.14
Taiwan	1.12	12.50	1.12	0.10	1.66
Thailand	0.15	12.50	0.15	0.00	0.24
USA	46.99	1.15	1.15	1.15	23.96
Regions					
North America	49.03	2.15	2.15	2.15	25.00
Europe	31.22	4.54	90.00	3.54	25.00
Asia	16.88	90.00	5.13	3.84	25.00
South America	1.10	1.10	1.10	90.00	25.00
Others	1.77	2.21	1.62	0.47	0.00

Note: Weights represent the weights of a global portfolio manager in each of the listed countries. A 4.23 weight should be interpreted as the global portfolio having 4.23 per cent of its investable dollars in that particular country's equity index.

previous analysis to hedge the global portfolio (Hedged with Three Best). The fourth method uses three relatively liquid currencies, JPY, EUR, and GBP, with a hedge ratio of 1 to hedge the global portfolio (JPY–EUR–GBP). That is, an amount equal to 33 per cent of the exposure of the entire global portfolio is used to hedge in each of these three currencies, and the fifth method hedges all currencies according to the in-sample optimal weights presented in Table 6 (Unconstrained Optimal Hedge). The results are presented in Table 8 and in Figure 2.

Let us focus on some of the results in Table 8. The discussion will focus primarily on the Benchmark portfolio hedging results, given its reflection of the market capitalisation weighted global portfolio. First, by observing the Local Currency risk versus the Unhedged risk, one can see that risk rises about 0.49 per cent per annum from foreign exchange risk. For other global allocations, the rise is between 1.5 and 5 per cent. It is highest for the South American global portfolio, where foreign exchange risk plays a large role. Secondly, since we are most concerned with the question of whether currency hedging is really beneficial in the global portfolio case, the two rows labelled Unhedged and Hedged ($h = 1$) are of most interest. One can see that for the Benchmark case, the risk decreases by 0.50 per cent from hedging, thus bringing the risk of the global portfolio closer to that of the local currency risk and accomplishing its purpose. One will also notice that the mean return of the global portfolio decreases, representing in part the cost of hedging. Thirdly, we should examine the SR to determine whether the reduction in risk from hedging more than compensated for the increase in costs in terms of mean return. In the Benchmark case, the SR

Table 6 Optimal currencies and weights

Futures market	Benchmark	Asia tilt	Europe tilt	South America tilt	Equal tilt
Australia	0.020	0.027	0.015	−0.086	−0.010
Brazil	0.002	−0.004	0.005	0.462	0.123
Britain	0.093	0.014	0.268	0.005	0.075
Canada	0.023	0.024	0.017	0.051	0.024
Denmark	0.302	0.098	0.580	0.174	0.343
Europe	−0.123	−0.105	−0.054	−0.121	−0.191
Hong Kong	−0.083	0.008	−0.178	−0.291	−0.157
India	−0.003	0.068	0.015	0.053	0.006
Japan	0.121	0.130	0.011	0.032	0.185
Mexico	0.021	0.027	0.023	0.319	0.109
New Zealand	−0.007	−0.012	−0.012	0.042	0.004
Norway	−0.003	0.008	−0.007	0.018	0.003
Singapore	0.020	0.119	−0.005	−0.211	−0.022
South Africa	0.009	0.008	0.012	−0.007	−0.000
South Korea	−0.001	0.143	−0.018	0.000	0.004
Sweden	0.015	0.005	0.041	0.139	0.048
Switzerland	0.028	0.025	0.081	−0.067	−0.001
Taiwan	0.019	0.131	0.034	−0.022	0.016
Thailand	−0.002	0.105	−0.003	−0.042	−0.015
United States	NA	NA	NA	NA	NA
R^2	0.995	0.988	0.997	0.919	0.969

Note: The weights represent the in-sample optimal weights. Thus, for the benchmark, the optimal weighting would be to put 2 per cent of the portfolio value in AUD futures, 0.2 per cent in BRL futures, 9.3 per cent in the GBP futures, and so on. These optimal weights do not need to add up to 100 per cent.

decreases from 0.0076 to −0.0638. Thus, although hedging reduced the global portfolio's overall risk, it reduced the return sufficiently to reduce the overall risk-adjusted return.[16] This may be the relevant criterion for a fund manager wishing to decide whether to hedge or not. In fact, the SR decreased for all global portfolios, except the one heavily invested in South America. The SR decreased substantially for the European tilted portfolio (from 0.1492 to −0.0145). Fourthly, for all of the portfolios except the European-tilted and the Benchmark portfolio, the in-sample unconstrained optimal hedge did not improve the SR over a simple hedge ratio of 1 for each currency. The main reason the SR decreased by hedging is due to the steady depreciation of the US dollar throughout this period. Fifthly, hedging with the three most optimal currencies produced results that are as effective as either the simple hedge ratio of 1 for every currency or the unconstrained optimal hedge. Sixthly, hedging with the three very liquid currencies of JPY–EUR–GBP did not work well at reducing risk for almost all of the global portfolios, as would be expected.

From this preliminary analysis, it seems that whether hedging a global currency portfolio was better than not hedging a global portfolio during the period 1999–2006 depended on the degree of depreciation of the US dollar versus the currencies of countries in which the global portfolio manager was heavily invested in. The greater the depreciation, the worse was the hedging performance. For all of the global portfolios, except the one heavily invested in South America, currency hedging did not improve, and in some circumstances, significantly decreased the SR.

These results are based only on a small sliver of historical data (from 1999 to 2006) due to data constraints. It would certainly prove useful to investigate a prior time period, especially during the Asian crisis, where presumably the risk of not hedging was much greater. Overall, the results

Table 7 Representative optimal currencies and weights

Global portfolio	Currency 1	Currency 2	Currency 3	$\bar{R}^2$
Benchmark	GBP 0.09641	DKK 0.23066	JPY 0.14	0.98
Asian tilt	JPY 0.17018	KRW 0.20438	THB 0.20	0.93
European tilt	GBP 0.27304	DKK 0.64070	ZAR 0.02	0.99
South American tilt	BRL 0.52022	MXN 0.31089	CHF 0.06	0.95
Equal weight	BRL 0.15038	DKK 0.20473	JPY 0.19	0.94

Note: These optimal currencies were chosen in-sample. The weights represent the optimal weights. Thus, for the benchmark, the optimal weighting would be to put 9.64 per cent of the portfolio value in GBP futures, 23.1 per cent in DKK futures, and 14 per cent in the Euro. These optimal weights do not need to add up to 100 per cent.

Table 8 Multiple currency hedging performance

	Mean	SD	Max	Min	SR	Begin date	End date
Benchmark Portfolio							
Local currency	2.12	14.30	7.68	−11.11	−0.0605	1999:09	2006:08
Unhedged	3.10	14.79	8.54	−11.43	0.0076	1999:09	2006:08
Hedged (h=1)	2.08	14.29	7.69	−11.12	−0.0638	1999:09	2006:08
Hedged with 3 best	2.19	14.54	7.93	−11.31	−0.0547	1999:09	2006:08
JPY–EUR–GBP	1.32	15.13	7.43	−11.11	−0.1100	1999:09	2006:08
Unconstrained optimal hedge	2.13	14.32	7.68	−11.15	−0.0600	1999:09	2006:08
Asian tilt							
Local currency	6.44	17.38	12.26	−13.44	0.1974	1999:09	2006:08
Unhedged	7.44	19.10	12.67	−14.31	0.2312	1999:09	2006:08
Hedged (h=1)	6.72	17.18	12.31	−13.14	0.2158	1999:09	2006:08
Hedged with 3 best	6.78	17.36	12.57	−13.55	0.2168	1999:09	2006:08
JPY–EUR–GBP	5.66	19.32	14.37	−14.49	0.1374	1999:09	2006:08
Unconstrained optimal hedge	6.71	17.33	12.31	−13.19	0.2130	1999:09	2006:08
European tilt							
Local currency	2.99	16.66	11.31	−14.87	−0.0001	1999:09	2006:08
Unhedged	5.58	17.32	13.46	−14.46	0.1492	1999:09	2006:08
Hedged (h=1)	2.75	16.65	11.32	−14.85	−0.0145	1999:09	2006:08
Hedged with 3 best	2.85	16.87	11.34	−15.02	−0.0084	1999:09	2006:08
JPY–EUR–GBP	3.80	16.86	12.35	−14.14	0.0482	1999:09	2006:08
Unconstrained optimal hedge	2.93	16.72	11.33	−14.88	−0.0038	1999:09	2006:08
South American tilt							
Local currency	20.89	22.74	18.70	−15.16	0.7853	1999:09	2006:08
Unhedged	21.63	28.84	21.89	−19.86	0.6452	1999:09	2006:08
Hedged (h=1)	22.42	22.88	20.26	−13.89	0.8470	1999:09	2006:08
Hedged with 3 best	22.41	22.65	20.10	−13.93	0.8551	1999:09	2006:08
JPY–EUR–GBP	19.85	29.11	21.06	−20.26	0.5789	1999:09	2006:08
Unconstrained optimal hedge	22.13	22.82	20.16	−14.56	0.8369	1999:09	2006:08
Equal weight							
Local currency	7.01	15.86	9.93	−11.25	0.2527	1999:09	2006:08
Unhedged	7.88	17.83	10.85	−13.34	0.2730	1999:09	2006:08
Hedged (h=1)	7.40	15.78	10.03	−10.92	0.2783	1999:09	2006:08
Hedged with 3 best	7.39	16.00	9.82	−11.48	0.2742	1999:09	2006:08
JPY–EUR–GBP	6.10	17.99	10.02	−13.21	0.1726	1999:09	2006:08
Unconstrained optimal hedge	7.35	15.84	10.30	−10.98	0.2743	1999:09	2006:08

Note: The Global portfolio hedging performance is computed over the sample period where all relevant variables exist. Local currency is the no hedge case, Unhedged USD represents the returns of the global portfolio in USD without hedging, Hedged (h=1) represents the global portfolio return in USD with a hedge ratio of 1 in every currency, Hedged with 3 best represents the hedging performance of the three most representative currencies with their appropriate optimal hedging weights, JPY–EUR–GBP represents the hedging performance using the three liquid currencies mentioned with a hedge ratio of 1, and the Unconstrained optimal hedge is the hedging performance using the optimal in-sample hedge ratio with no constraints on the number of hedging currencies. The mean is the annualised mean of the monthly average returns, the SD is the annualised standard deviation of monthly returns, and SR is the Sharpe ratio. Max refers to the maximum monthly return during the sample period. Min refers to the minimum monthly return during the sample period.

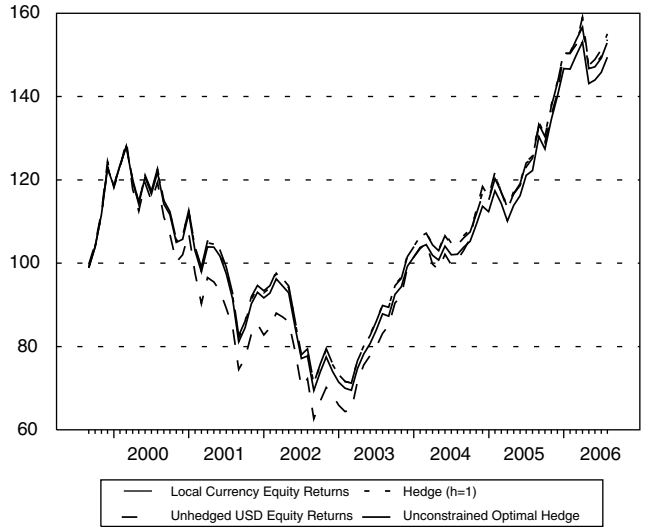

Figure 2 Local currency, unhedged USD, and hedged indices

indicate how detrimental global currency hedging can be on a risk-adjusted return basis when the home currency is depreciating.

Conclusions

In contrast to perceived wisdom, hedging currency risk during the period 1999–2006 was not beneficial for global portfolio managers with exposures to equity markets in selected key industrialised and emerging market countries. Specifically, it did not significantly reduce the monthly volatility of the portfolio and neither did it improve the risk-adjusted return performance of the portfolio. In fact, in some global portfolios, it actually reduced the efficiency of the portfolio investment by significantly reducing the SR. On the positive side, currency hedging did bring the US dollar returns more in line with those of the local currency returns, which was the original objective of hedging in the first place.

For global portfolio managers with positions in many countries, it is found that perhaps surprisingly, currency diversification does substantially lower portfolio risk. Another finding is that an in-sample optimal hedge, while effective, produced similar risk-return results as a strategy of hedging every currency with a hedge ratio of 1. In addition, hedging with an optimal representative sample of three currencies — thus minimising transaction costs and other hedging costs — was as effective as hedging each currency with a hedge ratio of 1. These are indeed encouraging results for practitioners, particularly since a persistence of this phenomenon in the future would imply a considerable reduction of administrative and financial costs from hedging a global portfolio.

Given the evidence from recent data on emerging markets and selected industrialised countries from 1999 to 2006, global portfolio managers did not need extremely sophisticated methods to hedge their currency risk in the absence of specific currency views. Even simple hedging yielded satisfactory results. Nonetheless, it is important to remember that hedging is not necessarily an optimal investment strategy over any given time period; in the context of this analysis, the best performance would have been achieved by leaving the portfolio *unhedged* as the US dollar depreciated consistently from 1999 to 2006.

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Notes

1. In particular, he concerns himself with *rolling forward hedging;* the rolling over of short-dated (three to six months) forward contracts.
2. Correlation tables are available from the author upon request.
3. This needs to be investigated. It could be a data error or a backwardation due to demand–supply conditions in the ZAR forward market, but it seems unlikely.
4. It may be worth looking at how the statistics change over various horizons, such as a 3-month, 6-month, and 12-month horizon.
5. This does not include own-currency correlations.
6. Let us construct a brief example to illustrate the point. Suppose a global manager invests in two countries, A and B. Country A and country B's exchange rates have the following volatility versus the home currency, 0.10 (or 10 per cent). Suppose the manager has 50 per cent invested in country A and B, respectively. If the correlation between the currencies is perfect (ie 1), then the manager will experience an additional 10 per cent currency volatility from the positions. The only way to eliminate all currency risk is to use a hedge ratio of 1 for each currency (ie 0.5 for country A and country B). Suppose the correlation was -0.25 between the currencies. This would tell the manager that his currency risk from the investments is 0.0612 (or 6.12 per cent). Thus, almost half of what each individual currency is. This is the splendour of diversification. It is still the case that to remove all foreign exchange rate risk, a hedge ratio of 1 in each currency is however needed. Given the costs of hedging (ie the interest rate differential), he may, however, choose a smaller hedge ratio. In this specific case, a hedge ratio of 0.5 reduces the total exchange rate risk to 3.06 per cent. A manager may be content with this level of risk, given the costs of hedging the currency, especially exotic currencies. A hedge ratio of 0.80 for each currency would reduce the risk to 1.22 per cent. A hedge ratio of 0.95 would reduce it to 31 bps. It should be emphasised that the only way to remove all exchange risk is a hedge ratio of 1 in both currencies. Of course, this neglects basis risk and other issues.
7. The hedge ratio in this paper is defined as $h = (N_f \cdot \text{Size of Contract} \cdot F_t)/V_t$. This is known as dollar matching; some investment professionals prefer to define the hedge ratio in equal positions, where the price of the futures contract would be replaced with the par value of the futures or spot price of the underlying contract.
8. The expression in Equation (5) can be reduced to Var $(s_i + s_i R_i - hR_{i,F})$. If we take the variance of this expression and differentiate with respect to h and set this equal to 0, we will find the optimal hedge ratio. Without any approximations, $h^* = (\text{Cov}(s_i, R_{i,F}) + \text{Cov}(s_i R_i, R_{i,F}))/(\text{Var}(R_{i,F}))$.
9. There are various issues with computing optimal hedge ratios from linear regressions. These include that the assumptions of normality of the errors may not be valid, especially in foreign exchange, that the relationship between the dependent and independent variables is not linear, and perhaps, most devastating is that the estimated hedge ratios are *unstable* over time.
10. It might be worthwhile at some point to investigate whether different maturity contracts are better for hedging, although in the grand scheme of things, this is most likely a secondary issue.
11. The Sharpe ratio is measured as the average of the monthly returns of the portfolio minus the monthly return of the one-month Treasury bill divided by the volatility of this term.
12. From combinatorics, this means there are 5,814 combinations to run.
13. One could also investigate a higher number of currencies to use for hedging, such as ten. Rather than performing a series of step-wise regressions, the manager could construct a global optimisation problem and solve given the constraint of choosing only a limited amount of currencies. In matrix terms, $\text{Var}(R_{\$}^{H} - R) = \mathbf{w}'\boldsymbol{\Sigma}_1\mathbf{w} + \boldsymbol{h}'\boldsymbol{\Sigma}_2\boldsymbol{h} - 2\mathbf{w}'\boldsymbol{\Sigma}_3\boldsymbol{h}$, where $\boldsymbol{\Sigma}_1$ is the variance–covariance matrix of $s_i(1 + R_i)$, $\boldsymbol{\Sigma}_2$ is the variance–covariance matrix of $R_{i,F}$ and $\boldsymbol{\Sigma}_3$ is the covariance matrix of $s_i(1 + R_i)$ and $R_{i,F}$. We can ignore the first term and, thus, we would have to minimise the last two terms. This is a standard quadratic minimisation problem. To select a finite set of currencies, we would have to add a non-linear constraint on the number of currencies. This could be done with a standard optimisation package.
14. MSCI-Barra's global weights as determined by their index composition were used for this purpose.
15. By using an in-sample comparison, the results are biased to favour optimal hedging. Thus, the reader should keep this in mind when analysing the results. Out-of-sample testing was not performed for three reasons. First, given that the hedging results for in-sample hedging were not good when all of the information was known, it is unlikely that out-of-sample testing will prove superior. Secondly, the limited sample of data makes out-of-sample testing difficult. Thirdly, the main focus of this paper is not to discuss the most optimal ways to hedge currency risk, but rather to examine whether some basic hedging techniques were beneficial versus not hedging in the period 1999–2006.
16. One should focus on the relative change in the SR, rather than the absolute level, as these equity returns are price returns, not total returns.

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