Stockholm School of Economics
Master's Thesis in Finance

Exchange rate hedging of equity portfolios

- *evaluation of an OLS approach*

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ABSTRACT

With an increasing level of international diversification in equity portfolios comes an increase in the importance of the implicit foreign exchange rate exposure. While purchasing power parity might hold in the longer run it is evident that exchange rate movements can have sizable effects on portfolio returns at conventional time horizons. This thesis evaluates a strategy of hedging currency exposures according to ratios calculated by the method of ordinary least squares. For an investor with base currency SEK evidence is found indicating that an OLS approach significantly reduces portfolio return variance compared to common benchmark hedge ratios such as zero, fifty or one hundred per cent.

Tutor: Associate Professor Andrei Simonov.

1. Introduction

How much to hedge of the implicit currency exposures resulting from investing in foreign equities is an important decision for asset managers. While it is often said that currency investing is a zero-sum game, where a bilateral appreciation in one currency is accompanied by the depreciation of the other, the volatility of exchange rates is generally large and can have significant impact on the returns of international equity portfolios. Figures 1 and 2 show yearly returns of the MSCI World index in local currencies and the currency effects experienced by investors measuring their returns in SEK and USD respectively.[1] One can see that the currency effects have been substantial, especially for the Swedish investor, including almost doubling the return in 1993 and 2005 and almost erasing all of the 14 per cent equity return in 2006. The standard deviations of these equity returns were 16.5 per cent for local returns, 16.3 per cent for USD returns and a markedly higher 20.4 per cent for the SEK returns.

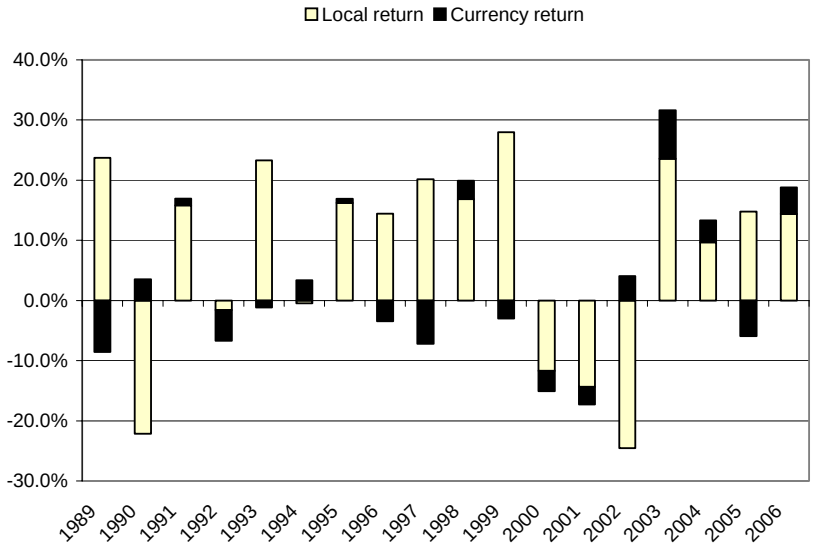


Figure 1. MSCI World equity returns measured in local currencies and differences when measuring in USD.

[1] The MSCI indices are leading benchmark indices for asset managers worldwide.

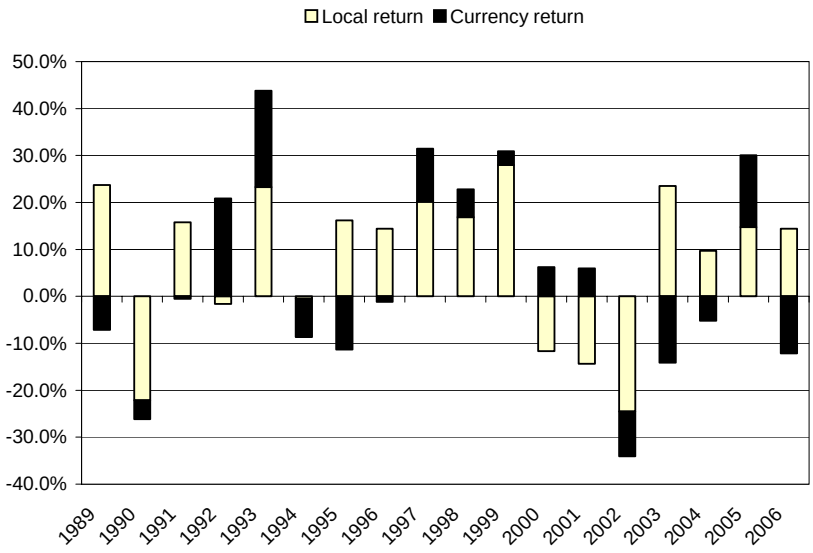


Figure 2. MSCI World equity returns measured in local currencies and differences when measuring in SEK.

The academic view on how to manage the currency risk of international equity portfolios is mixed. Perold & Schulman (1988) argues that foreign exchange exposure constitutes a risk without reward, why investors should hedge all of their implicit currency exposure. At the other end of the spectrum, Froot (1993) states that for long-term investment horizons purchasing power parity implies that zero hedging constitutes an optimal strategy. Black (1989), using a general equilibrium framework, comes up with a formula for the so called universal hedge ratio that is dependent on the expected return and volatility of the market portfolio as well as the average volatility of exchange rates. The resulting hedge ratio lies between zero and one depending on the input estimates. Using historical data from two different periods his estimates of the universal hedge ratio are 30 per cent and 73 per cent respectively.

In practice asset managers are diverse in their management of currency risk. Many view the stock markets as being volatile enough that currency effects in a diversified global portfolio are considered being less important white noise, especially when considering the widely held view of long-term currency returns being zero. This argument as well as a wish to leave the hedging decision to the investors are common motivations for policies

of no hedging. Other institutional investors are concerned about their liabilities, foe example insurance companies or pension funds, why they are implementing asset-liability management strategies where a large part of the liabilities are regarded as being in the domestic currency. This typically leads to hedging more of their foreign currency exposure. Others do not have a clear currency strategy at all which is hardly surprising given that there seems to be no generally accepted best practice in the area.

In a working paper, Campbell, de Medeiros & Viceira (2007) presents interesting empirical results from a strategy that aims to minimize portfolio return volatility by considering cross-correlations between equity markets and foreign exchange rates. Their methodology has some intuitively appealing properties, such as for example that hedge ratios can be different for different currencies and that hedge ratios vary according to the portfolio allocation. On the negative side, these calculated hedge ratios are likely to vary over time and may be too large (above 100 per cent) or too small (less than 0 per cent) to be implemented by investors.

The purpose of this thesis is to empirically evaluate the properties of this latter model from the perspective of a Swedish investor. Daily market data is used to back-test the historical performance from using this hedging strategy. This enables taking a closer look at how the hedge ratios evolve over time. The results show hedge ratios that are clearly unstable over time. On average however, during the time period studied the Swedish investor should have been long the Swiss franc, the Euro and the British pound, while being net short the Australian, Canadian as well as the US dollar. The Yen should on average have been completely hedged. Using these *ex post* estimated average hedge ratios would have reduced the portfolio volatility by approximately 3 percentage points compared to a 100 per cent hedged alternative. A more important finding is that a dynamic strategy of hedging according to the historically *ex ante* calculated hedge ratios reduces the portfolio volatility by more than 1.5 percentage points compared to the 100 per cent hedged alternative.

The rest of the thesis is organized as follows. Section 2 briefly presents the literature on currency hedging of equity portfolios including the Campbell et al. working paper. Section 3 discusses the transaction costs associated with hedging of foreign exchange rate exposure using forward contracts. Section 4 describes the data and methodology used for evaluating the performance of applying the suggested hedge strategy in practice. Section 5 presents the numerical results and section 6 gives some concluding remarks.

2. Literature

Black (1989) discusses the optimal hedge ratio for investors in a world where everyone can hedge the real exchange rates and where there are no barriers to international investing. This hedge ratio can be calculated using only three inputs; the expected return and volatility of the world market portfolio and the average volatility of exchange rates. According to the author, in equilibrium expected changes in exchange rates and correlations between equity returns and exchange rates cancel one another out, why they are not included in the formula. The resulting hedge ratio is the same for all countries (or currencies) and is larger than zero and less than one hundred per cent. The formula is derived for investors holding the world market portfolio. For an investor holding a different portfolio, the author suggests some adjustments of the hedges. For bond investments, the same approach leads to an optimal hedge ratio of 100 per cent.

Froot (1993) on the other hand distinguishes between long term and short term hedging horizons. He argues that for short term horizons, full hedging might be appropriate to minimize portfolio real return volatility, but for long horizons, purchasing power parity (PPP) implies that a policy of no hedging is optimal and that full hedging may increase real return volatility. His explanation is based on mean reversion in real exchange rates due to PPP. Mean reversion according to PPP makes the currency return variance at some time horizon approach zero. This hypothesis is evaluated by using data between 1802 and 1990 on US equity prices, US and UK interest rates as well as the dollar-sterling exchange rate. According to his sample data and calculations, real exchange rate hedges would have reduced real return volatility regardless of time horizon while

nominal hedges would have lost their real return volatility reducing properties at longer time horizons.

Perold & Schulman (1988) reach the opposite conclusion. They argue that the volatility from currency exposures in international equity portfolios are large enough to make currency hedging more efficient than further international equity diversification in reducing portfolio return variance. Given that a one hundred per cent hedge ratio significantly reduces the portfolio risk at no or marginal costs they suggest that portfolio managers should have a full hedge as the long-run investment policy and that deviations from this policy should be regarded as an active decision. The authors do not suggest that this policy would minimize the risk; rather that it removes most of it. In order to minimize the volatility the authors, in a footnote, prescribe that the investor should hedge according to the ex ante "beta" of foreign returns with respect to currency fluctuations. The authors also say that it is difficult to estimate these coefficients with much precision and that the derived "optimal" hedge ratios will not be stable over time.

In a working paper, Campbell, de Medeiros & Viceira (2007) derives a formula for calculating optimal hedge ratios of international equity portfolios. Assuming one-period mean-variance preferences they state the problem facing an investor trying to minimize a given portfolio's variance by optimally choosing a currency exposure. Their major assumptions are that the risk premia on equity returns over local risk-free rates are constant, that expected excess currency returns and their variances are constant and finally that the covariance between portfolio returns and currency returns are constant. Solving a resulting mean-variance optimization problem where *n* foreign currencies are available gives the following expression for the volatility minimizing investor's optimal currency demand, which according to the authors should approximately hold in discrete time:

$$\tilde{\Psi}_t^* = -Var\left(\tilde{\Delta}s_{t+1} + \tilde{i}_t - \tilde{i}_t^{\,d}\right)^{-1} Cov\left(1'\omega_t\left(r_{t+1} - i_t\right), \tilde{\Delta}s_{t+1} + \tilde{i}_t - \tilde{i}_t^{\,d}\right)$$

where ω_t = is the (n + 1 × n + 1) diagonal matrix of weights on domestic and foreign stocks at time t, Δs_{t+1} is the (n + 1 × 1) vector of first differenced log spot exchange rates, r_{t+1} is the (n + 1 × 1) vector of log gross nominal stock returns in local currencies, i_t is the (n + 1 × 1) vector of log(1 + nominal short-term interest rates) and i_t^d is the (n + 1 × 1) vector of the scalar log(1 + short-term nominal domestic interest rate) multiplied by a unit vector. This resulting currency demand vector can be obtained by regressing the portfolio excess returns on a scalar and the excess currency returns and switching the signs of the slopes. These currency demands are defined as the particular currency's weight in the portfolio, less the domestic currency value of the amount of forward exchange rate contracts for the currency per domestic currency units invested in the portfolio. This regression approach bears resemblance to the Perold & Schulman discussion. Starting from a one hundred per cent hedge ratio you arrive at the optimal hedge ratios by adjusting for correlations between equity markets and currencies. If there are no correlations the optimal hedging strategy is the full hedge. If there is a positive relation between local equity returns and an exchange rate one should hedge more while if there is a negative relation one should hedge less. For a sample period from 1975 to 2005 of value-weighted, equally-weighted and home-biased portfolios of stocks in Australia, Canada, the EMU countries, Japan, Switzerland, the UK and the US, the authors find that "optimal hedging" reduced volatility relative to 100 per cent hedging for all base currencies. They conclude that in general long positions in US dollars, euro and Swiss franc and short positions in the Australian and Canadian dollars, Japanese yen and British pounds reduce the risk for international equity investors. The results are checked for robustness by looking at time horizons ranging from one month to one year and by splitting the sample period in two sub samples.

The literature suggests a number of reasons for correlations between equities and currencies to exist. Fundamentals such as money supply, price levels, income levels, as well as supply and demand of goods may affect both currencies and company earnings which in turn affect stock prices. Generally such fundamentals are viewed to be

predictive for exchange rates over longer horizons.[2] Another theory that is much cited among practitioners is that of portfolio rebalancing effects. If a foreign equity market rallies, domestic institutional investors will reduce their holdings in order to maintain a specific world equity markets allocation. This re-allocation will in turn affect foreign exchange rates by the forces of supply and demand. Hau & Rey (2004) examine this theory by using data on equity returns, equity flows and exchange rate returns for 6 large economies. They find evidence that equity returns and currency returns trigger portfolio rebalancing, which in turn affect exchange rates. Hau & Rey (2002) also find that the predicted negative correlation between foreign equity market returns and the corresponding exchange rate returns is related to the level of financial market integration (as measured for example by stock market capitalization relative to GDP).

Cheung & Chinn (2000) use a survey methodology to, among other things, find out which factors according to foreign exchange traders do affect exchange rates. The responses indicate that news about macroeconomic variables is quickly incorporated in exchange rates, that the importance of individual variables shift over time, and that the traders view economic fundamentals to be important only at longer time horizons.

Finally it is important to note that relationships between equity markets and exchange rates may be different on an industry level than on a country level. Jorion (1991) finds significant differences in dollar exchange rate exposure between equities in different industries, where for example export-oriented industries tend to gain from a decreasing dollar.

3. Hedging costs

Transaction costs in the foreign exchange market are not very transparent as the trading does not take place on centralized exchanges. In the absence of commissions the direct costs are in the form of bid-ask spreads. Figure A1 which is included in the appendix

[2] See for example Mark (1995) who finds predictive components in exchange rates at long horizons but concludes that short-time changes tend to be dominated by noise.

illustrates the averages of one half bid-ask spread divided by the mid forward price for selected currency forwards and tenors from 2001 until 2007. These averages are calculated using daily last bid- and ask-quotes as reported by Bloomberg.[3] The spreads are very low compared to those of other asset classes and they are decreasing during the period studied, although the latter is not shown in the figure. From the figure it can also be seen that the spreads are increasing with increasing length of the forward contracts, and that the spreads are lower for major currencies than for minor ones. The average one-way bid ask-spread as a percentage of the forward rate for a two-month contract during the time period was 0.023 per cent. If it is assumed that currency hedging of an equity position involves entering forward contracts to sell the foreign currency every two months, the cost of hedging a currency during a year, using rolling 2-month forward contracts, can roughly be approximated by a percentage figure of 0.14 per cent. Obviously, this cost could be made lower by rolling the hedges using longer intervals, but that would come at the expense of increasing the basis risk. Perold & Schulman (1988) estimates the annual cost of hedging using 6-month contracts to 12 basis points, which is somewhat in line with my estimate considering their longer tenor but older data.

Transaction costs of roughly 0.14 per cent per year for a 100 per cent hedge policy can be economically significant and should be carefully evaluated against the benefits that come from hedging. Moreover, DuCharme (2007) refers to research where execution rate data from 36,000 real transactions were compared to the range of prices during the corresponding trade days. The average cost of executions, measured as deviations from the mid price of the day, was estimated at 9 basis points which "significantly exceeds most estimates of the FX bid and offer spread", and a histogram of the transactions were skewed towards the worst rates of the day.

Aside from the bid-ask spread, many practitioners view the interest rate differential as an additional cost. If uncovered interest rate parity (UIP) holds one could expect the costs of hedging to equal the transaction costs in terms of bid-ask spreads. However, the theory of

[3] The forward quotes are contributed and indicative.

UIP is highly disputed, especially in the shorter term.[4] A standard approach employed empirically to test the UIP theory is to run the following regression:

$$s_{t+1} - s_t = \alpha + \beta\left(I_{d,t} - I_{c,t}\right)$$

where *s* is the logarithm of the currency rate expressed as units of the domestic currency per unit of foreign currency and the *I*:s are the yields of the domestic and foreign currency respectively. If UIP holds the coefficient of the interest rate differential should be unity. The resulting statistics from regressions of the above equation for the eight different currencies using SEK as base currency is included in table A1 of the appendix. The observations used are monthly non-overlapping data from 2001-01-01 until 2007-11-30. None of the estimated coefficients were significantly different from zero even at a 10 per cent level using OLS regression. This result indicates that over the period studied, the forward price was not an unbiased predictor of future spot prices, at least not for time to maturity of a month. There are many practitioners as well as researchers claiming that investors could profit from this so called forward rate bias.[5] The concern of this thesis however is to evaluate a volatility minimizing hedging strategy why expected returns due to forward discounts or premiums will not be considered.[6] This should not be detrimental to the portfolio returns as long as the sign and size of the interest rate differentials do not affect the calculated hedge ratios in a systematically unfavorable way.

4. Data and description of methodology

According to the Campbell, de Mediros and Viceira (2007) paper investors can obtain what is commonly referred to as hedge ratios by subtracting the currency demand multiplied by the inverse of the currency weight in the portfolio from the constant 100

[4] See e.g. Chinn and Meredith (1998) or Bollerslev et al (2000) on the so called forward premium puzzle.
[5] See for example VanderLinden, Jiang & Hu (2002) describing a hedging strategy that according to them outperforms standard benchmarks in terms of risk-adjusted returns.
[6] The Campbell, de Medeiros & Viceira (2007) working paper includes an expression for the optimal currency demands that considers expected currency returns. In that formula the risk aversion coefficient is included.

per cent. This currency demand can be obtained by regressing portfolio local excess returns on currency excess returns and a constant and multiplying the coefficient estimates by minus one. A problem with this approach is that these coefficients are likely to vary over time. One reason may be, as indicated by Cheung & Chinn (2000), that the focus of the market on different fundamental variables is likely to shift over time. Furthermore it is evident that market reactions to changes in fundamental variables also shift over time. At some points in time an interest rate cut is seen as positive news for a currency while at other times it is seen as negative. Also, the increasing level of financial integration between countries and markets may alter the correlations between equities and exchange rates due to changing patterns of capital flows. Hence, all else equal, the hedge ratios preferably should adjust rapidly in response to changes in the relationships between equities and exchange rates. On the other hand, time series data of exchange rates and equity returns pose problems with collinearity and autocorrelation that call for using a large data set in estimating the parameters. The use of daily instead of weekly or monthly data in this thesis is an attempt to strike a balance in including a sufficient number of observations without having to use excessively long time periods for the estimations.

The currencies included in the evaluated portfolios are the Australian, US and Canadian dollars, the British pound, the Euro, the Swiss franc, the Japanese yen and the Swedish krona. Foreign exchange spot prices are collected from Bloomberg as daily last traded price and equity prices are proxied by the relevant MSCI World indices which are the standard benchmark indices of fund managers. Interest rates are collected from Bloomberg as the interbank offered rates fixings. The term structures used for calculating forward currency prices are modeled using these interbank yields for maturities of one week, one month and two months, and using linear interpolation in between.[7] Table 1 provides summary statistics for the equities and currency data, where all statistics are calculated using monthly return data.

[7] As a validity check theoretical forward prices were calculated using these interest rates and compared to historical indicative contributed forward (mid) rates for these specific maturities. The differences were found negligible and with signs varying over time.

	Annualised s.d.	Min	Max	Annualised return
United States				
Equities	14.0%	-11.4%	9.9%	1.8%
Currency	10.09%	-7.15%	6.19%	-2.6%
EMU				
Equities	17.7%	-17.5%	14.1%	3.6%
Currency	4.51%	-2.52%	3.32%	0.6%
United Kingdom				
Equities	12.8%	-12.0%	8.8%	1.0%
Currency	7.7%	-5.5%	5.3%	-0.2%
Japan				
Equities	15.5%	-9.5%	13.6%	3.8%
Currency	10.9%	-9.2%	9.1%	-2.4%
Switzerland				
Equities	13.5%	-12.4%	10.9%	3.0%
Currency	6.1%	-6.4%	5.5%	-0.4%
Canada				
Equities	15.4%	-14.4%	12.7%	10.0%
Currency	9.7%	-6.7%	7.5%	2.3%
Australia				
Equities	10.7%	-7.2%	8.4%	9.8%
Currency	9.1%	-6.3%	7.1%	1.5%
Sweden				
Equities	25.2%	-18.7%	22.4%	6.7%
Currency	n.a.	n.a.	n.a.	n.a.

Table 1. Summary statistics of equity markets and currency returns during the time period 1999-01-01 until 2007-11-30. Currency returns are measured against the SEK.

The performance of the hedging strategy is examined from the perspective of an investor with SEK as base currency and using two different equity portfolios. The first portfolio is weighted according to the relative market capitalizations of the included regions per December 2007, where accordingly the domestic equity holding is a tiny 1.4 per cent and the largest holding is US equities at 43 per cent of the portfolio value. The second portfolio is biased towards the domestic equity market, with a 50 per cent domestic allocation and the remaining invested according to the relative market capitalizations.

The performance of the hedging strategy is evaluated by back-testing these two portfolio allocations on both an ex post and an ex ante basis using different hedge ratios. The ex post evaluation uses constant hedge ratios during the evaluation period, which have been calculated using data from this same period. The ex ante evaluation uses time varying hedge ratios which are calculated using a rolling estimation window consisting of 260 calendar days of data immediately prior to the evaluation period. Here, the estimation and evaluation window is rolled forward using a step size of two months and hence does not make use of any information that was not available at the time of implementing the hedges. Additionally the historical performance of hedging the portfolios using static hedge ratios of 0, 50 and 100 per cent is calculated. This is done in order to facilitate a comparison of the regression approach to a set of commonly used static policies.

A practical problem with this regression approach of determining hedge ratios comes from the fact that equity allocation decisions are often taken much in isolation from currency allocation decisions. For example if a specific currency has a negative correlation with the equity portfolio returns it is likely that the corresponding calculated optimal currency demand will be large. If then the equity allocation to this country is not large enough, the corresponding optimal hedge ratio will be negative. In practice many investors would be reluctant to implement negative hedge ratios by for example entering forward contracts to buy foreign currencies. The same problem applies to cases where the calculated hedge ratio turns out to be greater than 100 per cent. Relatively few investors would go short currencies in excess of their implicit currency holdings. To consider these common policies among institutional investors the performance of a number of constrained dynamic hedge strategies are also calculated. One performance series is calculated using the so called optimal hedge ratios but constrained to be between zero and one hundred per cent. This corresponds to a typical real world hedging policy. I also relax the constraints somewhat and calculate the performance of hedging using constraints of the absolute values of individual hedge ratios to be less than or equal to 100 and 200 per cent respectively.

The hedge position performance is calculated assuming that 2-month rolling forward contracts are used. Rebalancing to original equity weights also takes place every second month coinciding with the expiration of the forwards. Since rebalancing and hedging is done on a two-month basis the hedging will only approximately follow the hedge ratio percentages. Depending on the performance of the equity markets, the hedging will deviate from the target ratios during the time periods between rebalancing events. The performance of the no hedge strategy is calculated on a daily basis according to spot exchange rates while the hedged alternatives are calculated by assuming that forward currency prices are given by the covered interest rate parity relation:

$$F_{c,t} = S_{c,t}\left(1 + I_{d,t}\right)/\left(1 + I_{c,t}\right)$$

where $S_{c,t}$ is the spot exchange rate at time t for currency c expressed in units of the base currency per unit of the foreign currency c, $I_{d,t}$ is the risk-free interest rate of the base currency for the time period until the next rebalancing event and $I_{c,t}$ is the corresponding risk-free interest rate of the foreign currency c. Transaction costs related to the bid-ask spread are considered by increasing or decreasing the forward price by 0.023 percentage points when entering the contract (corresponding to the average bid-ask spread for the 2-month tenors in the historical data examined). The time period studied is chosen to start on the 1st of January 2001 and end on the 30th of November 2007 in order to avoid dealing with pre-Euro currencies and ease the collecting of data.

5. Results

The historical calculated optimal hedge ratios for the home biased and market capitalization weighted portfolios are depicted in figures 1 and 2. In order to ease the comparison, the hedge ratios are reported as positions in percentages of the total portfolio value that should be entered long (negative hedge ratio) or short (positive hedge ratio) using forward contracts in the respective currency in order to minimize total portfolio return volatility. The magnitude of the hedge ratio as it is usually reported would seem

remarkably high for some currencies during part of the period since the corresponding equity allocation is small relative to the magnitude of the linear relationship between the currency and the equity portfolio. This is particularly true for the Swiss franc and the Euro. During most of the bear stock markets of 2002 and during the second half of 2006 a large long position in the Swiss franc and a large short position in the Euro appear to have offered a good hedge for a Swedish investor against the movements of the stock market. This could indicate that the Swiss franc had a strong tendency to appreciate (depreciate) against the Euro when the stock markets fell (rose) during these periods. It is tempting to try to interpret the variability of the hedge ratios over time.[8] The calculated optimal ratio for the Euro has shown variability by both being highly negative and highly positive at different points in the time period studied while the signs of the suggested hedge ratios of the other currencies have been more stable. The Swiss franc in particular seems to show a consistent negative hedge ratio which is in line with the Campbell et al (2007) thoughts of this currency serving as a safe haven for investors in times of turbulent financial markets. The shift in the calculated hedge ratio during the end of the time period for the Yen, where a previously consistent positive hedge ratio turns negative for both portfolios, might also be worth noting. There has been a lot of attention in the media to the unwinding of so called carry trades where investors borrow cheap in one currency to invest the proceeds in higher yielding assets. According to the media the recent market turbulence has increased the risk aversion of investors and prompted exits from carry positions funded in Yen which has been followed by an appreciation of the currency. Apparently, in the recent past the Yen has tended to appreciate when the stock markets fall why the dynamically calculated optimal hedge ratio has turned from positive to negative.

[8] The hedge ratios have also been calculated over time using two-day, three-day and weekly data leading to similar results. Using daily data works well despite possible data problems due to different time zones.

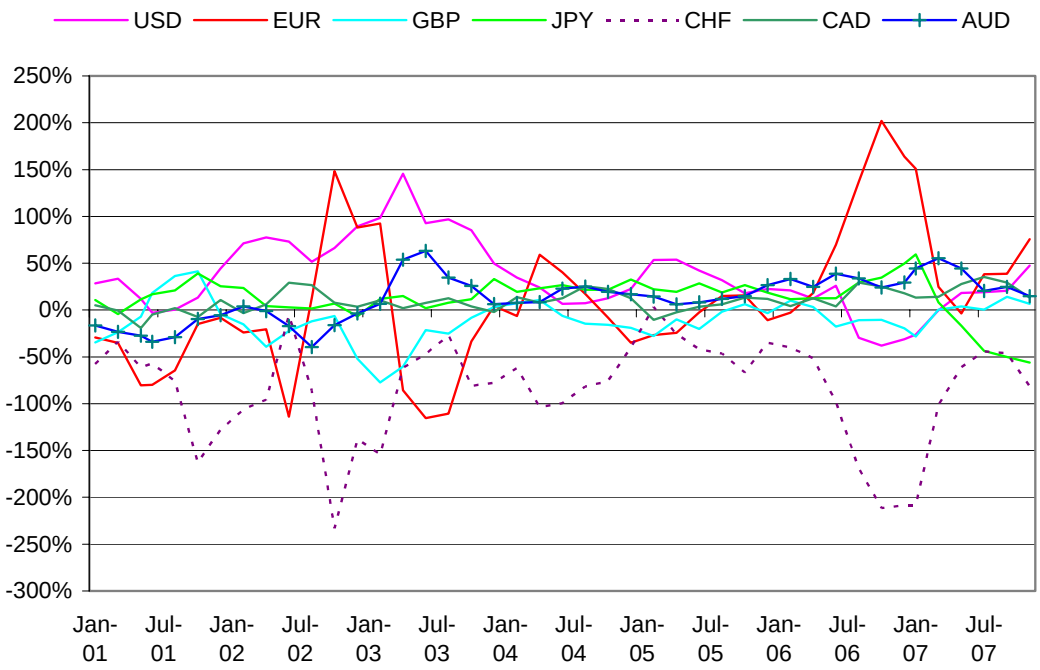


Figure 1. *Calculated rolling hedge ratios (as % of total portfolio value) for the home-biased portfolio.*

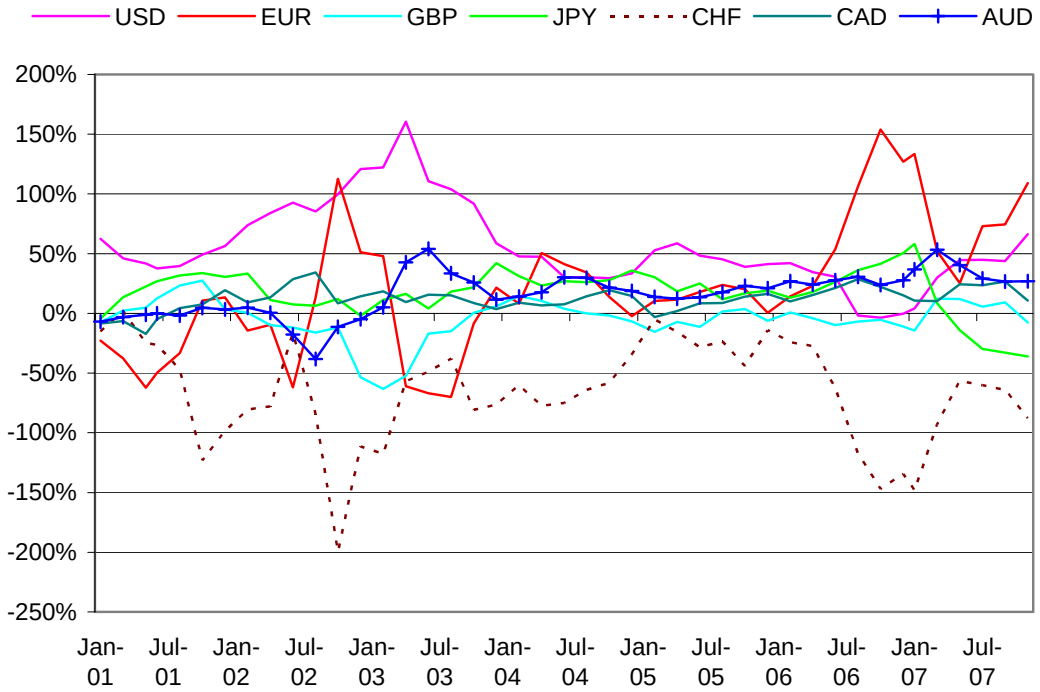


Figure 2. *Calculated rolling hedge ratios (as % of total portfolio value) for the market capitalization weighted portfolio.*

The ex post optimal hedge ratios per currency during the time period are depicted in table 2. These results suggest that an investor having the specified asset allocations, and with base currency SEK, should not have hedged but instead have taken further long positions in the Swiss franc. The result for the Euro is mixed – for the market capitalization weighted portfolio the optimal hedge ratio during the period would have been to hedge a small fraction of the Euro exposure, while for the home biased portfolio one should have increased this exposure as indicated by a negative hedge ratio. Furthermore, the Yen should have been almost exactly one hundred per cent hedged. For the British pound the optimal ratios are different for the two portfolios with an almost full hedge in the market capitalization weighted portfolio and a less than half hedge indicated for the home biased portfolio. The result regarding the rest of the currencies indicates that these should have been over-hedged.

	Market cap. weighted portfolio		**Home-biased portfolio**	
	Weight	*Optimal HR*	*Weight*	*Optimal HR*
AUD	4%	23%	2%	19%
CAD	4%	12%	2%	9%
CHF	3%	-80%	2%	-99%
EUR	23%	4%	11%	-2%
GBP	10%	8%	5%	2%
JPY	12%	13%	6%	6%
SEK	1%	n.a.	51%	n.a.
USD	43%	59%	22%	40%

Table 2. Weights of currencies and ex post calculated optimal hedge ratio as percentages of total portfolio value during the time period 2001-01-01 until 2007-11-30.

Figure 3 and 4 show the back-tested performances of the home biased portfolio and the market capitalization weighted portfolio using the static 0, 50 and 100 per cent hedge strategies together with the dynamic "optimal" strategy. Also included is the "optimal" strategy with constraints on the hedge ratios to lie between zero and one hundred per cent. For both portfolios, the optimal strategy had the best outcome from a mean and

variance perspective. However, since the dynamic strategies do not aim for increasing returns, the return component is not interesting. It is interesting to note the striking resemblance between the performances of the constrained (0 – 100 per cent) and the static 100 per cent strategies. These performances closely track each other suggesting that for most currencies and most of the time the calculated optimal hedge ratios may have been close to 100 per cent. The currencies that often should not have been hedged, namely the Swiss franc and the British pound, are quite small allocations in the portfolio which is the reason why simply not hedging them does not dramatically alter the performance.

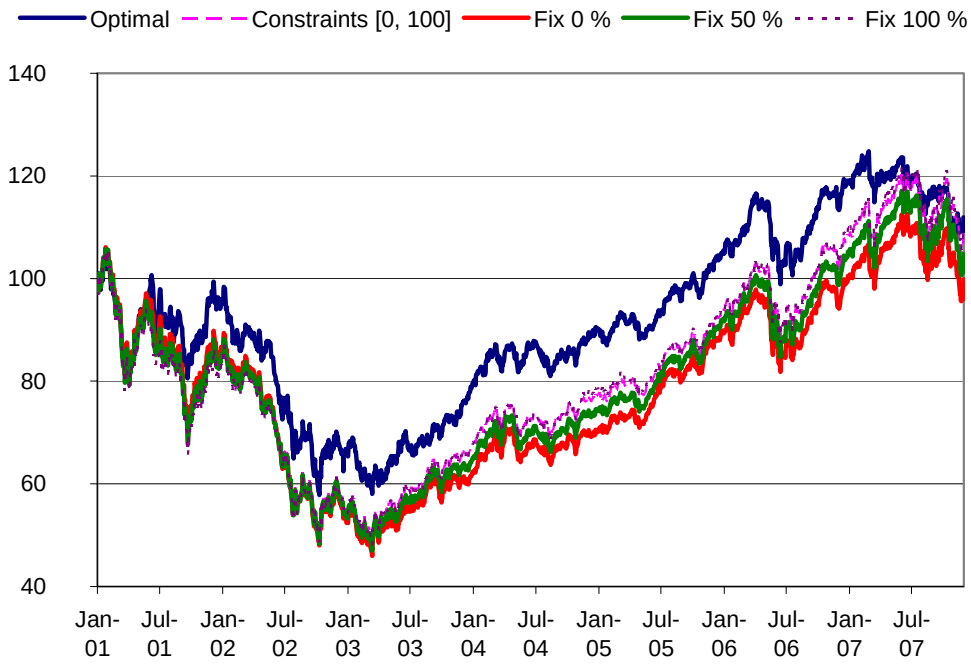


Figure 3. *Back-tested performance of the home-biased portfolio using five different hedging strategies.*

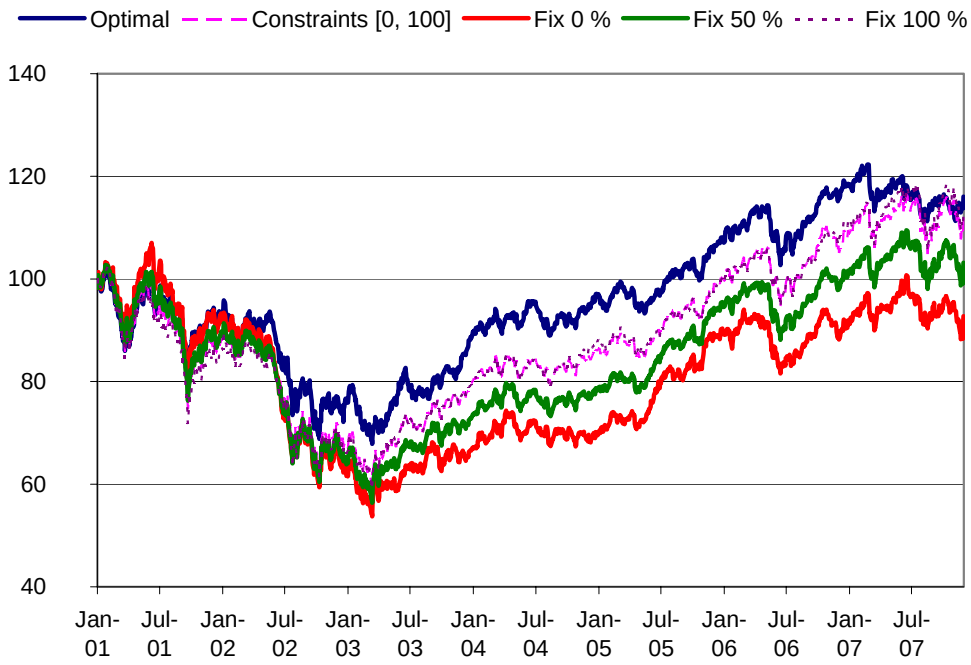


Figure 4. *Back-tested performance of the market cap. weighted portfolio using five different hedging strategies.*

Table 3 reports summary statistics of the various strategies. From a volatility perspective the dynamic strategies outperform all of the naïve static (0, 50 and 100 per cent) strategies, both when the calculations are based on daily and monthly returns. For the market capitalization weighted portfolio, the dynamic unconstrained strategy experienced a one percentage point lower volatility than the best naïve static alternative when calculating the volatility measure using daily return data. Using monthly return data, the dynamic unconstrained strategy experienced a 1.3 percentage points lower volatility. The same finding holds for the home biased portfolio where the volatility based on daily data is 0.8 percentage points lower for the unconstrained dynamic strategy than that of the best naïve static alternative. With volatility calculated using monthly data the difference is larger at 1.8 percentage points. Moreover, these reductions in portfolio variance do not seem to come at any expense. Included in the appendix are test statistics for differences in means between the returns of the un-hedged and various dynamically hedged strategies. As return data from financial time series are generally not considered being normally distributed, both the t test for paired samples and the nonparametric Wilcoxon Signed

Ranks test are used. For both the portfolios none of the tests supports rejecting the null hypothesis of a zero difference in means between the returns at any reasonable level of significance. Also included in Table 3 are performance statistics for the two portfolios when hedged using ratios calculated from data of the whole time period. The volatilities of these returns are lower than for the unrestricted dynamic strategy. This is however not very surprising as these calculations are based on ex post data and hence benefits from hindsight.

	Geometric return	**Std. dev. (daily data)**	**Std. dev. (monthly data)**
Market capitalization weighted portfolio			
Optimal (static, ex post)	0.58%	12.21%	9.57%
Optimal (dynamic, ex ante)	2.17%	12.71%	11.00%
Constraints [0%, 100%]	1.64%	13.36%	12.09%
Constraints [-100%, 100%]	1.97%	13.18%	11.74%
Constraints [-200%, 200%]	4.57%	12.81%	11.58%
Fixed 0 %	-1.08%	14.88%	13.27%
Fixed 50 %	0.45%	13.83%	12.33%
Fixed 100 %	1.87%	13.74%	12.52%
Home biased portfolio			
Optimal (static, ex post)	-0.05%	16.49%	14.55%
Optimal (dynamic, ex ante)	1.64%	17.07%	15.84%
Constraints [0%, 100%]	1.22%	17.72%	17.54%
Constraints [-100%, 100%]	1.26%	17.58%	17.44%
Constraints [-200%, 200%]	2.50%	17.38%	17.27%
Fixed 0 %	-0.02%	17.95%	17.73%
Fixed 50 %	0.68%	17.85%	17.60%
Fixed 100 %	1.35%	17.94%	17.68%

Table 3. Summary statistics of back-tested strategies during the time period 2001-01-01 until 2007-11-30. Returns and standard deviations are expressed on an annualised basis. 260 days per year are assumed when scaling the standard deviations from daily return data.

6. Conclusion

Using daily data on exchange rates, interest rates and equities, evidence is found pointing towards the possibility of significantly reducing the return variance of international equity portfolios by appropriately constructing exchange rate hedging policies. In line with the results of Campbell, de Medeiros and Viceira (2007), hedging of exchange rates using hedge ratios calculated by OLS regressions is found to be more efficient in reducing portfolio variance than using standard static policies of no hedge, half hedge or full hedge. This is shown by calculating the historical returns for a Sweden based investor during the time period between 2001 and late 2007 using these different hedging strategies. While the calculated optimal hedge ratios vary over time, it is shown that even a dynamic strategy of using rolling ex ante observation data to estimate hedge ratios reduced the return variance compared to the best performing static ratios. The results indicate that the "free lunch" of Perold and Schulman (1988) is still there in the 21st century as no statistically significant differences in means of the returns are found between the zero hedge and dynamically hedged strategies. The practical implications for asset managers concerned about nominal return volatilities are clear. There is a lot to be gained from constructing hedge ratios taking into consideration the cross correlations between asset returns and exchange rates of a particular portfolio at hand.

References

Black, F., “Universal Hedging: Optimising Currency Risk and Reward in International Equity Portfolios”, Financial Analysts Journal, July-August 1989.

Campbell, J., de Medeiros, K. & Viceira, L. ”Global Currency Hedging”, Working paper, Harvard University, Massachusetts, March 2007.

Cheung, Y., Chinn, M., “Currency Traders and Exchange Rate Dynamics: A Survey of the US Market”, Working Paper No. 251, CESifo Working Paper Series, February 2000.

DuCharme, M., “First Steps in Foreign Exchange Transaction Cost Analysis”, The Journal of Performance Measurement, Spring 2007.

Froot, K., “Currency Hedging over Long Horizons”, National Bureau of Economic Research, Cambridge, Massachusetts, 1993.

Hau, H., Rey, H., “Exchange Rate, Equity Prices and Capital Flows”, National Bureau of Economic Research, Cambridge, Massachusetts, December 2002.

Hau, H., Rey, H., “Can Portfolio Rebalancing Explain the Dynamics of Equity Returns, Equity Flows, and Exchange Rates?”, The American Economic Review, May 2004.

Jorion, P., “The Pricing of Exchange Rate Risk in the Stock Market”, The Journal of Financial and Quantitative Analysis, September 1991.

Mark, N., “Exchange Rates and Fundamentals: Evidence on Long-Horizon Predictability”, American Economic Review, Vol. 85, 1995.

Perold, A. & Schulman, E. “The free lunch in currency hedging: Implications for Investment Policy and Performance Standards”, Financial Analysts Journal, May-June 1988, 45-50.

VanderLinden, D., Jiang, C., Hu, M., ”Conditional Hedging and Portfolio Performance”, Financial Analysts Journal, July-August 2002.

Appendix

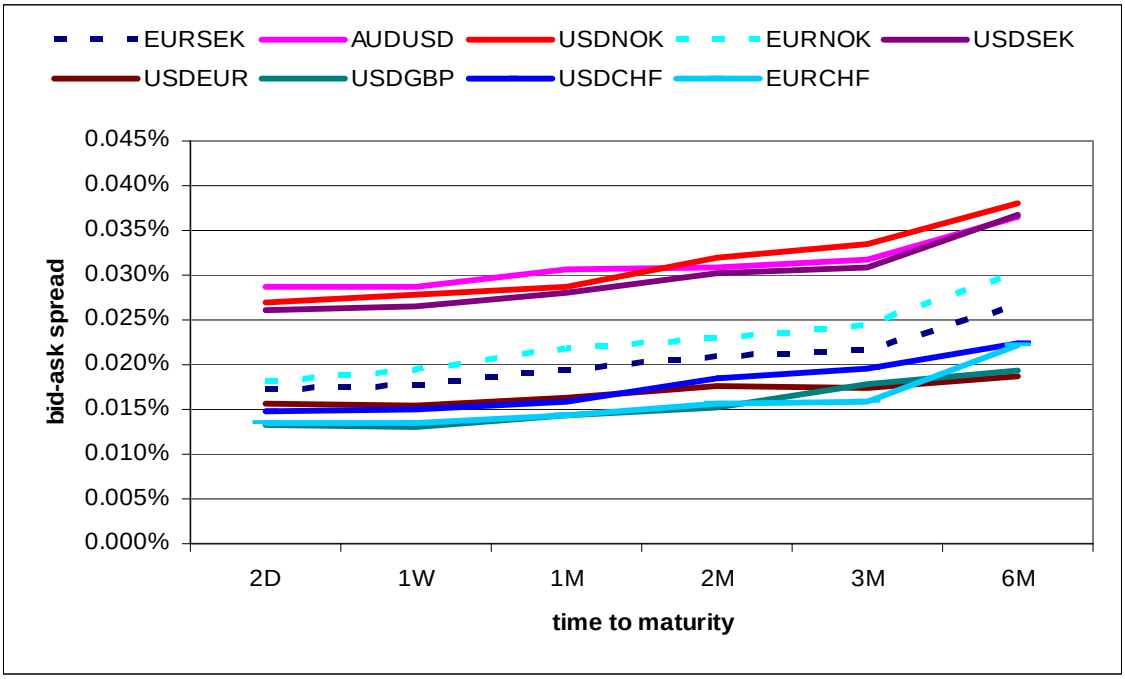


Figure A1. *Average of ½ of the bid-ask spread divided by the forward price for various currency forwards during 2001 – 2007.*

	Intercept	Sig.	Slope	Sig.
AUD	0.0011	0.8593	0.1288	0.9644
CAD	-0.0006	0.8590	-4.0333	0.2479
CHF	0.0030	0.4801	-2.3062	0.3577
EUR	0.0007	0.6680	-1.3008	0.6684
GBP	-0.0031	0.4781	-1.7401	0.5238
JPY	-0.0051	0.6657	0.3465	0.9406
USD	-0.0048	0.1710	-2.4625	0.2567

Table A1. *Regression results from regressing monthly currency returns on lagged interest rate differentials using SEK as base currency, using data from 2001-01-01 until 2007-11-30.*

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	HR 0 - Optimal	,0000	,0059	,0001	-,0003	,0002	-,416	1791	,677
Pair 2	HR 0 - 0-100	,0000	,0017	,0000	-,0001	,0000	-1,172	1791	,241
Pair 3	HR 0 - 100-100	,0000	,0015	,0000	-,0001	,0000	-1,348	1791	,178
Pair 4	HR 0 - 200-200	,0000	,0025	,0001	-,0002	,0000	-1,558	1791	,120

Table A2. Results of paired samples t test of differences in means between unhedged and dynamically hedged strategies for the home-biased portfolio.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	HR 0 - Optimal	-,00011	,00619	,00015	-,00040	,00017	-,776	1791	,438
Pair 2	HR 0 - 0-100	-,00011	,00678	,00016	-,00042	,00021	-,665	1791	,506
Pair 3	HR 0 - 100-100	-,00011	,00654	,00015	-,00041	,00020	-,693	1791	,488
Pair 4	HR 0 - 200-200	-,00015	,00706	,00017	-,00048	,00017	-,914	1791	,361

Table A3. Results of paired samples t test of differences in means between unhedged and dynamically hedged strategies for the market capitalization weighed portfolio.

Test Statistics[c]

	Optimal - HR 0	0-100 - HR 0	100-100 - HR 0	200-200 - HR 0
Z	-,357[a]	-1,279[b]	-1,498[b]	-1,670[b]
Asymp. Sig. (2-tailed)	,721	,201	,134	,095

a. Based on positive ranks.

b. Based on negative ranks.

c. Wilcoxon Signed Ranks Test

Table A4. Results from the Wilcoxon Signed Ranks test of differences in means between unhedged and dynamically hedged strategies for the home-biased portfolio.

Test Statistics[b]

	Optimal - HR 0	0-100 - HR 0	100-100 - HR 0	200-200 - HR 0
Z	-,232[a]	-,846[a]	-,857[a]	-1,055[a]
Asymp. Sig. (2-tailed)	,816	,397	,392	,292

a. Based on negative ranks.

b. Wilcoxon Signed Ranks Test

Table A5. Results from the Wilcoxon Signed Ranks test of differences in means between unhedged and dynamically hedged strategies for the market capitalization weighted portfolio.