Currency Hedging of Global Portfolios
A Closer Examination of Some of the Ingredients

D. Johannes Jüttner\textsuperscript{a} and Wayne Leung\textsuperscript{b}

Abstract

The paper analyzes some of the ingredients of currency hedging and portfolio construction against the framework of mean-variance efficient portfolios. The currency hedging analysis is based on a range of exchange rates, consisting of the domestic dollar vis-à-vis the US dollar, the euro, the yen, the pound and Hong Kong dollar mainly from an Australian perspective. Our analysis focuses on the following input factors into the hedging process of foreign assets/liabilities. We explore the implications of the secular downward trend of the real trade-weighted exchange rate index of the domestic dollar for hedging effectiveness. The hedging costs resulting from unexpected cash flows and portfolio adjustments are in part estimated through a simulated forward contract hedging technique. The relevant inputs into the variance-covariance matrix of the optimal portfolio selection process are estimated on the basis of historical data. Comparing the forecast errors of share index and currency volatilities, using historical, implied and GARCH methods, provides mixed results. The paper also investigates a select number of forecasting methods that may be applied to other hedging inputs.

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1. Introduction

As more and more reliable information about foreign investment opportunities in debt and equity securities has become available in a timely fashion across the globe, due mainly to advanced computer technologies and liberalization of capital markets, the opportunity set of assets to be included in well diversified portfolios has rapidly expanded. This process was also driven by advances in finance and the emergence of new markets. Consequently, well diversified portfolios include, or ought to include on the basis of the mean-variance approach, sizeable proportions of international securities such as bonds and equities. The bulk of international portfolio selection is carried out by investment funds. Virtually all investment funds, even those with no foreign assets in their portfolios, are exposed to exchange rate risk. For some, holding foreign-currency assets unhedged or even outright short/long currency positions, is a design feature of their portfolios because they believe in their superior currency forecasting ability. Most funds, however, dread the losses from unfavourable currency movements more than they relish the gains from beneficial ones. This applies in particular to pension funds where protracted adverse currency swings can be severely detrimental to fund members close to retirement. Such funds therefore have a special interest in judicious hedging of their funds’ foreign currency exposure either through diversification and/or by putting explicit currency hedges in place.

In this paper we analyze some of the ingredients of currency hedging and portfolio construction in the framework of mean-variance efficient portfolios mainly from an Australian perspective. The currency hedging analysis is based on a range of exchange rates, consisting of the domestic dollar vis-à-vis the US dollar, the euro, the yen, the pound and Hong Kong dollar. Currency hedging presupposes a thorough grounding in relevant areas of finance and financial economics as well as judgment when the relative importance
of conflicting signals from the currency markets have to be assessed. Thus familiarity with the behaviour of the various exchange rates, such as the nominal and trade-weighted rates as well as their counterparts in real terms is essential. Textbook knowledge at time proves inadequate; for example, it fails to explain the unusual behaviour of our real trade-weighted exchange rate. The pronounced downward trend of the real currency index stands in stark contrast to the trendless real US dollar index. These divergent developments have significant implications for currency hedging by Australian fund managers which so far have not received appropriate attention.

Forward currency contracts of one to three months to maturity appear to serve as the main hedging instruments in the funds industry. They are relatively cost-effective, traded in liquid markets and are available for most currencies. Their short maturities allow fund mangers to adjust their hedges relatively frequently, however, only at significant cash flow costs and portfolio rebalancing expenses which are frequently glossed over in mean-variance portfolio selection studies. Another controversial issue concerns the impact of any existing currency risk premium on foreign asset returns. It appears to be widely overlooked that risk premia are not only payable, they might also be received by speculators and hedgers. Hedging in the portfolio context relies on the inputs into the mean-variance model and the preferred utility function. Leaving the latter on one side, the task ahead requires the estimation of variances of as well as correlations and co-variances between, currencies and securities.\(^1\) The latter consist of a selection of US, Japanese, German, French, UK, European and Hong Kong share price indices. Information about the correlations amongst daily currency returns, securities and between securities and currencies provides guidance for their hedging potential in the portfolio context. The empirical evidence regarding rolling correlations between share price indices and trade-weighted currency indices suggests time-varying relationships.

\(^1\) As this paper is mainly concerned with the currency-related inputs in the portfolio decision we make no attempts to discuss the evaluation of share price forecasts. A re-examination of the predictability of international asset returns is given by Neely and Weller (2000). We by-pass issues associated with actually feeding our input data into a portfolio optimizer. For a recent applications in the Australian context see Thorp (2003).
Volatilities of rates of return on shares and currencies form a further important portfolio
input. The novel feature of our approach consists in the use of several volatility estimates,
forecast methods and forecast error measures. First, we employ market-determined
volatility data for the optimization procedure where no reliance on historically data is made.
We work with implied volatility forecasts from exchange-traded share index options and
 currencies for the relevant variances. Second, corresponding volatility predictions are
extracted from historical data. Third, the GARCH(1,1) estimation procedure is used to
project volatility into the future. The three volatility predictions allow us to compute
forecast errors. Somewhat surprisingly we identify historical volatilities as having the
smallest mean prediction errors. While commonly in the portfolio selection process the
focus is limited to volatility (\(\sigma\)), options provide an information set beyond that suggested
by implied volatilities. Risk neutral density on the basis of risk reversal and strangle options
allows the extraction of implied skewness and kurtosis of share price indices and currencies.
As skewness gauges the asymmetry of market expectations, fund mangers are provided
with valuable information about the likelihood of an imminent possible devaluation of a
currency or a significant drop in share prices. Kurtosis indicates the possibility of extreme,
not necessarily symmetrical, - negative or positive – exchange rate or share price changes.
We have no information of whether these aspects of options volatilities have proved their
value for hedging and are being exploited by funds managers.\(^2\)

One of the most crucial tasks in the portfolio construction process concerns the forecasting
of the various exchange rates, rates of return of securities (which we ignore), volatilities and
correlations. For a start, we interpret the mean-reverting behaviour of the real exchange rate
for prediction purposes. As for the forecasting of nominal exchange rates, their modelling
on the basis of fundamental economic factors that are held to determine their behaviour has
so far been unsuccessful. This approach is therefore unsuitable for predictive purposes. The
informative content of forward exchange rates is clouded by the fact that they are
commonly biased. However, some approaches have turned the predictive content of the

\(^2\) Central banks such as the Deutsche Bundesbank (2001), the Bank of England (Bahra, 1997), the Bank
for International Settlements (Remolona and Scott, 1999) and the European Central Bank (Glatzer and
Scheicher, 2003) appear to rely increasingly on these features of options prices in order to gather information
about market sentiments beyond the realm of implied volatility.
forward discount on its head, by imbuing the spot rate with predictive power relative to the forward rate. Forecasts derive their legitimacy from market inefficiencies which may vary over time or across markets. For this reason fund managers rarely rely on only one prediction method. Other forecasting techniques that are frequently used include filter rules, momentum strategies and charting.

The paper is organized as follows. In section 2 we examine the downward trend behaviour of our real trade weighted exchange rate index, compare it with that of the trendless US counterpart and explore the hedging implications of the divergent behaviour of these indices. The following section 3 discusses hedging with forward contracts, their advantages, cash and rebalancing costs and evaluates the impact of the risk premium on hedged returns. Correlations amongst currencies and of currency returns with securities are explored in section 4. In part 5 we evaluate forecast errors associated with implied, historical and estimated GARCH volatility measures and broaden the volatility spectrum by capturing skewness and kurtosis of risk-neutral densities. Their implications for portfolio optimization and hedging are discussed. Section 6 examines currency and correlation forecasts.

2. Nominal and Real Exchange Rates as Hedging Guide

Studying the behaviour of exchange rates over the longer term may assist in the decision to hedge or not to hedge, either over the short or the long horizon. While all market-determined currencies fluctuate, some currencies may, in addition, exhibit a more or less pronounced upward or downward trend or remain stationary in the longer term. The Australian dollar appears to have lost value vis-à-vis its major trading partners over the last thirty years in nominal as well as in real terms. A secularly downward trending currency suggests that foreign assets should not be hedged, except when the domestic currency moves temporarily in an upward direction. This appears to be the environment which Australian-based funds have to content with. The decision of domestic funds not to hedge foreign equity investments therefore has turned out to be correct over the longer haul.3
2.1. Downward Drift of the Real Exchange Rate Index

Common sense suggests examining the longer term movements of the nominal and real trade weighted exchange rate indices before deciding over which time horizon it is sensible to hedge foreign investment. The consensus view amongst economists pictures the real exchange rate of a country as fluctuating around a stationary trend.\(^4\) Taking a stationary trend of the real trade-weighted exchange rate index as the benchmark, how does the Australian dollar compare? Fig. 1 shows the movement of the real trade weighted exchange rate index (RTWI) and the corresponding nominal trade weighted index (TWI) for the last thirty-three years.\(^5\) Fitting an exponential trend line through the real exchange rate index observations, a clear downward movement is discernible. The trend decline amounts to an annual rate of 0.864 per cent. In addition, the real currency index of the exchange rate appears to mean-revert around the falling trend. The successive RTWI cycles consistently reach lower peaks over time, though their troughs over the last two decades appear to have flattened. The movement of the nominal TWI in the same figure exhibits very similar features, except that the index appears to have bottomed out over the last one and a half decade when the peaks and troughs have become flatter. The more pronounced peaks and troughs in the RTWI compared to those of the TWI appear to be due to domestic/foreign inflation differentials. For example, the recovery of the real currency index after the steep decline following the infamous ‘banana republic’ statement by the then Treasurer Keating

\(^3\) The hedging in general of foreign bond investments by superannuation funds could be justified in terms of securing a predictable cash flow to match fixed pension payments.

\(^4\) Abuaf and Jorion (1990) demonstrate the stationarity of the real values of the British pound and French franc for over eighty years. Lothian and Taylor (1996) provide similar evidence for the two currencies for two centuries. Froot (1993, p. 2) explicitly states: “However, mean reversion in real exchange rates implies that these purchasing powers tend towards parity, so that real exchanger rates over time remain roughly constant”. With PPP as the only determinant of real exchange rates, given long-term constancy of the nominal currency ratios, these views become quasi a tautology. In the Australian case, additional factors appear to depress the nominal exchange rate ratio.

\(^5\) The real trade weighted index of the Australian dollar and other currencies is defined as the product of the current exchange rate to base-year rate and the ratio of the domestic to foreign price levels, ie.

\[
RTWI_{i} = 100 \prod_{i=1}^{n} \left( \frac{S_{i}^{t} \times P_{t}^{AUS}}{S_{i}^{t} \times P_{t}^{i}} \right),
\]

were \(w_{i}\) stands for the weight of the \(i\)-th country. When the price ratios in the bracket are omitted we obtain the nominal TWI.
in 1986 owed much to the rampant domestic inflation and only a moderate amount to nominal exchange rate changes.\(^6\)

Contrast this with the behaviour of the corresponding indices for the US dollar over the same period. The trade weighted real exchange rate index appears to mean-revert around a virtually trend-stationary value. The nominal index trends strongly upwards. In the literature mean reversion of the real exchange rate in general is assumed to occur around a horizontal line and downward trending mean reversion in real exchange rates is not considered.\(^7\)

2.2. Possible Reasons for the Secular Decline of the Real Exchange Rate

An exploratory analysis regarding the reasons for the apparent drift decline of the real value of the Australian dollar over the last thirty years can only be of a preliminary nature in the

Fig. 1: SA Nominal and Real Trade-Weighted Exchange Rate Indices, Jan. 1973 – Sept. 2004

\(^6\) Evidence for this dual-speed of prices and nominal exchange rates in the adjustment process has been presented by Engle and Morley (2001) and Cheung et al. (2003).

\(^7\) See footnote two for two representative views.
current context. Amongst the possible reasons we presumably can eliminate, *prima facie*, the existence of a risk premium or risk discount of the domestic currency. They drive a wedge between the forward rate, $F_{t,t+k}$, and the expected future spot rate, $S_{t,t+k}^e$ [see (5) below]. Under the risk premium (discount) hypothesis market participants expect the subsequent spot rate to lie above (below) the forward rate. The downward drift in the real exchange rate data appears to be compatible with the occurrence of a systematic over-prediction of the subsequent spot rate, ie. $S_{t,t+k}^e > S_{t+k}$. In other words, market participants appear to be perennially surprised how low the Australian drops after a shock as well as overestimating its recovery potential.

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8 Needless to say that our analysis applies only to the trade-weighted real exchange rate of a group of countries. Individual bilateral real exchange rates with the Australian dollar, of course, may behave differently though typically they will exhibit a downward trend.
Omitted variables could provide an alternative explanation for the downward drift of the real exchange rate index. Continuing productivity differentials between the traded and non-traded sectors in the economies of our trading partners (Harrod, 1933; Balassa, 1964; Samuelson, 1964), a brain drain, persistent current account deficits resulting in a gradual deterioration in our foreign investment position (Lane and Milesi-Ferreti, 2002) and non-membership in a currency block which could make our currency subject to repeated speculative attack, have the potential to cause a secular decline in the nominal rate. This in turn could account for the observed negative trend of the PPP-measured real value of our currency. This systematic downward movement over such a long time period appears to have gone unnoticed. To our knowledge there is a conspicuous absence of academic and institutional (eg. RBA) studies dealing with this feature of our currency though funds managers appear to be aware of its secular atrophy.  

2.3. Relevance of Real Trade-Weighted (or Bilateral) Exchange Rate Index for Foreign Portfolio and Hedging Decision

The mean-reverting behaviour of the real exchange rate around a downward trend has implications for currency returns and hedging. (1) Due to the negative trend, currency returns on foreign investments after conversion into domestic currency tend to increase over the longer time horizon. As the actual real exchange rate oscillates around the trendline, currency losses may occur in the short term, followed by, on average, even greater currency gains and so on. The downward trend in the real exchange rate index adds, over the longer haul and for a given level of risk, value to the hedged and unhedged foreign investment portion of Australian fund managers’ portfolio. However, these investment gains are somewhat illusory as the same bundle of foreign goods and services is now more expensive either because our nominal (and real) exchange rate has fallen and/or because overseas prices have risen by more than domestic prices pulling down the real exchange rate but leaving the nominal rate unchanged.

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9 An example for the latter group is Cassie (2001) who presents some drastic examples for the devaluation of the Australian dollar since the early 1970.
Hedging of exchange rate risk exposure is commonly carried out with derivatives instruments, predominantly with forward contracts on the basis of nominal values. How can we include real currency rates into the hedging decision? First, assume nominal exchange rate changes alone drive the real currency rate with domestic/foreign inflation differentials offsetting each other so that nominal drive real exchange rate changes. Under these conditions, hedging with forward or futures contracts covers both real and nominal exchange rate risk. Second, in the medium to long term inflation rates at home and/or overseas usually change and may diverge. To simplify matters, assume the domestic inflation rate increases with price stability overseas implying an increase in the real exchange rate. Hedging the total nominal value of the foreign asset return results in a loss in domestic currency due to inflation at home. The hedged amount buys less at home than overseas. This can only be avoided if fund members either purchase more imported goods, or fund managers increase the hedged amount by the inflation loss. For example, instead of selling US$100 million forward under a no-inflation regime we have to raise this amount to US$105 million when domestic prices increase by five percent. Conversely, a higher inflation rate overseas than at home would require a commensurate increase in overseas investment in order to afford the investor the same command over domestic and foreign goods. 

The above discussion shows that hedging with a nominal instrument such as a forward contract covers real exchange rate risk when movements in the currency are due to nominal exchange rate changes. When real currency movements are caused by inflation differentials, nominal hedge values no longer provide a reliable guide for expected real rates of return on investments. Effective hedging thus requires forecasting of real exchange rates. Their predictability is assessed by Siddique and Sweeney (1998).

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As hedging and consumer choice are not based on an integrated decision theory in the capital asset pricing theory, we are left in the dark about the ultimate savings-consumption response of the investor to a change in the inflation differential. The portfolio optimization approach to hedging within the capital asset pricing model depends only on risk and return for a given endowment. This criticism also applies to the cash flows associated with hedging to be discussed below.
3. Currency Hedging Instruments: Forwards, Futures and Options

Our current focus is on the features and problems of currency hedging using forward contracts; we ignore for the time being, the portfolio context where correlations among currency returns and between currencies and securities returns play a role in the hedging task. Foreign currency exposure can be hedged with forward, futures and options contracts. In terms of transactions costs, forwards and futures are the least expensive though they are associated with sizable unplanned domestic and foreign currency cash flows. In the case of futures, marking to market engenders a continuous in- and outflow of cash while the cash adjustment for forward contracts commonly occurs at maturity in a discrete fashion. Because of the high cost of hedging with options they are used sparingly, for example, when forward markets are disrupted. In contrast to forwards they constitute a net investment in the form of the premium; writing options may amount to speculative investments.

3.1. Forward Hedging and Unexpected Cash Flow Problems

The total expected return from the foreign investment (principal + interest/dividend), expressed in local currency, may be hedged or left unhedged, either completely or partially. Measuring the exchange rate risk exposure of a portfolio of domestic and foreign currency securities involves a complex process of ascertaining the portfolio’s total domestic securities and foreign currency return variances, calculating the co-variances between the returns of the various currencies as well as computing the co-variances between currency and securities returns. Fund managers then determine the portion of the currency risk to be hedged. After this computational task they select the hedging instrument, say forward contracts.\footnote{Portfolio selection and hedging may, of course, also be accomplished simultaneously rather than in the currency overlay fashion which we adopted for ease of exposition.} Hedging is accomplished by offsetting the long positions in foreign currencies with appropriate sell forward contracts.

Forward hedging locks in the forward currency rate for the duration of the contract.
However, even complete hedging of the initial investment and the expected cash payments (interest or dividends) does not protect the foreign investment entirely from currency exposure, though it removes the bulk of exchange rate risk. Hedging is less than perfect for the following reasons:

1. Unanticipated changes in the price of foreign bonds or shares leave the investor either over- or under-hedged.
2. Hedging in the forward and futures markets is commonly done with short-dated forward contracts, say, with a maturity of 1, 3 to 9 months out to one year. This means hedging would only provide currency protection for at most out to one year of a foreign investment with a maturity of, say, ten years. Under these circumstances the hedge cover has to be renewed every year or more often for shorter contracts at unknown forward rates.
3. To boot, whenever the contract forward rate, \( F_{t,t+k} \) deviates form the corresponding subsequent spot rate, \( S_{t+k} \), substantial unplanned cash flows and portfolio rebalancing at unknown spot exchange rates, interest rates and share/bond prices may occur. Deviation of subsequent spot rates form corresponding forward rates are the norm (see Fig. 4: Ex Post Forward Hedging Errors).

At time \( t \) the expected gains and losses in dollars associated with the forward transactions at maturity of the contract are given in equation (1).

\[
\text{FXG/L}_{t,t+k}^e = P_{t,t+k}^e \left( \frac{1}{F_{t,t+k}} - \frac{1}{S_{t,t+k}} \right) \tag{1}
\]

where

\( \text{FXG/L}_{t,t+k}^e \) : expected gain/loss on forward position in $A in \( t \) for \( t+k \)
\( P_{t,t+k}^e \) : expected foreign currency value of foreign currency portfolio at \( t \) for \( t+k \)
\( S_{t,t+k}^e \) : expected future spot rate at \( t \) for \( t+k \)

The end-of-period value of the foreign investment at \( t+k \) may deviate from its expected value, due to a change in the market interest rate in the case of bond investments. For example, a rise in euro-interest rates devalues the bond portfolio (principal and coupon payments received). In this case the actual value of \( P^* \) at \( t+k \) would be smaller than
expected. The same uncertainty applies to foreign share investments. Moreover, the subsequent spot rate $S_{t+1}$ may deviate from the expected exchange rate at maturity of the forward contract. At maturity the forward contract’s mark-to-market value (MTMV) is computed as follows

$$\text{MTMV} = \frac{P^*_{t+1}}{F_{t,t+1}} \left( \frac{1}{S_{t+1}} - \frac{1}{F_{t,t+1}} \right) \tag{2}$$

This version is tantamount to closing out of the forward contract at maturity; it involves cash-settlement of the contract rather than delivery of the two currencies.

- When at maturity $F_{t,t+1} < S_{t+1}$ that is, whenever the forward rate falls short of the subsequent spot rate a profit results.
- Conversely, hedging generates a loss when $F_{t,t+1} > S_{t+1}$

However, these gains/losses are reflected in actual cash inflows and outflows and they necessitate portfolio adjustments, even though the fund manager attains the hedged outcome. The difference between the hedged investment at the forward rate and its value at the subsequent spot rate engender cash flows. Assume a fund manager hedges a 2-year €100 million Eurobond position ($= P^e_{t+2}$) with a one year forward contract at $F_{t,t+1} = \€0.60/$A, locking in a hedged amount of $A166.667$ million. The subsequent spot rate at the end of the year turns out to be $S_{t+1} = \€0.59/$A. Plugging these values into (2) results in

$$\text{MTMV} = \€100m \left( \frac{1}{\€0.60/$A} - \frac{1}{\€0.59/$A} \right) = - \$A2.825 \text{ million}$$

That is, the hedged portfolio suffers a loss of - $A2.825 million as compared to an unhedged investment. In order to finance the loss on the forward contract, the manager sells part of the €-bonds, namely €1.667m, (=2.825x0.59). The €-position in the fund has dropped to €98.333m. However, due to the revaluation of the euro, the domestic currency equivalent of the portfolio amounts to $A166.667$ million (=98.333/0.59). That is, the hedger receives exactly the hedged amount. Had the investment been left unhedged, the
manager would not have incurred the loss but instead would have increased the $A-value of the portfolio by $A2.825m to $A169.492 million (=100/0.59) with an unchanged €100 million. In other words, the manager missed an opportunity to increase the value of the fund and may therefore be chided by fund holders and perhaps eventually lose his/her job. Therefore such opportunity losses are not merely a theoretical concept; they cause cash flows and prompt portfolio adjustments.

Hedging does not require the portfolio manager to actually sell the €-bonds in order to obtain the hedged amount of $A166.667 million at delivery time. Instead, and more commonly, the forward contract is marked to market at t+1, that is, valued at the prevailing contract forward rate which equals the spot rate at t+1 and cash-settled. Marking-to-market is tantamount to closing out that is common in a futures contract. The process of closing out would require the portfolio manager buying back the forward contract of €100m at the current exchange rate (0.59) for $A169.492m. Thus we obtain:

Sell contract results in $A166.667m
Buy contract results in $A169.492m
Loss - $A2.825m

This amount would have to be paid by the hedger to the counterparty in the forward contact. As explained, the hedger finances the payment by selling part of the value of the €-bond portfolio.

3. 2. Some First Hedging Lessons

This exercise provides several valuable lessons for the limited effectiveness of hedging.

- In the case where the maturity of the portfolio (2 years) exceeds the hedging period (1 year) the hedge has to be rolled forward. With a rolling hedge, the investor cannot be sure about the terminal value of the investment, ceteris paribus, because the hedge has to be renewed at an unknown forward rate.
- When the domestic currency is weak (on a downward trend), hedging creates opportunity losses; they are mitigated by hedging gains when the currency is strengthening.
Hedging of investments creates cash flow uncertainty and may cause **$A-cash-flow problems** with a volatile or trending currency. When the currency is on an upward trend, cash inflows occur, while cash flows out with a depreciating domestic currency. If the currency were not trending, the gains and losses would cancel each other out over time. However, with a downward movement of the domestic currency, the cash outflow have to be funded by either selling part of the foreign bond portfolio that may have decreased in value due to a foreign interest rate rise or by curtailing the fund’s cash holdings below an optimal level. In addition, the bank that provides the hedge is likely to make **margin call** when the mark-to-market value of the forward contract deviated significantly from the contract value. Fund managers claim that cumulative cash losses may grow to between 20 and 30% of the value of underlying pension fund portfolios (Lindahl, 1998) which is confirmed by our subsequent hedging simulations.

Moreover, a rolling hedge commonly necessitates **rebalancing of the portfolio** (purchases or sales of foreign currency assets). Again exchange rate volatility injects an element of uncertainty into the hedging process.

Unanticipated changes in local market interest rate (not considered here) affect the underlying value of the portfolio which thus becomes a stochastic variable for the whole investment horizon. The resulting **capital gains/losses** provide an additional source of risk. For example, if after one year the €-interest rate is lower than at the beginning of the first year, €-bond portfolio has risen beyond €-100 million. Under these circumstances, the hedge is less than complete. The opposite result occurs with a rise in interest rates. The same reasoning applies to shares.

In order to assess hedging effectiveness, the unhedged portfolio is used as the benchmark. Unhedged portfolios can be regarded as a hedged bond investment and an appropriate long position in the same foreign currency.

### 3.3. Hedging Costs

Portfolio hedging costs vary depending on the kind of instruments used. Forward and

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12 Margin calls occur on a daily basis with futures contracts.
futures contracts are regarded as generally inexpensive hedging instruments while options contracts are on the opposite end of the cost scale. Unlike forward positions, long options are net investments as already mentioned. Due to the diversity of hedging instruments, it is difficult to provide a single representative cost figure. Since forward contracts appear to be the preferred hedging instruments, we detail the cost related to such contract.

1) **Trading costs and management costs** associated with rolling a 6-month sell forward contract of a foreign currency include commissions and the bid-ask spread. Perold and Schulman (1988) estimate that trading costs of about 12 basis points per annum of the amount invested are incurred. Outsourcing the hedging task or appointing a hedge manager causes significant management costs. The Economist (1991) estimates the total hedging cost amount to between 25 – 30 basis points of the value of the fund.

2) **Cash flow and portfolio rebalancing costs** are associated with costly sell-offs or purchases of foreign currency securities in small parcels in order to cover (invest) hedging losses (gains). Alternatively, portfolio managers have to raise funds from unit holders or borrow in the money market. In any case these costs are more than irritants associated with the hedging process of portfolios as they may significantly subtract from or add to the portfolio outcome. The capital asset pricing model (CAPM) ignores these problems.

3) **Forward premia/discounts**, defined as $\ell n \left( \frac{S_t}{F_{t,t+1}} \right)$ are often also counted as hedging costs (Abken and Shrikhande, 1997). The domestic currency is trading at a premium when $S_t < F_{t,t+1}$ and at a discount when $S_t > F_{t,t+1}$. For the foreign currency a mirror-image discount/premium picture emerges. If the foreign currency (€ in our example) is trading at a discount, the domestic dollar is expected to appreciate and the Australian-based investor is advised to hedge. However, for the privilege of locking in the value of their investment at the ruling forward rate, the forward discount has to be paid. Needless to say, the forward discount can also be received; this happens when the foreign currency is trading at a premium. In this case, hedging locks in an exchange rate gain.
However, the cost view of the forward discount stands on shaky ground when the unhedged portfolio provides the benchmark. As far as the impact of the exchange rate on the portfolio is concerned a funds manager could expect the same outcome in the long term, regardless of whether the hedging occurs or not. To see this, invoke speculative efficiency where the forward rate serves as an unbiased predictor of the expected future spot rate, ie.

\[ S_{t,t+k}^{e} = F_{t,t+k} + e_{t,t+k} \]  

This equation suggests that on average the hedged equals the unhedged outcome. The analysis assumes the absence of a risk premium or risk-neutral investors.

4) An exchange rate risk premium that is factored into the forward rate could pose a significant cost. The risk premium is measured as the difference between the forward rate and the expected future spot rate, in relative terms we have

\[ P_{t,t+k} = \frac{S_{t,t+k}^{e}}{F_{t,t+k}} \] 

More commonly (4) is expressed in logarithms. Taking natural logarithms of (4) and writing the variables in lower cases, we obtain

\[ p_{t,t+k} = s_{t,t+k}^{e} - f_{t,t+k} \] 

A positive value of the risk premium, \( P_{t,t+k} > 1 \) (or \( p_{t,t+k} > 0 \)) drives a wedge between the expected spot rate and the forward rate resulting for levels of currency rates in

\[ S_{t,t+k}^{e} > F_{t,t+k} \] 

that is, the forward rate is a downward biased estimate of the expected future spot rate. As data for expected rates are not readily available, the risk premium is commonly unobservable.\(^{13}\) Therefore, the identification of the risky currency is not an easy task.

\(^{13}\) Data of expected future spot rates may be obtained on the basis of surveys of knowledgeable market participants or generated from forecasting models.
However, *ex post* information on the risk premium may be gleaned from subsequent spot rates. When the domestic currency bears the risk premium, due to perhaps persistently large current account deficits, we can expect the subsequent spot rate, $S_{t+k}$, on average, assuming rational expectations, to exceed the corresponding forward rate. Fig. 3 contains information about hedging outcomes; where we compare the 6-month forward rate, $F_{t,t+6}$, with the subsequent spot rate 6 months hence, $S_{t+6}$, and graph the difference $S_{t+6} - F_{t,t+6}$. Roughly, during the first half of the observation period from March 1999, the negative difference ($S_{t+6} < F_{t,t+6}$) between the outcome and the forward market’s predictions could be interpreted as suggesting that the domestic dollar had a risk discount while during the second half the positive forecast error it endured a risk premium from about September 2001 onwards in the 6-month forward rate.\(^{14}\) However, simple *ex ante* forecast errors or a learning problem by market participants could equally likely be responsible for the systematic *ex post* prediction errors. For a recent attempt to estimate currency risk premia see Bams et al. (2004).

**Fig. 3: Ex Post Forward Hedging Errors,** January 1999 to September 2003

\(^{14}\) This interpretation is based on the assumption of rational expectations. Moreover, the literature dealing with empirical estimates of the risk premium appears to agree on its time-varying nature. This is also consistent
3. 4. Implications for Hedging Foreign Assets/Liabilities with a Risk Premium

The impact of a risk premium on the cost of hedging depends on whether the domestic or the foreign currency is more risky. Investment funds typically are concerned with the situation where the foreign currency contains a risk premium in which they hold investments. Fund managers and others with this exposure, naturally, want to hedge. The market will therefore factor a risk premium into the forward rate, imposing additional hedging costs on investors. When hedgers sell the risky currency asset forward, they receive on average fewer domestic dollars than they would if they left their exposure uncovered and sold at the subsequent spot rate at maturity of the forward contract. It has to be emphasized that the foreign currency is risky but not necessarily the foreign investment asset. Conversely, hedging of foreign liabilities would be on average preferable to leaving the position uncovered.

The payment or the receipt of the risk premium occurs under the following conditions:

- A risk premium is paid by
  - a domestic investor whenever he/she **sells forward the risky currency** in the process of hedging a foreign currency asset.
  - a domestic borrower whenever he/she **sells forward the risky currency** in the process of hedging a foreign currency liability

- A risk premium is received by
  - a domestic investor whenever he/she **buys forward the risky currency** in the process of hedging a foreign asset
  - a borrower whenever he/she **buys forward the risky currency** in the process of hedging a foreign liability.15

In the context of the risk premium it is appropriate to refer briefly to the free-lunch-in-

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with the risk premia in forward rates changing with their maturities. For example, the 6-month forward rate may contain a premium but not the 1-month rate and vice versa.
hedging argument put forward by Perold and Schulman (1988). They advocated always hedging as a policy stance since hedging reduces risk while costing little. For their prescription to make sense they explicitly assumed absence of a risk premium, and now we can see why. With a risk premium in the foreign currency, hedging of foreign currency assets reduces rate of return (and risk) resulting in a disappearance of the free lunch. However, when the domestic currency is judged risky, domestic investors with hedged foreign assets receive the risk premium. All told, the free-lunch could still hold in the longer term when risk premia of the domestic and foreign currencies alternate in an offsetting manner over time. Under these circumstances the forward rate would be unbiased over the longer haul.16

3.5. Comparison of Hedged and Unhedged Investment over Longer Time Period

For the purpose of highlighting the extent of the cash flow problems with hedging, we compute the value of unhedged and hedged foreign investment in foreign currency and in domestic currency using 1, 3 and 6-month forward contracts without taking account of transactions costs. We assume an Australian investor hedges US dollar, euro and yen-denominated assets. The time period starts with the introduction of the euro at the beginning of 1999. The left-hand panels of Fig. 4 show the value development of US$1, hedged and unhedged, over time in local currencies (US$) while the right-hand panels express the results of hedging and not hedging in domestic (A$) currency. Starting with the interpretations of the graphs in the left-hand panel, it is clear that each US dollar held unhedged by an Australian investor has the same value at the end as at the beginning, ignoring any investment returns. This is given by the straight lines in the left panels of Fig. 4. Fairly priced futures and forwards have a zero value at inception, obviating the need for any profit/loss adjustments at the outset. With hedging, the foreign currency value of the

15 Appendix 1 contains some worked examples of the impact of the risk premium on hedging costs.
16 The assumption of unbiasedness of the forward rate is necessary but not sufficient to justify full hedging. In addition we need the assumption that the local-market returns are uncorrelated with exchange rates. Even ignoring any portfolio diversification effects resulting from covariances, a policy of always hedging in the medium term is imprudent when the exchange rate devalues by more than the forward rate indicated. Such hedging losses can mount in the meantime, endangering the job security of the fund manager, notwithstanding that these losses might be offset later by currency gains.
investment changes (dotted lines). Why does the US$1-investment rise and fall? During the
first half of 1999 the forward market underestimated the devaluation of the US$, as
reflected in the subsequent spot rate consistently exceeding the corresponding forward rate
\( F_{t,t+k} < S_{t+k} \). Consequently, *hedging profits* allowed the investor to purchase additional
foreign currency units. Subsequently, hedging losses occurred which had to be financed by
selling off part of the foreign investment (US$1). The dotted line in the left-hand graphs of
Figs. 4 to 6 track the gains/losses in the value of the US$, € and ¥-portfolios associated with
the hedging of these currencies. These are the cash flows that hedging managers complain
about and that cause costly portfolio reshuffling. The size of these cash flows for a given
portfolio is determined by the difference between the forward rate and the subsequent spot
rate. The differences between subsequent US$/A spot rates and the corresponding 6-month
forward rates since the beginning of 1999 until the September 2003 in Fig. 3 assist in the
interpretation of the hedged and unhedged outcomes.

From mid-1999 until the mid-2001, the revaluation of the US dollar was not adequately
captured by the forward market \( (F_{t,t+k} > S_{t+k}) \). Hedging losses occurred which had to be
financed by selling off part of the underlying foreign currency security. During this time the
hedged foreign currency portfolio would have lost about 20% of its value in hedging losses
due to $A devaluation surprises. However, the remaining US$-portfolio is now worth more
in Australian dollar terms guaranteeing the hedged amount.

The remainder of the period of observation was characterized by \( (F_{t+t+k} < S_{t+k}) \) which
allowed the investor to replenish the foreign currency component of the portfolio.

The three graphs in the right hand panel of Fig. 4 show the outcomes of hedged and
unhedged investments in domestic Australian dollars. As a general rule, the hedged
outcome locks in successfully the $A-value of the security over the hedged period even
though the hedged portfolio value exhibits variability. By contrast, the unhedged investment
in domestic dollars exhibits significant volatility. Again our results appear to echo the
substantial cash flow problems to which we referred to earlier.
Purely by coincidence, no doubt, the hedged and unhedged outcomes after about the 3-year period are very similar. The chance-nature of the finding appears to be borne out by the results of the same exercise carried out for hedged and unhedged investments in euro (Fig. 5) and yen (Fig. 6). There is not tendency for convergence between hedged and unhedged outcomes.

Fig. 4: Comparison of Hedged and Unhedged US$ Investment.
Fig. 5: Comparison of Hedged and Unhedged € Investment.

Fig. 6: Comparison of Hedged and Unhedged ¥ Investment.
4. Correlations Related to Currencies and Share Indices

In the following we examine some of the inputs into the variance-covariance matrix of the optimal portfolio selection process on the basis of historical data. The portfolio framework renders the hedging decision much more complex. For example, with several currencies in a portfolio of foreign assets, some of the correlation amongst currencies might have offsetting positive and negative effects. In order to place the relevant portfolio issues into the appropriate context we start with some comments on portfolio return and risk for the hedged and unhedged cases. In the portfolio framework the expected rate of return is linearly related to the weighted rates of return of the included assets. The portfolio’s variance on the other hand depends on

- the weighted covariances of the security returns
- the weighted covariances of corresponding exchange rates and
- the cross-covariances between exchange rates and security returns on a weighted basis.
4. 1. Equity and Currency Correlations

The extent to which rates of return covary determines diversification benefits. Co-movements are measured by correlations. In this section we examine the correlations amongst shares and currencies. Assume our portfolio consists of investments in share market indices of the S&P500, Nikkei225, FTSE100, STOXX50, DAX30, CAC40, HSI and the AOI. Monthly rates of return where computed from March 1989 to March 2004. Table 1 section A contains the correlation coefficients of rates of return expressed in local currency, that is, the STOXX index is expressed in euro, the Nikkei in yen etc. Due to time-zone differences between the investment returns in different exchanges, daily two-day rolling averages are reported. The positive and large correlation coefficients in this table reflect the co-movement of global stock markets first upwards and then downwards during the period of observation. In this respect, the evidence regarding the correlations is time specific. Noteworthy, and expected, are the large positive values of the correlations between the European exchange indices and between the latter and the US S&P500. For stock market index investors from Europe and the US, the share markets appear to behave very similar on a local currency basis, offering limited diversification benefits.

Parts B and C of Table 1 show the co-movements for the same bourses but now the local indices are expressed in US dollars and in Australian dollars, respectively. Again, due to time-zone differences between the investment returns daily two-day rolling average are reported. The correlation coefficients are all smaller when expressed in US$ (B). Exchange rate movements of the US$/€ against the euro, the yen, and the other currencies are responsible for this. For example, the STOXX50 and the S&P500 may both rise by similar percentages in their local currencies but the US$ may devalue against the euro at the same time, lowering correlations. A similar picture emerges when indices are expressed in $As in part C of the table, though some correlation coefficients are significantly reduced by the currency effect. As a general rule one can say that even though the various bourses moved

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17 See Abken and Shrikande (1997) for an algebraic exposition of the relationship between the variance and the covariances and cross-covariance in the case of two and n currencies. They also provide solutions for hedged and unhedged portfolios.
largely in lockstep up and down, the respective currencies did not.

**Table 1: Correlation Matrices of Daily 2-Day Total Index Returns in Various Currencies**

**A**

Pairwise Correlation Matrix of Daily 2-day Share Index Returns (Local Currency)
(3/3/89 to 3/3/04)

<table>
<thead>
<tr>
<th></th>
<th>S&amp;P 500</th>
<th>NIKKEI 225</th>
<th>FTSE 100</th>
<th>STOXX 50</th>
<th>DAX 30</th>
<th>CAC 40</th>
<th>HSI</th>
<th>AOI</th>
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<td></td>
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<td>CAC 40</td>
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**B**

B : Pairwise Correlation Matrix of Daily 2-day Share Index Returns (USD)

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<th>STOXX 50</th>
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<tr>
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**C**

C : Pairwise Correlation Matrix of Daily 2-day Share Index Returns (AUD)

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<th>CAC 40</th>
<th>HSI</th>
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<td>S&amp;P 500</td>
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<td>FTSE 100</td>
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<tr>
<td>STOXX 50</td>
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<td>0.26</td>
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"NIKKEI 225", "STOXX 50" and "HSI" are price indices
Total return index version has been used for "S&P500", "FTSE 100", "DAX" and "AOI"
Data for AOI, DAX and CAC started from 29/5/92, 1/7/91 and 1/3/90, respectively.
All data are obtained from Datastream except CAC 40, which is from Yahoo. The USD and AUD denominated correlations for CAC 40 in Table B and C, respectively are calculated using the USD/FRF and the USD/AUD exchange rates provided by Datastream
Finally, we examine the pairwise correlations between the seven currencies vis-à-vis the US in Table 2, section A and of the A$ against the other currencies in B. Part A presents the correlation matrix of pairs of exchange rates from the vantage point of US investors. For example, the coefficient of 0.27 in the first column measures the correlation between the €/US$ and the ¥/US$ exchange rates. Table 2 part B does the same from the Australian investor’s perspective. Two features stand out. First, the European currencies before the introduction of the euro vis-à-vis the US dollar behave like a currency block which the mark and franc joined at the beginning of 1999. The pound continues to shadow the euro. For example, on average, the correlation coefficient of the £/US$ and the US$/€ exchange rates was 0.5 only slightly less than its link with the DM/US$. Second, the correlations from the Australian investor (section B) perspective are much higher than those associated with the US$. Thus the A$ appears to have more in common with the non-US currencies than with the US$.

Table 2 Pairwise Correlation Matrices of Daily Currency Returns: 3/3/89 to 3/3/04

A
(US Investor Perspective)

<table>
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<th>€</th>
<th>£</th>
<th>DM</th>
<th>FF</th>
<th>SHK</th>
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B
(Australian Investor Perspective)

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</table>

All returns are measured as differences of natural logarithms of levels. Correlations with EURO are based on the period from 4/1/99; DM and FF on the period up to 31/12/98.
4. 2. Rolling Cross Correlations

So far we computed the averages of the correlations between share indices on the one hand and currencies on the other. We now analyse the cross-correlations between equity indices and their corresponding trade-weighted currencies. In Fig. 7 in the first two boxes on the left hand side this is done for the S&P500 and the US$-trade-weighted exchange rate index between 2 January 1991 and 30 May 2003.\(^\text{18}\) The top graph for each index displays the development over time of the two (share and currency) indices and the graph below shows the 6-month rolling correlations of 1-week returns of the two indices. This procedure is repeated for the remaining five equity indices and their corresponding trade weighted exchange rates, namely for the Nikkei225 and the ¥-TWI index, the FTSE100 and the £-TWI, the DAX and the DM-TWI, the CAC and the FF-TWI, and finally, the AOI and the $A-TWI. In order to make interpretation of the correlations easier, share price and exchange rate movements for the same time period have been included in the respective top graphs. They provide a visual impression of the co-movements. The rolling-correlations-graphs at the bottom of each pair convey an impression of significant variability of these correlations. For the US the correlations up to about 1999 were relatively small in absolute value. From then on they started to exhibit larger swings as both time series moved up and subsequently down together. The large positive swing of the cross correlation from about 0.20 at the beginning of 1999 to a value of rho of 0.70 a year later means the S&P500 and the dollar both rose in value. This parallel movement benefited European-based investors in the US share market as they gained from rising US share prices and an increasing value of the dollar.

\(^\text{18}\) For the mark and the franc the sample period ends in 31 December, 1998.
Fig. 7: Equity Indices and Trade Weighted Indices and their Index Return Correlations

Index Values: S&P500 and $US TWI

Index Values: NIKKEI225 and ¥ TWI

Index Values: FTSE100 and £ TWI

Index Values: DAX100 and DM TWI

FTSE100 and £ TWI

DAX100 and DM

6-month Rolling Correlations of 1-Week Returns
5. Forecasting Volatilities

The essential inputs into the mean-variance hedging model, namely expected returns of assets and currencies, their co-variances and correlations are uncertain. That is, they may change unexpectedly and often do so dramatically. Despite this, the majority of contributions to the mean-variance hedging literature are based exclusively on raw or manipulated historical data. This essentially backward looking approach may at times provide a false picture of the benefits form diversification, either overstating or understating expected portfolio returns and benefits from diversification.

Forecasts of assets returns and co-variances can take historical data only as a point of departure. Obviously the informative content of historical data depends on the length of time for which these historical time series are available. For example, the S&P500 is available since 1926, for other indices the historical records are much shorter. Longer time series store a greater wealth of experience than those having become available only in recent years. The stock of historical data for currencies in general covers an even shorter record. However, even data series with a ‘long history’ of ups and downs in the fortunes of
the stock market and currency gyrations may be of limited value when structural changes in economic fundamentals occur. Under these circumstances changes in the domestic and international political environment, monetary and fiscal policies, consumer confidence, technological changes, the emergence of new industries, decline of others as well as any looming regional crises have to be factored into forecasts.

It would be beyond the scope of the present paper to address the issue of forecasting comprehensively on a theoretical and applied basis. For this reason we focus on currencies and employ four methods of volatility predictions. We examine forecasts of volatilities of the Australian dollar, the yen, the pound against the US dollar based on historical data, on volatilities implied by options prices and on daily as well as monthly econometric estimates of the GARCH family.

5.1 Volatility Definitions and Data

The evaluation of out-of-sample volatility predictions requires their comparison with volatility outcomes. Since implied volatilities entail, say, 1-month ahead forecasts for options with the same maturity, care has to be taken to space the forecast intervals for the remaining volatility prediction techniques in a similar manner.

Realized standard deviation on an annual basis from day \( t \) for the next \( d \) days is defined as\(^{19}\)

\[
\sigma_{t,d}^{RV} = \sqrt{\frac{252}{d} \sum_{i=1}^{d} s_{t+i}^2}
\]  

(7)

where \( s_{t+i} = \ln(S_{t+i}/S_{t+i-1}) \) measures the return of the spot rate for day \( t+i \).

We call realized standard deviation henceforth realized volatility; it provides the benchmark for assessing volatility forecast according to the predictions methods. Realized

\(^{19}\) For the definitions of volatilities see, for example, Christoffersen and Mazzotta (2004).
volatilities for each month are calculated as the annualized standard deviations of daily returns over the calendar month. As mentioned, we are using four volatility specifications to forecast realized volatility. Three are based on time series data and one is derived from options prices.

Forecasts using 1-month historical volatilities are based on the ex-post realized volatility calculated for the previous month. One basic historical volatility measure can be defined as

$$\sigma_{t, d}^{HV} = \sqrt{\frac{252}{d} \sum_{i=1}^{d} s_{t, d+i}^2} \quad (8)$$

The historical model amounts to an equal-weighted average of past squared daily continuously compounded exchange rate changes.

The Generalized Autoregressive Conditional Heteroskedastic \([\text{GARCH}(1,1)]\) model for 1-month volatility forecasts are derived from\(^{20}\)

$$\sigma_t^2 = \omega + \alpha s_{t-1}^2 + \beta \sigma_{t-1}^2 \quad (9)$$

with

$$\gamma + \alpha + \beta = 1$$

where \(\sigma_t^2\) stands for the variance rate of continuously compounded exchange rate changes to be predicted for time \(t\); \(\sigma_{t-1}^2\) measures their corresponding observed values at \(t - 1\). For the parameter \(\omega\) we have \(\omega = \gamma V_L\) where \(\gamma\) is the weight assigned to long-term volatility \(V_L\) and \(\alpha\) and \(\beta\) are estimated coefficients.

We estimate the GARCH model on the basis of daily and monthly exchange rate changes. This allows us to obtain 1-month-ahead predictions as averages of daily data and monthly

\(^{20}\) For the derivation of (9) see Hull (2003, pp. 374 – 377).
forecasts, say, from the end of the month of the current to the next month.

Using daily data our parameter estimates of (9) are based on a rolling 2-year return history up to the last business day prior to the forecast month. Daily predictions are calculated using a dynamic forecast method for each day ahead (up to the number of actual business days in the month) then averaged to give an expected volatility over the whole calendar month. This method ensures that the forecast period of daily exchange rate changes always equals one month. However, this forecasting device assumes the same information set (in terms of $\omega$, $\alpha$ and $\beta$) throughout the month that forms the basis of volatility predictions. In other words, the forecaster uses the same estimated parameters of (9) as the daily volatility predictions are generated for the next month.

An alternative version of the GARCH(1,1) model similarly takes (9) as a point of departure. However, the estimation procedure is now based on monthly non-overlapping volatility data. In other words the time subscripts in (9) refer to months while in our previous version they denote days. As we are reducing the sample to monthly observations, estimates of (9) are based on a rolling 5-year return history up to the last business day prior to the forecast month. As a result our sample of monthly predictions shrinks, starting only in December 1998. In principle, monthly observations may be obtained from daily averages of each month, by taking beginning-of-month, mid-month, end-of-month data or any date in-between. Our forecasts are based on end-of-month observations. Since the data are now more widely spaced, we computed exchange rate changes as $s_i = (S_i - S_{c,i})/S_{c,i}$ where $i$ is not fixed but depends on the actual number of business days per month (21 on average) and is the last business day in the calendar month.

Lowering the frequency of the data from daily to monthly allows us correspondingly to predict volatility at monthly intervals albeit only for a shorter time period.

**Implied volatility** predictions for each calendar month are based on the latest implied

---

21 The estimates were carried out using EViews 5.
volatility observation prior to the given calendar month. All 1-month implied volatility
data for the three currencies are from Bloomberg and based on at-the-money call options.22

Historical daily currency data are obtained from the Federal Reserve website and
Datastream. Returns are calculated from the point of view of an US investor in each
currency - a currency appreciation against the $US is treated as a positive return.

5.2 Volatility Forecast Error Analysis

Forecast errors for each calendar month are defined as the difference between the forecast
and the realized volatility for the three currencies. The forecast error distributions for the
three currencies which are based on four volatility extraction techniques are presented in
Figures 8 while Table 3 contains the averages and standard deviations of the error statistics
for available time periods (Panel A) and the results for the common time span December

Historical volatilities provide the best average error statistic for all three currencies (Table
3), regardless of the time period used. The second best forecast outcomes are generated by
the GARCH method when monthly averages of daily forecast are used. As expected, the
performance relating to monthly GARCH volatility predictions performs on average
marginally worse. There is little difference between the various methods when predictive
power is measured in terms of dispersion; the standard deviations are all in the same
ballpark.

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22 The Bloomberg volatility data differ slightly from those obtained from Datastream which we use to
calculate GARCH volatilities. The latter operate on a 5-day week while the former do not provide data for
holidays. As an aside it is mentioned that the GARCH(1,1) forecasts required estimating several hundred
regression equations.
Tests of the GARCH equations (9) did not provide output values for two monthly estimates. We therefore varied the period of observations to obtain results. The alternative of omitting the estimates was less appealing to us.
$US/£ 1-Month Volatility Forecast Errors:
Implied: Aug 97 to Jul 03
1m Hist: Feb 89 to Dec 03
GARCH(1,1): Jan 91 to Nov 03
MTHLY GARCH: Dec 98 to Nov 03

For monthly GARCH, Return = (S(t) - S(t-i))/S(t-i) instead of log(S(t)/S(t-1))
For monthly GARCH, a 5-year model is used instead of a 2-year model
Since hundreds of GARCH models are generated automatically by
programming in Eviews 5, we have not carried out any tests about the
goodness of fits of the models (eg. Ljung-Box residual or LM tests).

Table 3: 1-Month Volatility Forecast Error Statistics for Varying Periods

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Implied</td>
<td>Historical</td>
</tr>
<tr>
<td><strong>Currency</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A</td>
<td>0.010</td>
<td>0.000</td>
</tr>
<tr>
<td>¥</td>
<td>0.006</td>
<td>0.000</td>
</tr>
<tr>
<td>£</td>
<td>0.005</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Forcast error statistics are based on available periods

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Standard Deviation</th>
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<tbody>
<tr>
<td></td>
<td>Implied</td>
<td>Historical</td>
</tr>
<tr>
<td><strong>Currency</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A</td>
<td>0.013</td>
<td>-0.001</td>
</tr>
<tr>
<td>¥</td>
<td>0.013</td>
<td>0.002</td>
</tr>
<tr>
<td>£</td>
<td>0.006</td>
<td>-0.001</td>
</tr>
</tbody>
</table>

Forecast error statistics are based on the period Dec 98 - July 03

The currency hedging manager may also be interested, perhaps even primarily so, in the
whole pattern of forecast errors when unusually large exchange rate changes occur. In this
case one would have to compare the error statistics at higher multiples of standard deviations.

In the literature a variety of methods exists to assess the predictive content of implied volatilities. Jorion (1995), Andersen and Bollerslev (1998), Pong, Shackleton, Taylor and Xu (2004) and Christoffersen and Mazzotta (2004) use regression analysis to assess the informational content and predictive power of implied currency volatilities and time series models. Typically, univariate and bivariate regression techniques are estimated. In the first approach realized volatility is regressed on the corresponding forecast of the selected model. In the second, the implied volatility forecasts are paired with another prediction model as regressors to assess their incremental contribution to forecast accuracy. Commonly these studies compare the coefficient of determination ($R^2$) for evaluating the forecast prowess of different models.

A somewhat roundabout, but informative, approach to assessing the future volatility environment consists in examining the future path of some of the likely volatility determinants. Studies by Schwert (1989), Mixon (2002), and Glatzer and Scheicher (2003) estimate the economic determinants of implied volatility of share index options. Jüttner and Leung (2004) explain the volatility changes for nineteen currencies on the basis of volatility changes of the model-determinants of exchange rates. Provided a set of economic factors influencing currency volatilities can reliably be established, one would need to forecast the likely development of these factors in order to better understand the volatility pricing process of the foreign exchange market. Such an exercise does provide us with a new handle on expected currency volatility as it allows us to gain insights into the markets’ overall information processing mechanism.

### 5.3 Beyond Implied Volatility: The Rich Information Set of Risk-Neutral Probability Density

The historical, GARCH and implied volatility analyses provide some useful insights into the error structure of volatility forecasts. However, the information only pertains to standard
deviations of equity and currency return distributions. In other words, these volatilities contain a very narrow uncertainty concept which is confined to the dispersion around the mean of the probability density function. Fund mangers require more pertinent information for portfolio selection. Does the market predict a negatively skewed distribution or are there fat tails in some of the density functions? Both features could portend a future collapse in shares or a disastrous drop in the values of certain currencies. Surely, fund managers (and others) would like to know more about such probabilistic forecasts across the whole range of distributions.

Risk neutral density (RND) provides an avenue for extracting these features of expected return distributions. It provides portfolio managers with a broad menu of volatilities forecasts regarding the behaviour of currencies, share price indices, short and long-term interest rates and other asset/rates for which active options trading exist. The densities are distilled from corresponding options pricing models. Specifically, what information can be gleaned from options? As already mentioned, we can back out of an at-the-money call option on euros the €/$A implied volatility. To recover the entire RND, we have to go two steps further. First, RND provides information about skewness which is the third moment of the distribution. Implied skewness gauges the asymmetry of market expectations around the mean. For instance, negative skewness of the probability density underlying a 3-month €/$A option means that the market views a $A-depreciations as more likely than a $A-appreciation by the same percentage. Second, kurtosis or the fourth moment of the RND, indicates the probability of extreme, not necessarily symmetrical – negative or positive - exchange rate changes.

The method of extraction of the array of information from the RND of options on US dollars consists of combining the following financial instruments with the same maturity (see Malz, 1997).

(1) Implied volatilities for three months are obtained by solving the Garman-Kohlhagen call option price formula for standard deviation. However, this metric measures the symmetric volatility of an at-the-money option.
(2) The so-called risk reversal captures the market sentiment regarding the skewness of tail risk where skewness measures the asymmetry between the chance of large exchange rate movements upwards and downwards. A buy risk reversal is established by buying a call and selling a put option where both are deeply and equally out-of-the-money. This allows market participants to trade skewness. For example, when the probability of loss inherent in the written option exceeds the chance to profit from the call option, the risk reversal takes on a negative value. Any such value differences entail asymmetric exchange rate expectations. In this specific case the market attaches a larger probability to option writer’s losses due to the exchange rate falling below the strike price than to the call option buyer’s gains due to the currency rate rising above the strike rate. The price of the risk reversal (difference between the two positions) measures the skewness of the density function.

(3) The implied volatility of an at-the-money option portrays only narrowly the risk around the strike rate of log-normally distributed rate changes. However, extreme exchange rate changes happen more often in reality than the log-normal distribution would suggest. That is, observed distributions of exchange rate changes have fat tails. Market traders react to this feature by factoring a higher volatility for deep out-of-the-money options and in-the-money options in call (put) premia. This pricing behaviour results in the famous volatility smile.

Strangle options are used to measure fat tails or kurtosis of the density function. They entail the purchase of deep out-of-the-money buy call and put options. Implied distributions with fatter tails are more slimmer than the lognormal variety. As a consequence small and large exchange rate changes are more likely and in-between changes less likely than the lognormal distribution would suggest.

Further research is needed to explore the usefulness of the information extracted from the whole range of implied probability of the density function of options. For example, do tail percentiles assist in the management of exchange rate risk? As indicated in an earlier

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24 A discussion of risk reversals is provided by Remolona and Scott (1999)
footnote central banks appear to rely on this information source to gauge market sentiment. Likewise, there does not appear to be any research carried out on the economic determinants of the higher moments of density functions such as skewness and kurtosis. It would be interesting to investigate, for example, how often and to what extent fat-tailed distributions are followed by above average exchange rate changes.

6. Forecasting Other Portfolio Inputs

Hedging, as part of the investment decision, is based on current information about likely future exchange rate movements, on their variances and co-variances amongst currencies and with securities included in the portfolio. We already discussed volatility and density forecasts but we have not said anything about exchange rate and correlation predictions. Portfolio theory remains mute about this enormous preparatory task except claim market efficiency. However, currency markets clearly show mean reversion in real exchange rates which entails elements of their predictability, options contain information about future volatilities as well, conditional volatility models entail its predictability. These features may be useful for portfolio construction. Are nominal exchange rates predictable?

6. 1. Forecasting Nominal Exchange Rates

A multitude of forecasting methods exists and funds managers are advised to keep an open mind to the, often diverging, messages they can contain. Studying several forecasts minimizes the danger of overlooking important information. We consider fundamental-structural forecasting techniques, time series models and several technical trading rules.

6. 1. 1 Structural-Fundamental Forecasting

The term structural suggests that the forecasting model captures the model-based structure of the economy which takes into account fundamental economic variables such as interest and inflation differentials, economic growth and other variables. A very simple, though successful forecasting approach under conditions of hyperinflation, is \textit{ex ante} purchasing
power parity. The expected domestic/foreign inflation differential determines the rate of revaluation or devaluation as the case may be.

However, the limitations of more general and sophisticated structural-fundamental models of the nominal exchange rate were laid bare in a study by Meese and Rogoff (1983). They showed that out-of-sample (ex post) forecasting with such models did no better than the random walk without drift. However, if such ex post forecasts perform that poorly, we cannot vest much faith into ex ante predictions on which fund managers base their longer term (from quarterly upwards) hedging decision.25

6.1.2 Information Content of Forward Rates.

The forward rate may contain useful information about exchange rate expectations, despite the fact that a host of studies have found it to be a biased predictor of the expected future spot rate. One often cited reason for the bias concerns the existence of a time-varying risk premium. Several approaches by academic studies attempt to measure the risk premium. Gokey (1994) amongst many others, tries to quantify the risk premium by relating it to its presumed economic determinants, such as expected real interest rate differentials or ex ante deviations from purchasing power parity. An alternative approach models the risk premium in the context of the intertemporal capital asset pricing model (Baillie and Bollerslev, 2000). Assuming one could nail down and measure reliably the risk premium in forward rates, a long-standing issue in international finance could be settled. This issue concerns the question whether forward rates are biased or unbiased predictors of expected future spot rates. For example, a risk premium in the $A would result in a downward biased forward rate as given in (6).

Hedging practitioners appear to circumvent the forward bias problem in their own ways. Kritzman (1993), VanderLinden et al. (2002) are amongst the numerous studies devoted to forward hedging in the face of forward bias. The latter paper provides evidence of

25 Ex post out-of-sample predictions use observed values for the dependent and the independent variables, while ex ante forecasts predict the dependent variables on the basis of the estimated parameters of the model and predicted values of the independent variables.
forecasting success for conditional hedging rules where the term conditional refers to the
hedging decision being made contingent on information available at the time. The authors
start with the assumption that the current spot rate is a better predictor of the expected
futures spot rate as far as the unbiased property is concerned. Consequently, they establish a
prima facie case for hedging of foreign currency assets when the domestic currency is
trading at a discount

\[ S_t > F_{t,t+k} \]  

(10)

This is the opposite of what covered interest parity would suggest. Note, hedging in the
presence of forward rate bias takes the current spot as the predictor of the expected future
spot rate. That is, instead of (3) we have

\[ S_{t+k}^e = S_t + e_{t,t+k} \]  

(11)

Conversely, when \( S_t < F_{t,t+k} \) no hedging is recommended.

Vanderlinden et al. continue by combining covered interest rate parity with ex ante
purchasing power parity to derive real interest rate parity which implies that real, inflation-
adjusted interest rates, are equalized on a global basis. However, when real interest rates at
home exceed those in the rest of the world, capital will flow in and the exchange rate
appreciates. The authors set two conditions for hedging. Hedge when the spot rate exceeds
the forward rate and the domestic real interest rates is higher than the foreign real rate. The
two preconditions for hedging (or not hedging) play the role of an insurance policy. This
behaviour of only taking a decision after several test have passed is not unusual when
agents are faced with uncertainty.

6. 1. 3 Filter Rules, Momentum Strategies and Charting

It appears short-term profitable opportunities exist due to inefficiencies in foreign currency
markets. Two frequently cited reasons for inefficiencies in foreign exchange markets stem
form noise trading and central bank intervention. Numerous trading strategies have been
applied to profit from such market inefficiencies. In the following we analyze one technical trading strategy and mention others.

A **filter rule** is a mathematical rule that can be applied mechanically to engender buy or sell signals. A filter rule generates profits when momentum or ‘bandwagon’ effects drive the exchange rate further in the direction indicated by the initial trend. For example, an x percent filter rule may lead to the following trading strategy. A buy signal for domestic currency implies purchasing the domestic currency whenever it rises x percent above its most recent trough of the spot rate. The purchase of the $A is financed by borrowing US$s at r*. The return from long position in domestic currency between t and t+1 consists of the

- exchange rate gain \( \ln \left( \frac{S_{t+1}}{S_t} \right) \)
- interest earned on the long position in domestic currency, \( r \)
- minus the interest expense on the foreign currency borrowing, \( r^* \)

Levich and Thomas (1993) employ, amongst other technical strategies, several filter rules. Taking into account the size of the trading profit, its risk and transactions cost, the authors claim their trading rules produce risk adjusted abnormal returns when compared to a buy and hold strategy.

Okunev and White (2003) find evidence for the profitability of **momentum-based trading strategies** while Taylor and Allen (1992) evaluate the usefulness of **charting** for currency predictions. A recent paper by Olson (2004) suggests that risk-adjusted profitability of using moving average crossover rules may have declined in recent years.

### 6.2 Forecasting Correlations

The structure of **correlations** plays a vital roll in the portfolio selection process. Relevant correlations in the international context concern the co-movements amongst global share markets rates of return and cross-correlations between share markets and currencies returns as well as amongst yields and currencies. There is one major difference between share market correlations on the one hand and those amongst currencies on the other; the first can take on all positive values while all currencies cannot all rise or fall together at the same
time.

Relying on naïve historical correlation data as input in the portfolio choice model may be suboptimal as a general approach but this is unquestionably so when regime changes occur, such as when global economic activities become increasingly less synchronized, currency blocks emerge or when commodity currencies are buoyed by good news. Logic suggests to predict correlations rather than rely on their historical averages. One strand of the literature (eg. Erb, Harvey and Viscanta, 1994) regresses correlations against its presumed economic/financial determinants. Research of this kind enhances our understanding of share price and currency fluctuations and allows fund managers to ascertain the plausibility of specific correlations obtained form historical data.

As a spill-over from the contagion debate a new line of research has opened up about the interpretation of correlation increases during episodes of heightened return volatility. Forbes and Rigobon (2002)\textsuperscript{26} impute the observed inter-market correlations during and after the 1987 cash, the Mexican Crisis of 1994 and the Asian Crisis of 1997 to the associated rise in return volatilities. In other words, “… correlation breakdowns may reflect time-varying volatility of financial markets rather than a change in the relationship between asset returns” (Loretan and English, March 2000). This approach appears to have profound implications for the risk-return profile of optimal portfolios. First, to the extent that fund managers use relatively short historical intervals (or longer intervals while applying geometrically declining weights) for volatility and correlations computations that fall into atypically low or high volatility periods, the estimated correlations will be too low or too high, respectively. As a result, such correlations inputs exaggerate or understate diversification benefits for the two episodes, respectively. It remains to be seen whether similar corrections apply to currency linkages as exchange rate correlations breakdowns can only occur on a regional (eg. Asian Crisis) basis or for ‘branded’ currencies (eg. commodity currencies).

\textsuperscript{26} Based on NBER 1999 Working Paper 7267.
7. Conclusions

Internationally diversified portfolios, including those with foreign currencies as a separate asset class, require management of their foreign currency risk exposures. We focus on some of the elements of the exchange rate hedging process. First, hedging instruments are all expressed in nominal values while exchange rate changes commonly and significantly fluctuate in real terms. We analyse the implications of this discrepancy for the hedging process and find the portfolio optimizing approach wanting. It fails to cope with international inflation differentials that are not reflected in offsetting currency movements. Moreover, the secular downward trend in the real exchange rate poses further problems for hedging. Second, the hedging of medium to longer term international currency exposures reveals significant hedging costs in the form of unplanned cash flows and portfolio adjustments. In addition, when shorter term hedging contracts are employed, the hedged outcome over the longer haul becomes uncertain. As well, the existence of a nominal exchange rate risk premium may increase the cost of hedging. Third, we estimate correlations amongst currencies and share indices and cross-correlations of currencies and shares. The evidence on this level of aggregation suggests that European exchanges on a local currency basis largely move in lockstep. However, their index changes are also closely related to the US market movement. This cannot be said of the Asian and the Australian bourses. As expected, the currency correlations clearly identify the euro, the US dollar and the yen as currency blocks. Fourth, our currency volatility models support the notion that exchange rate gyrations are predictable; forecasts based on historical data appear to outperform implied and time series models. Projections into the future of whole probability density functions of exchange rate changes and their evaluation as tools for portfolio selection remain for further research.
References


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Appendix 1

Impact of Foreign Currency Risk Premium on Hedging Overseas Assets/Liabilities

<table>
<thead>
<tr>
<th>Risk premium in Foreign Currency € (=risk discount of domestic currency, $A)</th>
<th>Risk premium in Domestic Currency $A</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_{t,t+k}^e &lt; F_{t,t+k}$</td>
<td>$S_{t,t+k}^e &gt; F_{t,t+k}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AUS Investor with Foreign €100m-Asset</th>
<th>Hedge: <strong>Sell</strong> €100m forward at 0.615 for $A162.602m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hedge in case no risk premium exists:</td>
<td>$S_{t,t+k}^e = F_{t,t+k}$</td>
</tr>
<tr>
<td><strong>Sell</strong> €100m forward at 0.60 for $A166.667m</td>
<td><strong>Outcome</strong> as compared to no risk: AUS investor <strong>pays</strong> risk premium of $\ln(0.615/0.60) = -0.0247$ or -2.47% when hedging foreign investment and € is more risky.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AUS Borrower with €100m-Liability</th>
<th>Hedge: <strong>Buy</strong> €100 forward at 0.615 for $A162.602m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hedge in case no risk premium exists:</td>
<td>$S_{t,t+k}^e = F_{t,t+k}$</td>
</tr>
<tr>
<td><strong>Buy</strong> €100 forward at 0.60 for $A166.667</td>
<td><strong>Outcome</strong> as compared to no risk: AUS borrower <strong>receives</strong> risk premium of -2.47% when hedging foreign liability and € is more risky.</td>
</tr>
</tbody>
</table>

For the interpretation of the table we explain the transactions in the north-east quadrant where the domestic currency bears a risk premium and the Australian investor of a €100 million portfolio hedges the associated exchange rate exposure by selling €100m (in the safe currency) forward which implies buying $A166.667 million (the risky currency) at the forward rate of €0.60/$A. In order to compute the risk premium involved, we compare this outcome to a situation where no risk premium exists. In this case the forward rate would equal the expected future spot rate of $S_{t,t+k}^e = \ldots$
$F_{t, t+k} = \varepsilon 0.615/$A. The hedging outcome for the Australian investor would then only be $A162.602. The risk premium then amounts to ln(166.667/162.602) = 0.0247 or 2.47%. As the investor has bought the more risky currency ($A) in the forward market, he/she receives the risk premium which $A4 065 (166 667 – 162 602) in dollar terms. The three remaining quadrants have to be interpreted in a similar fashion. Remember, one is always paying the risk premium when selling the more risky currency in the forward market, and receiving it when buying the more risky currency.