Currency Risk Hedging: No Free Lunch
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Abstract

Currency risk hedging in international portfolios typically aims at minimizing portfolio volatility. In a purely out-of-sample context, this paper looks beyond the effect on portfolio risk and finds that currency hedging comes at a serious cost. While hedging lowers volatility of international equity and bond portfolios, it also lowers portfolio returns. The reduction in average returns more than offsets the decrease in variance and as a result, Sharpe ratios often deteriorate. In addition, hedging induces more negative skewness and significantly higher kurtosis in portfolio returns. We extend a no-arbitrage model of interest rates and exchange rates with an equity component and show that, in the model, hedging indeed lowers returns. Currency expected returns are positively related to the covariance between currency and equity returns. Consequently, the hedging portfolio takes short positions in currencies with positive expected returns, thereby lowering overall portfolio returns. The model also generates the observed negative effects of hedging on Sharpe ratios and skewness.

JEL classification: G11, G15

Keywords: Currency risk, currency hedging
Currency risk hedging in international stock and bond portfolios has been widely hailed in both the academic and practitioner literature as a free lunch.\footnote{See for example, among many others, Black (1988, 1993), Eun and Resnick (1988), Pérold and Schulman (1988), Glenn and Jorion (1993) and Campbell et al. (2010).} Indeed, if currencies have zero expected returns and positive volatility, currency hedging reduces volatility while leaving portfolio expected returns unaffected. In this case, currency risk hedging improves risk return trade-offs of international portfolios at no cost.

However, if currency risk is priced, currency risk hedging may affect the expected return on the portfolio in addition to its risk. Indeed, there is increasing evidence of a premium for currency risk. Several international asset pricing models show that, in equilibrium, when currency risk induces deviations from purchasing power parity, investors require to be compensated for bearing exchange rate risk.\footnote{See, for instance, Solnik (1974b), Sercu (1980), Stulz (1981), and Adler and Dumas (1983).} Importantly, Dumas and Solnik (1995), De Santis and Gerard (1998) and Lustig and Verdelhan (2007) among others, report empirical evidence of a premium for currency risk. These results suggest that bearing exchange rate risk may actually improve the performance of international portfolios and that currency risk hedging is not necessarily costless.\footnote{A large literature documents the attractiveness of simple currency speculative strategies in isolation, such as the carry trade. See, for example, Burnside et. al. (2006, 2008), Burnside et al. (2007), Lustig and Verdelhan (2007) and Jurek (2008) for the carry trade, Binny (2005) for PPP- and momentum-based strategies and De Zwart et al. (2009) for technical and fundamental strategies.}

Based on out-of-sample strategies, we confirm that currency risk hedging reduces portfolio variance. However, we also show that there is a serious downside to currency hedging: average returns are lower, Sharpe ratios do not improve, portfolio skewness worsens and kurtosis increases. Consequently, if investors have preferences over more than just variance, an unhedged stock or bond portfolio dominates a hedged portfolio.

Our sample consists of stock returns from the seven largest developed markets over the July 1975 to December 2009 period. We take the perspective of investors from each of these markets by performing our analysis using returns denominated in all seven home currencies. We use an equally weighted international equity portfolio as a base portfolio and add currencies in an overlay fashion. In order to test changes in the risk, Sharpe ratio, skewness and kurtosis of a portfolio when adding currency positions, we derive simple tests based on the method of moments, which do not rely on normality assumptions. We focus on the well-known minimum variance hedging strategy.
and examine a full hedging strategy as a robustness check.

Campbell et al. (2010) show that currency hedging significantly reduces portfolio risk in-sample. We confirm these findings for out-of-sample hedging strategies for almost all home currencies. However, we also find that currency risk hedging lowers average returns. The decrease in returns is highly economically significant. Averaged over all seven home currencies, mean unhedged equity returns are 0.52% per month while hedged equity returns are 0.31% per month; a decrease of more than 40%. In addition, the decrease in average returns is statistically significant for Euro-zone and Swiss investors. Moreover, while unhedged returns are always significantly positive, hedged equity returns are no longer significantly different from zero, except for the Australian dollar home currency. As a result, hedging generally fails to improve the portfolio risk-return trade-off. In fact, we often find substantial decreases in portfolio Sharpe ratios.

Next, we examine the impact of currency risk hedging on higher moments of portfolio returns. To the best of our knowledge, our paper is the first to analyze this. Currency returns are typically not normally distributed. For example, Brunnermeier, Nagel and Pedersen (2009) show that carry trade returns are negatively skewed, relating the profitability of the carry trade to crash risk. This suggests that changing the exposure to currency risk by means of hedging may also affect the skewness of the overall portfolio returns. In fact, we find that currency risk hedging tends to worsen the skewness of international portfolios. Averaged over all seven home currencies, the skewness of unhedged equity portfolios is -0.94, while the skewness of hedged equity returns is -1.28, a decrease of 37%. Furthermore, we find that the kurtosis is significantly higher for hedged than for unhedged equity returns. While investors may not have clear preferences over kurtosis per se, fat tails in combination with negative skewness is disliked.

Overall, our results suggest that currency risk hedging is not a free lunch. This suggests that cross-border portfolios may actually benefit from being exposed to currency risk. While unhedged portfolios are naturally exposed to exchange rate risk due to positions in foreign assets, in addition, investors can actively add “pure investment” or “speculative” currency positions to the portfolio. A well-known speculative currency strategy is the carry trade, which takes long positions in high interest rate currencies and short positions in low interest rate currencies. We indeed find that this even further improves portfolio performance.

Our findings are similar when hedging currency risk in international bond portfolios. Furthermore, our results are robust when using a full hedge, when using value-weighted and home-biased
base portfolios, and based on sub-sample periods.

To gain a better economic understanding of the negative effects of currency risk hedging, we extend the theoretical framework of Backus, Foresi and Telmer (2001) and Lustig, Roussanov and Verdelhan (2010, 2011) with an equity component. In this framework, the stochastic discount factor in each country is driven by a local (interest rate) factor and a global (equity market) factor, and the underlying state-variables follow Cox-Ingersoll-Ross (1985) type processes. In the model, expected currency returns correlate positively with the covariance between currency and equity returns. This helps us explain why hedging lowers returns. A positive covariance between currency and equity returns leads to a negative weight of the currency in the hedging portfolio. Hence, the hedging portfolio takes short (long) positions in currencies with high (low) expected returns, thereby lowering overall portfolio expected returns. We calibrate this model such that the implied first and second moments match the empirical ones as closely as possible. Simulation results show that currency hedging of equity portfolios indeed leads to lower portfolio variance but also lower mean returns, Sharpe ratios and skewness, which is consistent with our empirical findings. Unlike our empirical findings, the simulated model generates a lower kurtosis for the hedged portfolio, which is intricate to the log-normal specification.

This paper is structured as follows. The following section discusses theory and related literature on currency hedging. Section 2 describes our empirical methodology and Section 3 discusses the data. Section 4 presents the main empirical results. Section 5 discusses the theoretical framework that helps us understand the negative effects of hedging on portfolio performance. Section 6 discusses a number of robustness checks and Section 7 concludes. The appendix derives the method of moment tests and the moment conditions of our theoretical model. A separate Internet Appendix includes additional robustness checks.

1 Theory and related literature

1.1 Currency risk hedging

Holding foreign assets exposes investors to currency risk. For example, consider a US investor who invests in a German stock portfolio. Denote $S_t$ the spot exchange rate for one Euro expressed in
US dollars at time $t$. The dollar return on her investment is expressed as

$$R_t^g = \frac{P_t^e S_{t+1}}{P_t^e S_t} - 1 = (1 + R_t^{e,c})(1 + R_{t+1}^c) - 1,$$

where $P_t^e$ is the stock price at time $t$ denoted in Euro and $R_{t+1}^c = S_{t+1}/S_t - 1$, i.e., the return on the US dollar Euro exchange rate. The investor can hedge her exchange rate risk by taking positions in forward contracts. Denote $F_{t,t+1}$ the predetermined forward exchange rate in US dollars for selling one Euro with delivery at time $t + 1$. Suppose the investor sells Euro forward by the amount of $-w_t^{hedge}/S_t$. The hedged return on the German stock investments is

$$R_{t+1}^h = R_t^g + w_t^{hedge} f_{t+1}$$

where $f_{t+1} = \frac{F_{t,t+1} - S_{t+1}}{S_t}$.

A key question is: what is the optimal $w_t^{hedge}$? This remains a controversial issue. In practice, some investors choose to hedge all or part of the currency risk, while others decide to remain unhedged. In fact, the debate on optimal currency hedging strategies is still ongoing.

Assuming zero expected returns on currencies, the optimal hedge simply minimizes the portfolio variance. Solnik (1974) shows that if currency and equity returns are uncorrelated, the optimal hedge is a unitary or full hedge, i.e. $w_t^{hedge} = -1$. However, if currencies and equity returns are correlated, a full hedge may not minimize risk. Instead, the optimal hedge is the minimum variance hedge, which can be calculated as

$$w_t^{hedge} = -\frac{Cov(R_t^g, R_t^c)}{\text{Var}(R_t^c)}.$$  \hspace{1cm} (1)

The minimum variance hedge can be calculated as the slope coefficient in an OLS regression of the unhedged portfolio returns on a constant and the currency returns. If currency and unhedged equity returns are positively correlated, the foreign currency depreciates when the foreign investment has negative returns. Therefore, the currency receives a negative weight in the hedging portfolio.

Perold and Schulman (1988), focusing on a full hedge, argue that in the long run currency returns are zero and therefore currency hedging can be seen as a “free lunch”: it reduces risk without affecting portfolio returns. Froot (1993) concludes that a full hedge does not provide risk reduction benefits for long horizons, due to the mean-reversion of real exchange rates. However,

\footnote{Eun and Resnick (1988) and Kaplanis and Schaefer (1991) also document risk reduction benefits from full hedges.}
using a larger number of currencies over a longer sample period, Campbell, Serfaty-de Medeiros and Viceira (2010) and Schmittmann (2010) do not find any horizon effects.

Campbell et al. (2010) find that the composition of a minimum variance hedging portfolio differs from a unitary hedge, particularly for equities. They show that investors should short currencies that are more positively correlated with equity returns (such as the Australian dollar and the Canadian dollar) and they should take long positions in currencies that are negatively correlated with equity returns (e.g., the US dollar, the Euro and the Swiss Franc). For bond portfolios, the optimal hedge is close to a unitary hedge due to the low correlation between bond returns and currency returns. Based on an in-sample analysis, they show that the minimum variance hedging strategy significantly reduces portfolio volatility.

1.2 Nonzero expected currency returns

An important assumption in the discussion so far is that currency hedging does not affect portfolio expected returns. This may be a particularly stringent assumption, given the increasing empirical evidence of a premium for currency risk (see, e.g., Dumas and Solnik (1995), De Santis and Gerard (1998) and Lustig and Verdelhan (2007))\(^6\). Furthermore, currencies with high interest rates are shown to have high average returns, i.e. the well-known forward premium puzzle (e.g., Hansen and Hodrick (1980), Fama (1984)).

The existence of nonzero expected currency returns implies that currency risk hedging may affect portfolio mean returns and Sharpe ratios in addition to the variance. The existing literature on currency risk hedging commonly focuses on the impact on variance only. Only a few papers consider the effect of hedging on portfolio expected returns and Sharpe ratios. For instance, Eun and Resnick (1988) show that for the 1979 to 1985 period, unitary hedges increase mean returns and Sharpe ratios. However, the paper does not provide statistical tests and minimum variance hedging strategies are left out of the analysis.\(^7\)

The minimum variance hedging strategy is designed without taking into account the impact on expected returns. One may argue that investors who use this strategy care only about reducing risk

\(^6\)In addition, currency risk is priced in various international asset pricing models (e.g., Solnik, 1974b; Adler and Dumas, 1983).

\(^7\)Furthermore, Schmittmann (2010) finds that half and full hedges lead to increases or decreases in portfolio returns depending on the home currency. However, none of the changes are statistically significant.
and not about the potential impact on expected returns. However, the minimum variance strategy is optimal under the assumption that expected currency returns are zero. If this assumption is violated in the data, there may be consequences for minimum variance hedgers. Also, currency hedging needs arising from cross-border investments imply that investors already hold international stock or bond portfolios based on their preferences about risk and return (and, potentially, higher moments).

If currencies have nonzero expected returns, they may be considered a separate asset class rather than purely hedging instruments. In other words, investors may hold currencies for pure investment or speculative reasons, rather than only hedging motives. Glen and Jorion (1993) consider both hedging and speculative currency positions and find that the improvement in Sharpe ratios is mostly due to the hedging component rather than the speculative component. However, the results lose significance when using only equity portfolios as base assets or when using overlay strategies. Stronger evidence on the benefits of speculative currency investing are provided by the carry trade literature. The carry trade is a very popular currency speculative strategy, which exploits violations of the uncovered interest rate parity by borrowing in low interest rate currencies and lending in high interest rate currencies. This strategy has historically delivered a very attractive risk-return trade-off (e.g. Burnside et al., 2006, 2007, 2011; Brunnermeier, Nagel and Pedersen, 2009).8

Our paper focuses on currency risk hedging and uses the carry trade as a benchmark strategy. We compare hedged portfolios to unhedged portfolios, as well as to unhedged portfolios to which speculative currency positions are added.

1.3 Currency hedging and higher moments

Currency forward returns are typically not normally distributed (see e.g. Aggarwal, 1990). Amongst others, Brunnermeier et al. (2009) show that returns on the currency carry trade are negatively skewed and may be related to crash risk. In particular, they show both time series and cross-sectional evidence that high interest rate differentials predict negative conditional skewness. In-

8The literature provides several possible explanations for the high excess returns to currency carry trades. For instance, Lustig and Verdelhan (2007) show that these excess returns are compensation for exposures to US consumption risk. Farhi and Gabaix (2008) derive a theoretical model in which excess currency trade returns are generated by time-varying exposures to extreme rare event risks. Jurek (2008) and Brunnermeier et al. (2009) relate the excess currency returns to crash risk. Lustig, Roussanov and Verdelhan (2011) identify a single risk factor that explains the cross-section of currency excess returns.
vestors dislike negative skewness, as this subjects them to large potential losses. Therefore, in addition to the impact on volatility and expected returns, we also analyze the impact of currency risk hedging on the skewness of the portfolio. In addition, we consider the impact on the kurtosis of the portfolio. While investors may not have clear preferences over kurtosis per se, fat tails in combination with negative skewness is disliked. To the best of our knowledge, we are the first to look at the impact of currency hedging on higher moments of portfolio returns.

2 Empirical methodology

This section first discusses the construction of our out-of-sample hedging strategy. Next, we use method of moments techniques to derive tests for changes in the first four moments of portfolio returns as a result of adding currency positions. We also consider the Sharpe ratio as a summary statistic of the effect on expected returns and volatility.

2.1 Hedging portfolios

As a base portfolio, we use an unhedged equally weighted international equity portfolio. Following among others Campbell et al. (2010), we add currencies to these predetermined portfolio returns in a so-called overlay fashion. We focus on equally weighted country portfolios, because our analysis is entirely out-of-sample. DeMiguel, Garlappi and Uppal (2009) show that the equally weighted strategy delivers the best performance out-of-sample. Moreover this allows us to focus on optimally adding currencies to well diversified international stock portfolios, without having to optimize over individual country returns. Note that we take an equally weighted average over all seven value-weighted country equity index returns.

Denote the excess returns on the unhedged international stock portfolio as $r^x_t$ and denote the returns on $N$ currency forwards as $r^c_t$. We estimate the minimum variance hedging portfolio weights in month $t$ by regressing unhedged country portfolio returns on the currency forward returns, using the past 60 months of returns:

$$r^x_t = a + b^c_t r^c_t + u_t \text{ for } t = 1, ..., t - 60.$$  \(2\)

Section 6 discusses robustness checks where value-weighted and home-biased equity portfolios as well as international bond portfolios are used as base assets.
This results in the weights of the hedging portfolio \( w^{hedge} = -b \). The out-of-sample hedged country returns \( r_t^h \) are calculated as:

\[
r_t^h = r_t^x - b' r_t^c.
\]

2.2 Test for changes in portfolio risk, return and Sharpe ratio

We use the method of moments methodology to derive tests for changes in the first four moments of portfolio returns when adding hedging currency positions to unhedged returns. We start with a test for changes in a portfolio Sharpe ratio. Tests for changes in means and volatility follow. We consider the Sharpe ratio as a measure of the volatility-return trade-off. However, while we start with the first two moments, we do not assume a mean-variance framework. We allow returns to be non-normally distributed and in the next section we discuss tests for changes in higher moments.

When we compare the Sharpe ratio of a hedged portfolio to that of an unhedged portfolio, one set of the assets is not necessarily a subset of the other. Therefore, we cannot use the standard test for mean-variance spanning (see, e.g. Jobson and Korkie, 1989; Gibbons, Ross and Shanken, 1989; De Roon and Nijman, 2001). We derive a simple test for the difference in Sharpe ratios between any two portfolios, based on either overlapping or nonoverlapping assets. The test is based on the method of moments and does not rely on normality assumptions. Our approach is similar to Lo (2002), when assuming non-i.i.d. returns.\(^{10}\)

Let \( r_t \) be an excess returns and denote \( m_k \) the \( k \)th non-central moment \( E [r_t^k] \). In our application, \( r_t \) is the (out-of-sample) return on a portfolio consisting of equity or bond returns and currency positions.\(^{11}\) The Sharpe ratio of the excess returns \( r_t \) can be written in terms of the first and second moments:

\[
SR = \frac{E [r_t]}{\left( E [r_t^2] - E [r_t]^2 \right)^{1/2}} = \frac{m_1}{\left( m_2 - m_1^2 \right)^{1/2}}.
\]

\(^{10}\)Eiling et al. (2012) propose a two-stage test for differences in Sharpe ratios, which is based on regression analysis. Ledoit and Wolf (2008), without assuming normality, propose tests for differences in Sharpe ratios based on a bootstrap procedure.

\(^{11}\)Note that this test does not take into account estimation error in the portfolio weights. However, since we focus on out-of-sample analyses, portfolio weights are based only on past returns. Consequently, estimation error of those portfolio weights is not a concern for our out-of-sample application.
The moments $m_k$ can be estimated using

$$\frac{1}{T} \sum_{t=1}^{T} (r_t^k - m_k) = \frac{1}{T} \sum_{t=1}^{T} u_{k,t} = 0. \quad (5)$$

The covariance matrix of $\hat{m}$, denote as $\Omega(\hat{m})$ easily follows from the covariance matrix of $u_t$, denoted as $\Omega$. The covariance between $\hat{m}_k$ and $\hat{m}_l$ is simply $T^{-1} \text{Cov}[u_{k,t}, u_{l,t}] = T^{-1} \Omega_{kl}$, with $u_{i,t} = r_i^t - m_i$.

If the true difference between the Sharpe ratios of two portfolios $A$ and $B$ equals $\delta$, we have for the limiting distribution

$$\sqrt{T} \left( (\hat{SR}_A - \hat{SR}_B) - \delta \right) \rightarrow \mathcal{N} \left( 0, \quad \Omega \left( \hat{SR} \right)_{AB} \right). \quad (6)$$

where $\Omega \left( \hat{SR} \right)$ is the limiting variance of the Sharpe ratios, which depends on the first derivatives of the Sharpe ratio with respect to the first two moments. We derive the expression for $\Omega \left( \hat{SR} \right)$ in the appendix.

In addition to the Sharpe ratio, we also consider changes in its two components: risk and return. We use the same method of moments approach to test for the difference in standard deviations. Using a simple test for differences in means, we test whether the average out-of-sample returns of the unhedged portfolio equal those of the hedged portfolio. These tests allow us to examine both the economic and the statistical significance of the impact of currency risk hedging on the portfolio volatility mean returns and its risk-return trade-off.

### 2.3 Currency hedging and higher moments

The skewness of returns $r_t$ can be expressed as:

$$\text{Skew} = \frac{E \left[ (r_t - \mu)^3 \right]}{\sigma^3} = \frac{m_3 - 3m_2 \mu_1 + 2m_1^3}{(m_2 - m_1^2)^{3/2}}. \quad (7)$$

As is common in the literature (e.g. Mitton and Vorkink, 2007), we focus on standardized skewness, measured as the third central moment divided by the cube of the standard deviation. The advantage of this standardization is that the resulting measure of skewness is invariant to changes in scale. Variance and skewness are positively related and by controlling for variance in the standardized skewness measure we focus on the incremental skewness beyond the expected level based on changes in variance. We consider the portfolio variance separately. In order to derive the limiting distribution of skewness we proceed in the same way as with the Sharpe ratio, as is discussed in the appendix.
Finally, we consider the impact of currency hedging on the overall kurtosis of the portfolio. We first write the kurtosis as a function of the first four noncentral moments:

\[
K = \frac{E[(r_t - \mu)^4]}{\sigma^4} = \frac{m_4 - 4m_3m_1 + 6m_2m_1^2 - 3m_1^4}{(m_2 - m_1^2)^{3/2}}
\]  

(8)

and we derive the limiting distribution using the derivatives of \(K\) with respect to \(m_1\) to \(m_4\) (see appendix).

3 Data

Our analysis is based on monthly returns between July 1975 and December 2009. We consider seven major developed markets: the US, Euro-zone, Australia, Canada, Japan, Switzerland and the UK. For the stock returns from the Euro-zone we use a value-weighted average of Germany, France, Italy and The Netherlands, where the weights are based on the relative market capitalizations of the equity markets. We use pre-Euro exchange rates and interest rates from the region’s largest market, Germany. Stock returns for these seven different markets are measured by the MSCI total return indices. Interest rate data are from the OECD and from the International Financial Statistics database (IMF). Exchange rate data are also from the IFS database. We use one-month interest rate differentials to construct forward rates.

Table I provides summary statistics for excess stock and currency (forward) returns, measured in local currency. In the rest of our analysis we consider all seven home currencies. We find that the currency returns have lower means and lower volatilities than the equity returns. Furthermore, all equity returns are slightly negatively skewed. Except for the Yen and the Swiss Franc, all currency returns have negative skewness measures, ranging from -0.053 to -0.64. Finally, we observe excess kurtosis for Australian equity returns and Canadian and Australian dollar returns.

4 Empirical results

We start our analysis by examining the impact of currency risk hedging on portfolio risk, return and the portfolio Sharpe ratio. Next, we look at the impact on higher moments. Furthermore,
we use the carry trade speculative portfolio as benchmark, which we add to an unhedged stock portfolio and to a hedged stock portfolio.

4.1 The impact of hedging on volatility and expected returns

We first test whether the minimum variance hedge significantly reduces portfolio variance. Table II Panel A reports the results.

Each column reports the results for a different home currency. For example, the first column takes the perspective of a US investor and is based on returns denominated in US dollars. The table shows that currency risk hedging indeed reduces risk. For instance, the monthly standard deviation for a US stock investor is reduced from 4.62% to 3.83% when hedging currency risk; a reduction of 17%. For other home currencies the decrease in the monthly standard deviation ranges from 4% to 26%. The risk reduction is statistically significant for all home currencies except for Australian and Canadian dollars. A Wald test shows that the null hypothesis that the changes in standard deviation are jointly equal to zero for all home currencies is rejected at the 1% level. This shows that the results in Campbell et al. (2010) also hold out-of-sample for most home currencies.

If currency expected excess returns would be zero, we could stop here. Indeed, this is what many related papers do. However, in the presence of a currency risk premium, portfolio expected returns may also be affected by hedging currency risk. In fact, we find that currency hedging negatively affects portfolio returns. Panel B shows that currency risk hedging lowers portfolio returns for all seven home currencies. The decreases are highly economically meaningful. Averaging over all seven home currencies we find that mean unhedged equity returns are 0.52% per month while mean hedged returns are only 0.31% per month. Hence, hedging reduces average returns by 41%. In addition, for several home currencies the decreases in mean returns are statistically significant as well. For example, when taking the perspective of a Euro-zone investor, we find that currency risk hedging lowers average portfolio returns by more than half: from 0.63% to 0.31% per month. This decrease is statistically significant with a $t$-statistic of 1.97. The reduction in average returns is significant for the Swiss Franc home currency as well. Moreover, except for the Australian investor, all mean unhedged portfolio returns are significantly positive. However, when hedging currency risk, mean portfolio returns are no longer significantly different from zero.\textsuperscript{12} This further emphasizes that the

\textsuperscript{12}The results of these two types of tests can be reconciled, as they concern different null hypotheses: testing whether

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risk reduction of currency hedging comes at the cost of lower average returns.

In order to analyze the impact on the risk-return trade-off, in Panel C we test changes in the portfolio Sharpe ratio. We find that despite the significant reduction in volatility due to hedging, the portfolio Sharpe ratio decreases as a result of the lower average returns. The economic magnitudes are large: Sharpe ratios decrease by 23% (Canadian dollar perspective) to 41% (Euro perspective). The only home currency for which the Sharpe ratio remains almost the same is the Australian dollar. In addition to the economic significance, we present some evidence of statistical significance as well. While unhedged Sharpe ratios are significantly above zero for six home currencies, the Sharpe ratios of hedged portfolios are never significantly different from zero. Although our tests for the levels of Sharpe ratios suggest that currency hedging worsens the portfolio risk-return trade-off, we do not detect significant changes in Sharpe ratios.

These results suggest that currency risk hedging indeed lowers risk, but comes at the cost of lower average returns and does not improve the Sharpe ratio. In other words, we find that being exposed to currency risk actually improves portfolio performance in terms of average returns and Sharpe ratios.

4.2 The impact of hedging on higher moments

The summary statistics in Section 3 show that currency returns are typically negatively skewed and some have fat tails. In this section we consider the impact of currency risk hedging on the third and fourth moments.

4.2.1 Portfolio skewness

Table II Panel D reports the impact of currency risk hedging on portfolio skewness. We find that unhedged equity portfolio returns are negatively skewed. Adding a minimum variance hedge worsens the skewness for all home currencies except for the Yen. The decrease is economically large: skewness worsens by 16% (British Pound) to almost 200% (Australian dollar). For example, while an unhedged stock portfolio denominated in Australian dollars has a skewness of -0.43, the hedged stock portfolio has a skewness of -1.27. On average over all home currencies, the skewness of unhedged returns is -0.94, while the average skewness of hedged returns is -1.28; a worsening of the change in mean returns due to hedging equals zero versus testing whether the level of mean (hedged or unhedged) returns equals zero.
The decrease in skewness is statistically significant for Australian and Canadian investors. Moreover, the Wald test rejects the null hypothesis that the changes in skewness are jointly equal to zero for all home currencies.

These results show that currency hedging has another negative consequence: it worsens portfolio skewness. In other words, being exposed to currency risk may actually improve portfolio skewness.

**4.2.2 Portfolio kurtosis**

Next, we investigate the impact of currency risk hedging on the kurtosis of the overall portfolio. Table II Panel E reports the results. We find that currency hedging always increases the kurtosis of stock portfolios. The economic magnitude of the increase is large. On average across all home currencies the kurtosis of unhedged equity portfolios is 3.76 while the average kurtosis of hedged portfolios is 5.91; an increase of 61%. Moreover, the change in kurtosis is statistically significant for five out of seven home currencies, as well as based on the Wald test. As mentioned earlier, a higher kurtosis by itself is not necessarily bad. However, combined with a more negative skewness, the increase in kurtosis is yet another negative consequence of currency hedging.

**4.3 Speculative currency investing**

When comparing unhedged and hedged portfolios, we compare portfolios with and without currency risk. The unhedged portfolios are naturally exposed to currency risk by their positions in foreign equity or bonds. In this section, we construct an alternative benchmark by actively adding currency risk exposures to a portfolio. To this end, we consider currencies as a separate asset class rather than merely as hedging instruments.

As a speculative strategy we focus on the well-known carry trade. The carry trade takes long positions in currencies with positive interest rate differentials and short positions in currencies with negative interest rate differentials. We combine the individual currencies in an equally weighted portfolio, similar to Burnside et al. (2011) and Burnside (2011). The positions are rebalanced every month. At the beginning of each month, the total value of the portfolio is normalized to 1 US$. We add the carry trade portfolio to the unhedged country portfolio and calculate the out-of-sample portfolio returns in the subsequent month. Denote the weights in the carry trade portfolio by \( w^{spec} \).
The overall portfolio returns are calculated as:

\[ r_{t}^{\text{unh+spec}} = r_{t}^{x} + w_{\text{spec}} r_{t}^{c}. \]

Furthermore, we add the carry trade portfolio to a hedged equity portfolio. In other words, we add both hedging and speculative currency positions to the unhedged stock portfolio. This allows us to examine how the two currency strategies interact. For example, we analyze to what extent the benefits from currency hedging and currency speculation strengthen or offset each other. We expect that when a home currency has a high interest rate and is expected to appreciate, hedging benefits are relatively more important than when the home currency has a low interest rate. We construct the so-called “total” portfolio as follows:

\[ r_{t}^{\text{total}} = r_{t}^{h} + w_{\text{spec}} r_{t}^{c}. \]

Table III reports the results.

Panel A shows that except for the British Pound home currency, the portfolio standard deviation always increases when adding the carry trade portfolio to the unhedged stock portfolio. However, when adding the carry trade to a hedged country portfolio, the standard deviation is lower than of an unhedged equity portfolio for all home currencies except the Canadian and Australian dollars. In other words, the increase in risk due to speculation is typically more than offset by the volatility reduction due to hedging.

The carry trade portfolio is constructed by explicitly taking nonzero expected currency returns into account. Indeed, Panel B shows that as a result, adding speculative currency positions to an unhedged portfolio always increases average returns. The increase is statistically significant for all home currencies except for the Australian dollar. However, this significant positive effect on average returns is completely offset if we first hedge currency risk and add carry trade positions to a hedged portfolio. The last row of Panel B shows that the total effect of currency hedging and speculation on average returns is typically negative and insignificant. In other words, the mean returns of hedged portfolios to which a carry trade portfolio has been added are not significantly different from those of unhedged stock portfolios without the carry trade. This result highlights the magnitude of the negative impact of currency hedging on average returns: it is strong enough to offset the highly significant and positive effects of speculative positions.
Panel C shows that carry trade positions always improve the portfolio Sharpe ratio. The increases are economically meaningful; on average over all seven home currencies Sharpe ratios increase by 28%. The increases are statistically significant for four out of seven home currencies. However, similar to Panel B, we again find that the negative effects of hedging completely offset these improvements. The bottom row shows that when adding both hedging and speculative positions, Sharpe ratios similar to those of unhedged portfolios result and the difference is never statistically significant.

Next, we consider the effects on portfolio skewness. Panel D shows that adding a carry trade portfolio to an unhedged stock portfolio significantly worsens the skewness for Australian and Canadian dollar denominated portfolios. For the other home currencies the effect is either positive or negative, but not statistically significant. However, when adding the carry trade to a hedged stock portfolio, the skewness always worsens compared to the unhedged equity-only portfolio and the decrease is significant for five home currencies.

Finally, Panel E shows that when adding speculative carry trade positions to an unhedged equity portfolio, the kurtosis increases significantly only for the US and Canadian dollar home currencies. For the Yen and Swiss Franc the kurtosis even decreases slightly. The total effect of hedging and speculation on portfolio kurtosis is always positive except for the British Pound denominated stock portfolio. The change is statistically significant for Euro, Canadian dollar and Swiss Franc denominated equity returns, as well as in the joint test.

In sum, international equity portfolios benefit from active currency exposure. Adding carry trade positions generally increases mean returns and Sharpe ratios, it often decreases skewness and somewhat increases kurtosis. However, when adding both hedging and speculative currency positions, the positive effects of speculation are completely offset by the negative effects of currency risk hedging. This reinforces our previous conclusions that currency risk hedging, while reducing volatility, comes with negative consequences for mean returns, Sharpe ratios and higher moments. In order to gain more economic insight into what drives these results, in the next section we add an equity component to the currency model of Lustig et al. (2011) and Backus et al. (2001) and show that the model generates similar effects of hedging on portfolio returns.
5 Theoretical model

In order to understand our empirical results, we specify a model for the log stochastic discount factor in the spirit of Backus et al. (2001) and Lustig et al. (2011) in a multi-country setting. This model is known to explain the forward premium puzzle and the carry trades in currency markets. Backus et al. (2001) and Lustig et al. (2011) show that a Cox-Ingersoll-Ross (1985) (CIR) type of model for the log stochastic discount factor goes a long way in explaining the dynamics of currency forward returns.

We specify the log stochastic discount factor for country $i$, $m^i_t$, by a three-factor CIR-process:

$$-m^i_{t+1} = \alpha + 0.5 \lambda_m + \chi z^i_t + \sqrt{\gamma z^i_t u^i_{t+1} + \chi z^w_t + \delta^2 z^w_t + \kappa z^w_t u^w_{t+1} + \sqrt{\lambda_m} \varepsilon_{t+1}},$$

(9a)

where

$$z^i_{t+1} = \theta (1 - \varphi) + \varphi z^i_t + \sigma \sqrt{z^i_t u^i_{t+1}},$$

(9b)

and

$$z^w_{t+1} = \theta (1 - \varphi) + \varphi z^w_t + \sigma \sqrt{z^w_t u^w_{t+1}}.$$  

(9c)

The innovations $\varepsilon_{t+1}$ and $u_{t+1}$ are independent and standard normally distributed. As in Lustig et al. (2011) each stochastic discount factor is driven by two state variables: a local variable $z^i_t$ that is specific to each country’s stochastic discount factor, and a global state variable $z^w_t$ that is common to each stochastic discount factor. To keep the model as parsimoneous as possible, the parameters $\alpha$, $\lambda_m$, $\chi$, $\gamma$, and $\kappa$ are the same across countries. Likewise, the parameters that drive the dynamics of the state variables themselves are assumed to be identical across the state variables ($\theta$, $\varphi$ and $\sigma$). We allow for heterogeneity in global factor exposures. The global factor exposures of foreign countries are denoted by $\delta_i$, for $i = 1, \ldots, N$. As in Lustig et al. (2011), if there is no superscript $i$, the variables refer to the home-country.

We deviate from the model in Lustig et al. (2011) by adding an equity component. We specify only one equity return, which can be interpreted as the return on an (equally weighted) international equity portfolio. This is in line with the base portfolio of our empirical analysis. Specifically, the unexpected equity return is determined by the global state variable $z^w_t$ and an innovation $\varepsilon_{t+1}$:

$$r^e_{t+1} - E_t [r^e_{t+1}] = \sqrt{\lambda_w z^w_t u^w_{t+1}} + \sqrt{\lambda_e} \varepsilon_{t+1}.$$ 

The innovation $\varepsilon_{t+1}$ also affects the stochastic discount factor in (9a). This setup for the equity component is similar to Campbell and Viceira (2002). However, unlike Campbell and Viceira (2002), the equity risk premium will not be constant but it will vary with $z^w_t$, as the model inherits
the heteroskedasticity from the CIR specification. \( \lambda_e \) and \( \lambda_w \) control the variance of the equity return, whereas \( \lambda_m \) controls the covariance with the stochastic discount factor and thus the equity premium. We add 0.5\( \lambda_m \) to the constant in the stochastic discount factor, such that the equity innovation \( \varepsilon_{t+1} \) will not affect the risk free rate via the variance of the kernel. Including the equity component in the stochastic discount factor allows us to analyze the effects of combining currency and equity investments in one portfolio as we have done in our empirical analysis above.

From this setup, the change in the (real) exchange rate is given by

\[
\Delta s^i_{t+1} = m^i_{t+1} - m^i_t = \chi (z^i_t - z_t) + \sqrt{\gamma} \left( \sqrt{z^i_t u^i_{t+1}} - \sqrt{z_t u_{t+1}} \right) + \left( \sqrt{\delta^i z^w_t + \kappa z^i_t} - \sqrt{\delta^w z^w_t + \kappa z_t} \right) u^w_{t+1}.
\]

Appendix B shows that the conditional expectation of currency returns equals

\[
E_t [r x^i_{t+1}] = 0.5 \left\{ \text{Var}_t [m^i_{t+1}] - \text{Var}_t [m^i_{t+1}] \right\} = -0.5 (\gamma + \kappa) (z^i_t - z_t) - 0.5 (\delta^i - \delta) z^w_t.
\]

Hedging currency risk of the equity returns leads to the following minimum variance hedging portfolio weights:

\[
w^i_{t, \text{hedge}} = -\frac{\text{Cov}_t [r e_{t+1}, r x^i_{t+1}]}{\text{Var}_t [r x^i_{t+1}]}
\]

Since the sign of the hedge demand depends on the covariance between equity and currency returns, the key to understanding why hedging lowers portfolio returns is to write the expected currency returns as a function of this covariance. This covariance is a non-linear function of the state variables, for which we show in Appendix B that it can be approximated as:

\[
\text{Cov}_t [r e_{t+1}, r x^i_{t+1}] \approx \psi_0 - 0.5 \psi \kappa (z^i_t - z_t) - 0.5 \psi (\delta^i - \delta) z^w_t, \quad (12a)
\]

\[
\psi = \sqrt{\frac{\lambda_w}{\delta}} \sqrt{\delta + \kappa}, \quad (12b)
\]

where \( \delta \) is the cross-sectional mean of \( \delta^i \) and \( \psi_0 \) contains the constant terms of the linearization. With all parameters being positive, it follows directly that both the expected currency forward return in (11) and the covariance in (12) depend negatively on the state variables \( z^w_t \) and \( (z^i_t - z_t) \). As the state variables themselves are always positive, the effect of the global state variable will always be positive or negative on both the currency expected return and the covariance, depending
on the loading of the domestic ($\delta$) and foreign ($\delta^i$) stochastic discount factor on this state variable. Thus, the effect of the loadings on the global state variable is to make the expected currency return and covariance (or hedge ratio) high or low on in the cross-section. The effect of the local state variables on the other hand can be either positive or negative, depending on the difference $(z_i^t - z_t)$.

The fact that both the conditional expected return of the currency forwards and the conditional covariance depend negatively on the state variables $z_t^w$ and $(z_i^t - z_t)$ implies that they will be positively correlated. Thus, a high (low) covariance leads to a high (low) currency risk premium. At the same time, the currency will have a low weight in the minimum variance hedging portfolio. In other words, the hedging portfolio takes short (long) positions in currencies with high (low) expected returns. Consequently, hedging lowers overall portfolio returns. Hence, our empirical finding of the negative effects of hedging on mean returns also follows from the model.

In addition to the decrease in mean returns, the empirical analysis also shows that the magnitude of the decrease is strong enough to lower Sharpe ratios. Also, the analysis reports negative effects on higher moments. To examine whether the theoretical model generates similar effects on Sharpe ratios and higher moments, for which analytical results are more cumbersome and less intuitive, we perform a simulation analysis. First, we calibrate the model. Table IV shows the calibrated parameters that match the implied first and second moments as closely as possible to their empirical counterparts.\(^\text{13}\)

Panel A presents the model parameters whereas Panel B presents the implied and empirical moments. We calibrate the model for six different currency pairs, always taking the US dollar as the home currency. For each calibration, we minimize the squared difference between the implied and empirical moments, imposing a minimum value of the Feller condition of 10.\(^\text{14}\) Panel A reports the average parameter values across all currencies and Panel B reports the average values of the implied and empirical moments as well as the standard error of the cross-currency differences. Panel B shows that most of the implied moments are, on average, fairly close to their empirical counterparts. The biggest differences are for the average risk free rate and currency (forward) returns.

\(^{13}\) The moment conditions are derived in Appendix B.

\(^{14}\) The Feller parameter is $\frac{2(1-\phi)\phi}{\sigma_z^2}$. We set the minimum value at 10, to ensure positive processes of the state variables in all simulations.
as well as the currency (forward) volatilities. Nevertheless, in all cases the standard errors for the average differences are well below one percent per annum. The slope coefficients for the uncovered interest rate parity (UIP) regressions match the empirical counterparts very well, but the difference for the slope coefficient of the hedge regression is somewhat bigger. Still, the implied hedge ratio has the correct sign and the implied value is of the same order of magnitude as the empirical value.

5.1 Simulation results

Having calibrated the model to the empirical moments, our strategy is to simulate currency (forward) returns, interest rates and equity returns from the model and analyze the effects of currency hedging on equity portfolios in the same way as we did in Section 4. In particular, we analyze the effect of currency hedging on the portfolio mean, standard deviation, Sharpe ratio, skewness and kurtosis. Table V shows the effects of currency hedging based on the simulations.

Notice that in terms of the model parameters, countries differ only in $\delta^i$. Going from the first column to the last column in the table, all model parameters are the same except for the global factor exposure of the home currency, which increases from its minimum value from Table IV in the second column to the maximum value in the last column, in equal steps. Hence, for each column all seven currencies are included (corresponding to the seven different values of $\delta^i$), but the selection of the home currency varies across columns.

Panel A shows the effect of currency hedging on the standard deviation of the portfolio. As in the empirical analysis, there is always a significant reduction in volatility. Note that due to the fact that the simulated time series has 5000 observations, we observe relatively high $t$-statistics for the differences in volatility.

Panels B and C confirm the effect of hedging on mean returns and Sharpe ratios that we also observe in Table II. Although currency hedging reduces volatility, it also reduces the mean portfolio returns. The negative effect on the mean returns more than offsets the volatility reduction such that the Sharpe ratio decreases. Both the mean returns and Sharpe ratios for the home countries of the unhedged portfolios increase as the global factor exposure of the home country increases (going from the left to the right column), but the opposite is true for the hedged returns. This follows from (11) where the currency forward expected returns depends negatively on $\delta^i$. Hedging
currency risk completely erodes the expected returns and Sharpe ratios as $\delta^i$ increases, and even makes them negative.

Panels D and E show the effect of currency hedging on portfolio skewness and kurtosis, analogous to Panels D and E in Table II. The model simulations confirm that hedging reduces skewness. The worsening in skewness is significant in all seven cases. A difference with Table II is that the model implies that the unhedged stock portfolio has positive rather than negative skewness, which is an intrinsic feature of the log-normal specification. However, the important effect is the substantial worsening in skewness due to currency risk hedging. On average (over all seven columns) the skewness of the unhedged portfolios is 0.19, while the average skewness of hedged portfolio returns is only 0.02; a decrease of 89%.

The effects of hedging on portfolio kurtosis in Panel E are not in line with the empirical counterparts in Table II. Whereas the empirical results show an increase in kurtosis due to hedging across all currencies, Table V shows that in the model kurtosis actually decreases. Given the log-normal specification this may not come as a surprise, as in the model kurtosis depends directly on the variance and the hedging strategy is designed to reduced variance.

Overall, the model describes the effects of currency hedging on the portfolio moments well; in addition to the reduction in volatility, we also observe a decrease in mean returns, Sharpe ratios and skewness. The main difference is for effect on kurtosis, which is intricate to the log-normal setup of the model.

6 Additional analyses and robustness tests

We perform a number of further analyses and robustness tests for our empirical analysis. First, while so far we focused on adding currencies to international equity portfolios, as a robustness test we also consider international bond base portfolios. Next, we further analyze the effects of hedging on portfolio skewness by separately considering the skewness of the currency portfolio itself as well as the relevant coskewness measures to gain more insights into which component(s) drive the results. Finally, we consider an alternative hedging strategy based on a full hedge, we use value-weighted and home-biased base portfolios and we perform our analysis for two separate sub sample periods.
6.1 Bond portfolios

In this robustness test we use equally weighted international bond portfolios for the same seven developed markets as our base portfolios. We use 10-year interest rates to construct bond returns (see Campbell, Lo and McKinlay, 1997). Table VI reports the results.

First, similar to the results for equity base portfolios reported in Table II, we find that currency hedging in bond portfolios significantly reduces risk. The risk reduction is even more pronounced for bonds than for equities. For example, a US bond investor can reduce the monthly standard deviation from 2.38% to 1.44% when hedging currency risk.

However, we also find that currency hedging reduces average bond portfolio returns. Panel B shows that average returns of hedged bond portfolios are lower than average returns of unhedged portfolios for all home currencies except for the Australian dollar. While currency hedging leaves the average returns of Australian dollar denominated equity portfolios unaffected, the average returns of Australian dollar denominated bond portfolios are higher (although not statistically). This is related to the fact that the Australian dollar appreciated substantially over our sample period. Averaging over all home currencies, we find that the mean unhedged bond returns are 0.31% per month while the mean hedged bond returns are 0.21% per month; a reduction of 33%. In addition to the economic significance, we also find statistical significance of the decrease in average bond returns. Similar to equity portfolios, the reduction in average returns due to hedging is significant for Euro and Swiss investors. A Wald test strongly rejects the null hypothesis that the changes in average returns are jointly equal to zero for all home currencies.

Panel C reports the portfolio Sharpe ratios. We again find that currency hedging does not significantly change the Sharpe ratio for any of the home currencies. In contrast to the results for equities, we do observe increases in Sharpe ratios for four home currencies. These changes are not statistically significant, although for Australian and Canadian investors the hedged Sharpe ratios are significantly different from zero whereas the unhedged are not.

Next, panel D shows that currency risk hedging always negatively affects the skewness of bond portfolios, except for Yen denominated bond returns for which the positive change is close to zero and insignificant. In fact, while unhedged bond portfolios have positive skewness for all home currencies except for the Yen and Swiss Franc, hedged bond returns all have negative skewness.
The worsening in skewness is significant for the Australian and UK investors. Also, the Wald test rejects the null that all changes are jointly equal to zero.

Finally, Panel E shows that while hedging again increases kurtosis (except for UK Pound denominated bonds), the changes are not statistically significant.

In sum, the results for international bond portfolios are generally in line with those based on cross-border stock portfolios. Again, they highlight the negative impact of currency risk hedging particularly on mean returns, Sharpe ratios and skewness.

### 6.2 Skewness decomposition

The theoretical model in Section 5 generates similar negative effects of hedging on portfolio skewness as our empirical analysis. As we discuss below, changes in skewness are driven not only by the coskewness between currency and equity returns, but also by the coskewness between equity and currency returns as well as the skewness of the currency portfolio itself. In this section, we aim to gain further insights into which component(s) matter most.

The coskewness between the currencies and the base portfolio is known to measure the marginal contribution of the currencies to this portfolio (see, e.g., Kraus and Litzenberger, 1976; and Harvey and Siddique, 2000). However, our analysis focuses on the total effect of adding hedging or speculative positions to the base portfolios, implying that it does not suffice to focus on the marginal contributions only. To see this, let the total portfolio invest $w_x$ in the base portfolio with return $r^x_t$ and $w_c$ in the currency (hedging) portfolio with return $r^c_t$. Denote $y^x_t = r^x_t - \mu_x$ the de-meaned returns on the country base portfolio and $y^c_t = r^c_t - \mu_c$ the de-meaned returns on the currency portfolio. The total non-standardized skewness, $TSkew$, can be decomposed as:

$$TSkew[r_{p,t}] = E \left[ (w_x y^x_t + w_c y^c_t)^3 \right]$$

$$= w_x^3 TSkew [r^x_t] + 3w_x^2 w_c Cov [y^x_t, y^x_t^2] + 3w_x w_c^2 Cov [y^x_t, y^c_t^2] + w_c^3 TSkew [r^c_t]$$

$$= w_x^3 TSkew [r^x_t] + 3w_x^2 w_c TCoSkew [r^c_t, r^x_t] + 3w_x w_c^2 TCoSkew [r^x_t, r^c_t] + w_c^3 TSkew [r^c_t].$$

Taking the derivative with respect to $w_c$ one can show that $TCoSkew[r^c_t, r^x_t]$ is indeed the marginal effect of the currency portfolio on portfolio skewness. However, in our setting where $w_x = 1$ and $w_c = 1$, the last two elements are important as well. Thus, in order to understand the total effect of adding a currency hedging or speculative portfolio on the overall portfolio skewness, we also
need to consider the coskewness of the base portfolio with the currencies, $TCoSkew[r^*_f, r^*_c]$ and the skewness of the currency portfolio itself.

The above expression allows for a decomposition of the unscaled third moment of portfolio returns, i.e., the total skewness. However, to make skewness measures for different portfolios comparable, we need to scale by the cube of the standard deviation of each component, as in Expression (7). Consequently, the sum of the normalized components does not add up to the normalized skewness. Rather than analyzing the components separately, we therefore perform the following analysis. We calculate the normalized skewness of the hedged equity portfolio, leaving out one of the three components.$^{15}$ Then, we compare the resulting skewness measure of the hedged portfolio to the normalized skewness of the unhedged portfolio. This allows us to see which component(s) are the main drivers of the worsening in skewness due to currency hedging. The results are presented in Table VII.

[Insert Table VII about here]

We find that the change in skewness due to hedging becomes negative and significant for all home currencies when we leave out the first coskewness (i.e., between the returns on the currency hedging portfolio and the unhedged equity portfolio). This is in line with unreported results that this coskewness is typically positive. Hence, this suggests that the second coskewness as well as the skewness of the currency hedging portfolio itself matter most for the worsening of the equity portfolio skewness. Our base results show that the worsening in skewness is significant for the Australian and Canadian dollar home currencies. When we exclude the second coskewness, the change in skewness loses statistical significance for the Canadian dollar home currency. When we exclude the skewness of the currency hedging portfolio, the change in overall portfolio skewness loses significance for the Australian dollar home currency.

In sum, while the coskewness between the currency hedging portfolio and the equity portfolio is known to measure the marginal contribution of the currencies to the portfolio, we actually find that the other two components of the total change in skewness are the main sources of the negative impact of currency hedging on portfolio skewness.

$^{15}$For example, when leaving out the first coskewness, we calculate the skewness of the hedged stock or bond portfolio as: $(TSkew[r^*_f] + 3TCoSkew[r^*_f, r^*_c] + TSkew[r_{c,l}]) / \sigma^3_{hedged}$, where $\sigma_{hedged}$ is the standard deviation of the hedged country returns. We then compare this to the skewness of the unhedged portfolio, calculated as $TSkew[r^*_f] / \sigma^3_x$ where $\sigma_x$ is the standard deviation of the unhedged country portfolio.
6.3 Other robustness tests

We perform a number of robustness checks. For brevity, the results can be found in the Internet Appendix.

First, we use a unitary or full hedge, instead of a minimum variance hedge. The full hedge is optimal if the correlation between the base assets and the currency returns is zero. While the correlation is typically nonzero, particularly for equity base portfolios (Campbell et al., 2010), the full hedge is used in various existing papers and is therefore a relevant alternative hedging strategy. We find that out-of-sample the full hedge significantly reduces the standard deviation for five out of seven home currencies. For the Canadian and Australian dollar home currencies, the standard deviation is even slightly higher with a full hedge. This indicates that a full hedge may not always be optimal, even from a risk minimization perspective. Hedging again lowers mean returns, except for the Canadian and Australian dollar based portfolios. Similar to the minimum variance hedge, Sharpe ratios are not significantly affected. Furthermore, skewness becomes more negative and here the statistical significance is even higher than for the results presented in Table IV. Finally, kurtosis also increases significantly when implementing a full hedge.

Next, we use alternative unhedged stock portfolios. While individual country equity returns are value-weighted, international stock portfolios used in our analysis are equally weighted across countries. We use two alternative base portfolios. First, we consider value-weighted portfolios, where the country weights are based on the relative market capitalizations of equity in each of the seven countries. The results are very similar to those based on equally weighted portfolios.

Third, we use a home-biased base portfolio where the weight of the domestic equity returns is 50% and the remaining six countries are equally weighted. While the direction of the results is similar to the base results, the statistical significance is slightly lower. This is to be expected given that the home biased portfolio has less currency risk to begin with, which implies that currency hedging has a smaller impact on portfolio performance.

Finally, we perform a sub sample analysis by splitting our sample period into two. The first sub sample period is based on out-of-sample returns from July 1980 to March 1995 and the second sub sample period is based on the April 1995 to December 2009 period. The results are similar to the full sample results, although the significance levels are somewhat lower. In particular, the decrease in average returns is not significant in the second sub sample period. Nevertheless, we do
not detect significant improvements in Sharpe ratios despite the significant risk reduction due to hedging.

7 Conclusion

This paper shows that currency risk hedging does exactly what it aims to do: it reduces portfolio variance. However, currency hedging is not a free lunch. The risk reduction comes at the cost of lower average portfolio returns. Consequently, out-of-sample Sharpe ratios do not significantly improve and often even decrease. In addition, currency risk hedging worsens portfolio skewness and significantly increases portfolio kurtosis. These results imply that exposure to currency risk actually improves portfolio performance.

We show that the theoretical framework of Lustig, Roussanov and Verdelhan (2011) and Backus, Foresi and Telmer (2001), extended with an equity market component, can generate similar results. In the framework, currency excess returns are exposed to a local and a global factor. Analytical results show that hedging lowers portfolio returns, because of a positive relation between currency expected returns and the covariance between currency and equity returns. This implies that the minimum variance hedging portfolio takes short positions in currencies with positive risk premia (i.e., the currencies for which the covariance with equity returns is positive). Consequently, hedging lowers portfolio returns. A simulation analysis confirms that hedging reduces volatility and leads to lower mean returns at the same time. Our simulations generate decreases in Sharpe ratios and portfolio skewness, which is similar to our empirical results. However, the model is not able to generate the increase in kurtosis, which is intricate to the log-normal setup. In sum, in addition to the already known successes of these type of models in explaining UIP-puzzles and carry trades, our results show that they also generate both the positive and negative effects of currency hedging on the first three moments of portfolio returns.

Our findings have important implications for international investors with preferences over mean returns, skewness and kurtosis, in addition to variance. Unhedged portfolios outperform hedged portfolios in terms of average returns, Sharpe ratios, skewness and kurtosis. Given the impact of minimum variance of full hedging strategies on portfolio skewness and kurtosis, investors could design alternative hedging strategies taking these higher moments into account. This may be an important area for future research.
Appendix A: Derivation of method of moment tests

A.1 Test for changes in Sharpe ratios

For the Sharpe ratio we only need the first two moments, i.e., $\hat{m} = (\hat{m}_1 \ \hat{m}_2)'$. In order to derive the limiting distribution of Sharpe ratio, we need the first derivatives of the Sharpe ratio with respect to the first two moments. Taking the derivatives with respect to $m_1$ and $m_2$, we have:

$$\frac{\partial SR}{\partial m_1} = \frac{1}{\sigma} + \frac{\mu^2}{\sigma^3},$$

$$\frac{\partial SR}{\partial m_2} = -\frac{\mu}{2\sigma^3}.$$

where $\sigma = \text{stdev}(r_t)$. The limiting variance of sample Sharpe ratio is then calculated as

$$\text{Var} \left[ \hat{S}R \right] = \frac{1}{T} \frac{\partial SR'}{\partial m} \Omega \frac{\partial SR}{\partial m} = \frac{1}{T} \Omega \left( \hat{S}R \right).$$

Similarly, if we have two returns $r_{A,t}$ and $r_{B,t}$, then we have the joint covariance matrix of the first (two times) two moments

$$\Omega (\hat{m}) = \text{Var} \left[ (\hat{m}_{A1} \ \hat{m}_{A2} \ \hat{m}_{B1} \ \hat{m}_{B2})' \right],$$

where $m_{ik}$ is the $k$th moment of $r_{i,t}$, $m_{ik} = E \left[ r_{i,t}^k \right]$. The variance of the difference in Sharpe ratios $SR_A - SR_B$ is then found by

$$\text{Var} \left[ \hat{S}R_A - \hat{S}R_B \right] = \frac{1}{T} \left( \frac{\partial SR_A'}{\partial m_A} - \frac{\partial SR_B'}{\partial m_B} \right) \Omega \left( \frac{\partial SR_A}{\partial m_A} \frac{\partial SR_B}{\partial m_B} \right) = \frac{1}{T} \Omega \left( \hat{S}R \right)_{AB}. \quad (14)$$

If the true difference between the two Sharpe ratios equals $\delta$, we have for the limiting distribution

$$\sqrt{T} \left( (\hat{S}R_A - \hat{S}R_B) - \delta \right) \rightarrow N \left( 0,\ \Omega \left( \hat{S}R \right)_{AB} \right). \quad (15)$$

A.2 Test for changes in the standard deviation

Similar to the Sharpe ratio, the standard deviation depends on the first two moments only. Taking derivatives of the standard deviation with respect to $m_1$ and $m_2$, we have:

$$\frac{\partial \sigma}{\partial m_1} = -\frac{m_1}{\sigma},$$

$$\frac{\partial \sigma}{\partial m_2} = \frac{1}{2\sigma}.$$
The limiting variance of the standard deviation is then calculated as

\[
\text{Var}[\hat{\sigma}] = \frac{1}{T} \Omega^{-1} \Omega \frac{\partial \sigma}{\partial m}.
\]

A test for the difference in standard deviations follows in an analogous way as the test for differences in Sharpe ratios above.

A.3 Test for changes in skewness

The starting point are now the first three moments, \( m_1, m_2 \) and \( m_3 \). Denote the \( 3 \times 1 \) vector with the derivatives of \( \text{Skew} \) with respect to the first three moments, \( \partial(\text{Skew})/\partial m \), by \( G \), where

\[
\frac{\partial \text{Skew}}{\partial m_1} = 3 \left( \frac{\mu^2}{\sigma^3} - \frac{1}{\sigma} + \frac{\mu \text{Skew}}{\sigma^2} \right),
\]

\[
\frac{\partial \text{Skew}}{\partial m_2} = -3 \left( \frac{\mu}{\sigma^3} + \frac{1}{2 \sigma^2} \right),
\]

\[
\frac{\partial \text{Skew}}{\partial m_3} = \frac{1}{\sigma^3}.
\]

The covariance matrix of \( \hat{m} \) again easily follows from the covariance matrix \( \Omega \) of \( u_t \). The limiting variance of sample skewness is calculated as

\[
\text{Var} \left[ \hat{\text{Skew}} \right] = \frac{1}{T} G' \Omega G.
\]

Next, we consider the difference in skewness of returns \( r_{A,t} \) and \( r_{B,t} \). Let \( \Omega(\hat{m}) \) be the joint covariance matrix of the first (two times) three moments of \( r_{A,t} \) and \( r_{B,t} \). The variance of the difference in skewness \( \text{Skew}_A - \text{Skew}_B \) is found by

\[
\text{Var} \left[ \hat{\text{Skew}}_A - \hat{\text{Skew}}_B \right] = \frac{1}{T} \begin{pmatrix} G_A & -G_B \end{pmatrix} \Omega \begin{pmatrix} G_A \\ -G_B \end{pmatrix}.
\]

A.4 Test for changes in kurtosis

Let the \( 4 \times 1 \) vector \( D \) be \( \partial K/\partial m \), where

\[
\frac{\partial K}{\partial m_1} = -4 \left( \frac{m_3 - 3 m_1 \sigma^2}{\sigma^4} \right) + \frac{4 m_1 K}{\sigma^2},
\]

\[
\frac{\partial K}{\partial m_2} = \frac{6 m_2^2}{\sigma^4} - \frac{2 K}{\sigma^2},
\]

\[
\frac{\partial K}{\partial m_3} = \frac{-4 m_1}{\sigma^4},
\]

\[
\frac{\partial K}{\partial m_4} = \frac{1}{\sigma^4}.
\]
The covariance matrix of \( \hat{m} \) is calculated as before. The limiting variance of sample kurtosis is calculated as

\[
Var \left[ \hat{K} \right] = \frac{1}{T} D' \Omega D.
\]

Now \( \Omega (\hat{m}) \) denotes the joint covariance matrix of the first (two times) four moments of returns \( r_{A,t} \) and \( r_{B,t} \). The variance of the difference in kurtosis \( K_A - K_B \) equals

\[
Var \left[ \hat{K}_A - \hat{K}_B \right] = \frac{1}{T} \left( D_A \quad -D_B \right) \Omega \left( D_A \quad -D_B \right).
\]

**Appendix B: Moment conditions of theoretical model**

The first two moments of the state variables \( z^i \) and \( z^w \) are the same and can be expressed as:

\[
\begin{align*}
E_t [z_{t+1}] &= \theta (1 - \varphi) + \varphi z_t, \\
E [z_{t+1}] &= \theta, \\
Var_t [z_{t+1}] &= \sigma^2 z_t, \\
Var [z_{t+1}] &= \frac{\sigma^2 \theta}{1 - \varphi^2},
\end{align*}
\]

The exchange rate movement equals:

\[
\Delta s_{t+1}^i = m_{t+1}^i - m_{t+1}^i \\
= \chi \left( z_{t+1}^i - z_t \right) + \sqrt{\gamma} \left( \sqrt{z_{t+1}^i u_{t+1}} - \sqrt{z_{t} u_{t+1}} \right) \\
+ \left( \sqrt{\delta_{t} z_{t}^w + \kappa z_{t}^i} - \sqrt{\delta_{t+1} z_{t+1}^w + \kappa z_{t+1}} \right) u_{t+1}^w.
\]

As a first step, we calculate the first two moments of the exchange rate change, both conditional and unconditional. The first moments are:

\[
\begin{align*}
E_t [\Delta s^i_{t+1}] &= \chi (z_{t+1}^i - z_t), \\
E [\Delta s^i_{t+1}] &= 0. \tag{19}
\end{align*}
\]

The second moments are:

\[
\begin{align*}
Var_t [\Delta s^i_{t+1}] &= (\gamma + \kappa) (z_{t+1}^i + z_t) + (\delta^i + \delta) z_{t+1}^w - 2 \sqrt{\delta_{t} z_{t}^w + \kappa z_{t}^i} \sqrt{\delta_{t+1} z_{t+1}^w + \kappa z_{t+1}}, \\
Var [\Delta s^i_{t+1}] &\approx 2 \chi^2 \sigma^2 + \theta \left\{ 2 (\gamma + \kappa) + (\delta^i + \delta - 2 \left( \sqrt{\delta_{t} z_{t}^w + \kappa z_{t}^i} \right) \right\} \\
&= \theta \left\{ 2 \chi^2 \frac{\sigma^2}{1 - \varphi^2} + 2 (\gamma + \kappa) + (\delta^i + \delta - 2 \left( \sqrt{\delta_{t} + \kappa \delta_{t} + \kappa} \right) \right\}. \tag{21}
\end{align*}
\]
In the last variance we use the following Taylor series approximation: Define \( f(z^w, z^i, z_t) = \left( \sqrt{\delta^i z^w_t + \kappa z^i_t} \right) \) and denote with \( f_j = \partial f/\partial z^i_t \) etc. Then take a Taylor approximation for all \( z^j_t \):

\[
\left( \sqrt{\delta^i z^w_t + \kappa z^i_t} \right) \approx \left( \sqrt{\delta^i \theta + \kappa \delta \theta + \kappa \theta} \right) + (z^w_t - \theta) f_w + (z^i_t - \theta) f_i + (z_t - \theta) f_t.
\]

Taking expectations, the last three terms equal zero, and the first term equals

\[
\left( \sqrt{\delta^i \theta + \kappa \delta \theta + \kappa \theta} \right) = \theta \left( \sqrt{\delta^i + \kappa \delta + \kappa} \right)
\]

Simulations suggest this is fairly correct.

Next, from the stochastic discount factor we can derive the interest rate for currency \( i \):

\[
rf^i_t = -(E_t \left[ m^i_t \right] + 0.5 \text{Var}_t \left[ m^i_t \right]) = \alpha + \chi \left( z^i_t + z^w_t \right) - 0.5 (\gamma + \kappa) z^i_t - 0.5 \delta^i z^w_t.
\]

The unconditional interest rate is

\[
rf^i = E_t \left[ rf^i_t \right] = \alpha + 2 \chi \theta - 0.5 (\gamma + \kappa + \delta^i) \theta.
\]

The variance of the interest rate is

\[
\text{Var} \left[ rf^i_t \right] = (\chi - 0.5 (\gamma + \kappa))^2 \sigma_z^2 + (\chi - 0.5 \delta)^2 \sigma_z^2,
\]

and the autocorrelation of the interest rate is \( \varphi \).

The interest rate differential or forward premium is

\[
rf^i_t - rf_t = \chi \left( z^i_t - z_t \right) - 0.5 (\gamma + \kappa) \left( z^i_t - z_t \right) - 0.5 (\delta^i - \delta) z^w_t.
\]

The variance of the forward premium is

\[
\text{Var} \left[ rf^i_t - rf_t \right] = 2 (\chi - 0.5 (\gamma + \kappa))^2 \sigma_z^2 + 0.25 (\delta^i - \delta)^2 \sigma_z^2.
\]

The currency excess return equals

\[
x_t^i = rf^i_t - rf_t - \Delta s^i_t + \left( \frac{\sqrt{\delta^i z^w_t + \kappa z^i_t} \sqrt{\delta z^w_t + \kappa z_t} u^w_t}{\sqrt{\delta^i + \kappa \delta + \kappa}} \right)
\]

29
The first moments of this are
\[
E_t [rx_{t+1}^i] = -0.5 (\gamma + \kappa) (z_i^t - z_t) - 0.5 (\delta^i - \delta) z_t^w, \tag{29}
\]
\[
E [rx_{t+1}^i] = -0.5 (\delta^i - \delta) \theta. \tag{30}
\]

The second moments are
\[
Var_t [rx_{t+1}^i] = (\gamma + \kappa) (z_i^t + z_t) + (\delta^i + \delta) z_t^w - 2\sqrt{\delta^i z_t^w + \kappa z_i^t} \sqrt{\delta z_t^w + \kappa z_t}, \tag{31}
\]
\[
Var [rx_{t+1}^i] \approx 0.5 (\gamma + \kappa)^2 \sigma_e^2 + 0.25 (\delta^i - \delta)^2 \sigma_z^2 + 2 (\gamma + \kappa) \theta + \left( \delta^i + \delta - 2 \left( \sqrt{\delta^i + \kappa \sqrt{\delta + \kappa}} \right) \right) \theta + \theta \left( 0.5 (\gamma + \kappa)^2 + 0.5 (\delta^i - \delta)^2 \right) \frac{\sigma_e^2}{1 - \psi^2} + 2 (\gamma + \kappa) + (\delta^i + \delta - 2 \left( \sqrt{\delta^i + \kappa \sqrt{\delta + \kappa}} \right) \right) \tag{32}
\]

Using that \( E_t [Mt+1M_{t+1}^i] = 1 \) it follows that the conditional expected (excess) stock return equals:
\[
E_t [re_{t+1}] = -0.5 \psi Var_t [re_{t+1}] - Cov_t [re_{t+1}, m_{t+1}]
= -0.5 (\lambda_w z_t^w + \lambda_e) + \sqrt{\delta z_t^w + \kappa z_t} \sqrt{\lambda_w z_t^w} + \sqrt{\lambda_e \lambda_m}. \tag{33}
\]

This implies for the unconditional expected return:
\[
E [re_{t+1}] = -0.5 \lambda_w \theta - 0.5 \lambda_e + \sqrt{\lambda_w \lambda_m} + \theta \sqrt{\lambda_w \delta + \lambda_m \kappa}. \tag{34}
\]

And for the variances we have
\[
Var [re_{t+1}] = \lambda_e + \lambda_w \theta + (0.25 \lambda_w^2 + \delta \lambda_w) \sigma_e^2 - 0.5 \psi \sigma_z^2, \tag{35}
\]
\[
\psi = -0.25 (\theta^4 \lambda_w^3 (\delta + \kappa))^{-3/2} \left\{ \lambda_w^6 \theta^6 (4 \delta + 3 \kappa)^2 + \lambda_w^6 \theta^6 \kappa^2 \right\} \tag{36}
\]  
\[+3 (\theta^4 \lambda_w^3 (\delta + \kappa))^{-1/2} \left\{ 2 \lambda_w^3 \delta \theta^2 + \lambda_w^3 \kappa \theta^2 \right\}. \tag{38}
\]

For the minimum variance hedge, we need the covariance between the stock market factor and the currency
\[
Cov_t [re_{t+1}, rx_{t+1}^j] = Cov_t \left[ \sqrt{\lambda_w z_t^w} u_{t+1}^w, - \left( \sqrt{\delta^i - \delta} \right) \sqrt{z_t^w} w_{t+1}^w \right]
= -\sqrt{\lambda_w z_t^w} \left( \sqrt{\delta z_t^w + \kappa z_t^i} - \sqrt{\delta z_t^w + \kappa z_t} \right), \tag{37}
\]

We use a first order Taylor series approximation, where we approximate \( \delta z_t^w, z_t \) and \( z_i^t \) around their mean \( \delta \theta \) and \( \theta \), where \( \delta \) is the cross-sectional mean of \( \delta, \delta^i \). We first rewrite the covariance as
\[
- \left\{ \frac{\lambda_w}{\delta} \delta z_t^w \delta z_t^w + \frac{\lambda_w}{\delta} \delta z_t^w \kappa z_t \right\}^{1/2} - \left( \frac{\lambda_w}{\delta} \delta z_t^w \delta z_t^w + \frac{\lambda_w}{\delta} \delta z_t^w \kappa z_t \right)^{1/2} \right\}^{1/2}
\]

30
We first take the derivative w.r.t. $\tilde{\delta}z_t^w$. Because the two terms are similar, focus first on the first term in brackets:

$$\frac{\partial}{\partial \tilde{\delta}z_t^w} = \left( \frac{\lambda_w \tilde{\delta}z_t^w \delta^i z_t^w + \lambda_w \tilde{\delta}z_t^w \kappa z_t^i}{\delta} \right)^{-1/2} \left( \frac{\lambda_w \delta^i z_t^w + \lambda_w \kappa z_t^i}{\delta} \right).$$

Doing the same for the second term in brackets and evaluation at $\theta$ and $\tilde{\delta}$, we get

$$\frac{\partial \text{Cov}_t}{\partial \delta z_t^w} = -\frac{1}{2} \sqrt{\frac{\lambda_w}{\delta} (\tilde{\delta} + \kappa)^{1/2}} + \frac{1}{2} \sqrt{\frac{\lambda_w}{\delta} (\delta + \kappa)^{1/2}} = 0.$$

So this first term disappears in the approximation. Next, we take the derivative w.r.t. $\delta z_t^w$, which is

$$\frac{\partial \text{Cov}_t}{\partial \delta z_t^w} = -\frac{1}{2} \left( \frac{\lambda_w \delta z_t^w \delta^i z_t^w + \lambda_w \delta z_t^w \kappa z_t^i}{\delta} \right)^{-1/2} \left( \frac{\lambda_w \delta^i z_t^w}{\delta} \right).$$

Again, evaluation at $\theta$ and $\tilde{\delta}$, and adding the deviation term, gives:

$$-\frac{1}{2} \sqrt{\frac{\lambda_w}{\delta} (\tilde{\delta} + \kappa)^{1/2} (\delta^i - \delta) z_t^w}.$$

Doing the same for the derivative w.r.t. $\tilde{\delta} z_t^w$ and combine, gives for the Taylor term related to $z_t^w$:

$$-\frac{1}{2} \sqrt{\frac{\lambda_w}{\delta} (\tilde{\delta} + \kappa)^{1/2} (\delta^i - \delta) z_t^w}. \tag{38}$$

The next step is to take the approximation for $z_t^i$. The derivative is:

$$\frac{\partial \text{Cov}_t}{\partial z_t^i} = -\frac{1}{2} \left( \frac{\lambda_w \tilde{\delta}z_t^w \delta^i z_t^w + \lambda_w \tilde{\delta}z_t^w \kappa z_t^i}{\delta} \right)^{-1/2} \left( \frac{\lambda_w \delta^i z_t^w}{\delta} \right),$$

which after evaluating at $\theta$, $\tilde{\delta}$, gives:

$$-\frac{1}{2} \kappa \sqrt{\frac{\lambda_w}{\delta} (\tilde{\delta} + \kappa)^{1/2} (z_t^i - \theta)}. \tag{39}$$

Combining these derivatives readily leads to (12).

The unconditional covariance on the other hand is

$$\text{Cov} \left[ re_{t+1}, r x_{t+1}^l \right] = -\sqrt{\lambda_w} \left( \sqrt{\delta^i + \kappa} - \sqrt{\delta + \kappa} \right) \theta + 0.25 (\delta^i - \delta) \lambda_w \sigma_z^2 - 0.25 \sqrt{\lambda_w} (\delta^i - \delta) \sigma_z^2 (2\delta + \kappa) (\delta + \kappa)^{-1/2}. \tag{40}$$

The covariance of the UIP regression is expressed as:

$$\text{Cov} \left[ \Delta s_{t+1}^i, r f_t^l - r f_t \right] = \{2\chi (\chi - 0.5 (\gamma + \kappa)) \} \sigma_z^2,$$

where we use again that $\text{Var} [z_t] = \text{Var} [z_t^i] = V \text{ar} [z_t^w]$. The slope of the UIP regression is thus

$$\frac{2\chi (\chi - 0.5 (\gamma + \kappa))}{2 (\chi - 0.5 (\gamma + \kappa))^2 + 0.25 (\delta^i - \delta)^2}.$$
References


Table I. Summary statistics of monthly stock and currency returns

The table reports the summary statistics for monthly equity and currency returns for individual countries from July 1975 to December 2009, a total of 414 months. For this table all returns are in local currencies. Stock returns from 7 developed markets are constructed based on MSCI total return indices. Interest rate data are provided by the IMF. Exchange rate data are from the IFS database and we use one-month interest rate differentials to construct forward rates. The returns on the Euro stock market are constructed as the value-weighted returns from Germany, France, Italy and The Netherlands, weighted by the relative market capitalizations of the equity markets. For exchange rates and interest rates in the Euro-zone prior to 1999, we use those of the Euro-zone’s largest market, Germany. The table reports annualized mean returns and standard deviations, the skewness and kurtosis.

<table>
<thead>
<tr>
<th>Panel A: Country-level stock returns in local currency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (% p.a.)</td>
</tr>
<tr>
<td>----------------</td>
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<tr>
<td>5.6</td>
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<tr>
<td>15.8</td>
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<tr>
<td>-0.538</td>
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<tr>
<td>2.266</td>
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</table>

<table>
<thead>
<tr>
<th>Panel B: Currency forward returns vis à vis US$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (% p.a.)</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>0.0</td>
</tr>
<tr>
<td>10.2</td>
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<tr>
<td>-0.053</td>
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<td>0.785</td>
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</table>
Table II. Currency hedging in international stock portfolios

This table reports out-of-sample results of currency hedging in equally weighted international stock portfolios. We add a minimum variance hedge to an equally weighted country portfolio. Hedging portfolio weights are estimated based on an overlay strategy, using the past 60 months of data. In each column the unhedged international equity portfolio is expressed in a different home currency. Panel A reports the impact of currency risk hedging on the standard deviation of the overall portfolio returns. The panel shows standard deviations of unhedged and hedged portfolios, as well as the corresponding $t$-statistics in parentheses. Below, the panel reports $t$-statistics of the null hypotheses that the standard deviation remains unchanged after adding currency hedging positions ($t-stat(hedged− unh)$). The final column reports the $p$-values of the Wald test that the changes in standard deviations across all home currencies are jointly equal to zero. Panel B reports the results for portfolio mean returns and Panel C reports the results for portfolio Sharpe ratios. Finally, Panels D and E report the impact of hedging on the skewness and kurtosis of the portfolio returns.

<table>
<thead>
<tr>
<th>Home currency:</th>
<th>US$</th>
<th>Euro</th>
<th>Aus$</th>
<th>Cd$</th>
<th>Yen</th>
<th>SwF</th>
<th>BP</th>
<th>Wald test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A: Impact on portfolio standard deviation</strong></td>
<td></td>
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<tr>
<td>Unhedged stock portfolio</td>
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<tr>
<td>$Stdev_{unhedged}$</td>
<td>4.62%</td>
<td>4.56%</td>
<td>4.02%</td>
<td>3.99%</td>
<td>5.09%</td>
<td>5.15%</td>
<td>4.62%</td>
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<tr>
<td>Add minimum variance hedge</td>
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</tr>
<tr>
<td>$Stdev_{hedged}$</td>
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<td>3.84%</td>
<td>3.85%</td>
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<td>3.84%</td>
<td>3.83%</td>
<td>3.85%</td>
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</tr>
<tr>
<td>$t$-stat ($hedged− unh$)</td>
<td>(-3.67)</td>
<td>(-4.25)</td>
<td>(-1.04)</td>
<td>(-1.01)</td>
<td>(-4.09)</td>
<td>(-6.01)</td>
<td>(-4.13)</td>
<td>(0.000)</td>
</tr>
<tr>
<td><strong>Panel B: Impact on portfolio mean returns</strong></td>
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<td>Unhedged stock portfolio</td>
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<tr>
<td>$Mean_{unhedged}$</td>
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<td>0.63%</td>
<td>0.35%</td>
<td>0.41%</td>
<td>0.55%</td>
<td>0.65%</td>
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</tr>
<tr>
<td>$t$-stat</td>
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<td>(2.60)</td>
<td>(1.63)</td>
<td>(1.95)</td>
<td>(2.03)</td>
<td>(2.36)</td>
<td>(2.08)</td>
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<tr>
<td>Add minimum variance hedge</td>
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<tr>
<td>$Mean_{hedged}$</td>
<td>0.27%</td>
<td>0.31%</td>
<td>0.34%</td>
<td>0.31%</td>
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<tr>
<td>$t$-stat</td>
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<td>(1.53)</td>
<td>(1.68)</td>
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<td>(1.49)</td>
<td>(1.48)</td>
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</tr>
<tr>
<td>$t$-stat ($hedged− unh$)</td>
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<td>(0.355)</td>
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<tr>
<td><strong>Panel C: Impact on portfolio Sharpe ratios</strong></td>
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<tr>
<td>$t$-stat</td>
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<td>(2.38)</td>
<td>(1.60)</td>
<td>(1.88)</td>
<td>(1.88)</td>
<td>(2.19)</td>
<td>(1.95)</td>
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<tr>
<td>Add minimum variance hedge</td>
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<td>$SR_{hedged}$</td>
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<td>(1.42)</td>
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<tr>
<td>$t$-stat ($hedged− unh$)</td>
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<td>(0.07)</td>
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<td>(-0.76)</td>
<td>(0.302)</td>
</tr>
<tr>
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<td>Euro</td>
<td>Aus$</td>
<td>Cd$</td>
<td>Yen</td>
<td>SwF</td>
<td>BP</td>
<td>Wald test</td>
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<tr>
<td>Panel D: Impact on portfolio skewness</td>
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<tr>
<td>Unhedged stock portfolio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skew_{unhedged}</td>
<td>-0.735</td>
<td>-1.186</td>
<td>-0.427</td>
<td>-0.680</td>
<td>-1.320</td>
<td>-1.097</td>
<td>-1.102</td>
<td></td>
</tr>
<tr>
<td>t-stat</td>
<td>(-2.36)</td>
<td>(-2.42)</td>
<td>(-1.81)</td>
<td>(-1.75)</td>
<td>(-3.28)</td>
<td>(-2.82)</td>
<td>(-2.13)</td>
<td></td>
</tr>
<tr>
<td>Add minimum variance hedge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skew_{hedged}</td>
<td>-1.283</td>
<td>-1.286</td>
<td>-1.270</td>
<td>-1.294</td>
<td>-1.279</td>
<td>-1.288</td>
<td>-1.273</td>
<td></td>
</tr>
<tr>
<td>t-stat</td>
<td>(-2.43)</td>
<td>(-2.44)</td>
<td>(-2.36)</td>
<td>(-2.46)</td>
<td>(-2.43)</td>
<td>(-2.42)</td>
<td>(-2.44)</td>
<td></td>
</tr>
<tr>
<td>t-stat_{(hedged-unh)}</td>
<td>(-1.46)</td>
<td>(-0.52)</td>
<td>(-2.45)</td>
<td>(-2.55)</td>
<td>(0.11)</td>
<td>(-0.78)</td>
<td>(-0.88)</td>
<td></td>
</tr>
</tbody>
</table>

| Panel E: Impact on portfolio kurtosis |
| Unhedged stock portfolio | | | | | | | |
| Kurt_{unhedged} | 2.825 | 4.630 | 1.465 | 2.832 | 5.431 | 3.636 | 4.896 |
| t-stat | (1.96) | (1.33) | (1.33) | (1.29) | (2.39) | (1.41) | (1.40) |
| Add minimum variance hedge | | | | | | | |
| Kurt_{hedged} | 5.875 | 5.916 | 6.013 | 5.932 | 5.878 | 5.942 | 5.829 |
| t-stat | (1.62) | (1.63) | (1.65) | (1.64) | (1.63) | (1.62) | (1.63) |
| t-stat_{(hedged-unh)} | (1.20) | (2.50) | (1.72) | (2.02) | (0.21) | (1.91) | (1.78) | (0.028) |
Table III. Adding both hedging and speculative positions

This table reports results of adding speculative currency positions to an unhedged and to a hedged equally weighted international stock portfolio. Speculative currency positions are estimated as the tangency portfolio of currency returns, where we use the covariance matrix estimated based on the past 60 months of data. As the currency expected excess returns, we use the one month lagged interest rate differentials between the foreign and domestic interest rates. Hedging portfolio weights are estimated based on an overlay strategy, using the past 60 months of data. Hence, using only data up to month $t$ we estimate hedging and speculative portfolio weights, which we then use to calculate out-of-sample returns for the subsequent month. Panel A reports the impact of currency investing on the standard deviation of the overall portfolio returns. Speculative currency positions are added (with a weight of 100%) to an unhedged stock portfolio ("spec") as well as to a hedged stock portfolio ("total"). The table reports in parentheses the corresponding $t$-statistics as well as $t$-statistics of the null hypotheses that the standard deviation remains unchanged after adding currency positions. The final column reports the $p$-values of the Wald test that the changes in standard deviations across all home currencies are jointly equal to zero. Panel B reports the results for portfolio mean returns, Panel C for portfolio Sharpe ratios, and Panels D and E for skewness and kurtosis.

<table>
<thead>
<tr>
<th>Home currency:</th>
<th>US$</th>
<th>Euro</th>
<th>Aus$</th>
<th>Cd$</th>
<th>Yen</th>
<th>SwF</th>
<th>BP</th>
<th>Wald test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A: Impact on portfolio standard deviation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Add speculative demand to an unhedged portfolio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stdev_{spec}</td>
<td>5.04%</td>
<td>5.13%</td>
<td>4.03%</td>
<td>4.20%</td>
<td>6.72%</td>
<td>6.31%</td>
<td>4.51%</td>
<td></td>
</tr>
<tr>
<td>$t$-stat_{(spec–unh)}</td>
<td>(4.03)</td>
<td>(5.38)</td>
<td>(0.02)</td>
<td>(2.55)</td>
<td>(6.50)</td>
<td>(8.37)</td>
<td>(-1.27)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Add speculative demand to a hedged portfolio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stdev_{total}</td>
<td>4.16%</td>
<td>4.19%</td>
<td>4.62%</td>
<td>4.09%</td>
<td>4.57%</td>
<td>4.32%</td>
<td>4.10%</td>
<td></td>
</tr>
<tr>
<td>$t$-stat_{(total–unh)}</td>
<td>(-2.12)</td>
<td>(-2.50)</td>
<td>(1.95)</td>
<td>(0.54)</td>
<td>(-2.80)</td>
<td>(-5.29)</td>
<td>(-2.47)</td>
<td>(0.000)</td>
</tr>
<tr>
<td><strong>Panel B: Impact on portfolio mean returns</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Add speculative demand to an unhedged portfolio</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean_{spec}</td>
<td>0.76%</td>
<td>0.86%</td>
<td>0.52%</td>
<td>0.60%</td>
<td>0.78%</td>
<td>0.88%</td>
<td>0.69%</td>
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</tr>
<tr>
<td>$t$-stat</td>
<td>(2.83)</td>
<td>(3.13)</td>
<td>(2.42)</td>
<td>(2.67)</td>
<td>(2.18)</td>
<td>(2.61)</td>
<td>(2.89)</td>
<td></td>
</tr>
<tr>
<td>$t$-stat_{(spec–unh)}</td>
<td>(3.35)</td>
<td>(3.20)</td>
<td>(1.28)</td>
<td>(2.93)</td>
<td>(1.85)</td>
<td>(2.44)</td>
<td>(2.39)</td>
<td>(0.059)</td>
</tr>
<tr>
<td>Add speculative demand to a hedged portfolio</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean_{total}</td>
<td>0.49%</td>
<td>0.54%</td>
<td>0.51%</td>
<td>0.49%</td>
<td>0.53%</td>
<td>0.53%</td>
<td>0.50%</td>
<td></td>
</tr>
<tr>
<td>$t$-stat</td>
<td>(2.23)</td>
<td>(2.41)</td>
<td>(2.08)</td>
<td>(2.25)</td>
<td>(2.20)</td>
<td>(2.32)</td>
<td>(2.28)</td>
<td></td>
</tr>
<tr>
<td>$t$-stat_{(total–unh)}</td>
<td>(-0.22)</td>
<td>(-0.60)</td>
<td>(0.72)</td>
<td>(0.56)</td>
<td>(-0.11)</td>
<td>(-0.72)</td>
<td>(-0.08)</td>
<td>(0.627)</td>
</tr>
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</table>
Table III - continued

<table>
<thead>
<tr>
<th>Home currency:</th>
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<th>Euro</th>
<th>Aus$</th>
<th>Cd$</th>
<th>Yen</th>
<th>SwF</th>
<th>BP</th>
<th>Wald test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add speculative demand to an unhedged portfolio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR_{spec}</td>
<td>0.151</td>
<td>0.167</td>
<td>0.129</td>
<td>0.142</td>
<td>0.116</td>
<td>0.139</td>
<td>0.154</td>
<td></td>
</tr>
<tr>
<td>t-stat</td>
<td>(2.64)</td>
<td>(2.82)</td>
<td>(2.21)</td>
<td>(2.48)</td>
<td>(2.02)</td>
<td>(2.43)</td>
<td>(2.61)</td>
<td></td>
</tr>
<tr>
<td>t-stat_{(spec-unh)}</td>
<td>(2.56)</td>
<td>(2.10)</td>
<td>(1.23)</td>
<td>(2.40)</td>
<td>(0.50)</td>
<td>(1.05)</td>
<td>(2.54)</td>
<td>(0.203)</td>
</tr>
<tr>
<td>Add speculative demand to a hedged portfolio</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR_{total}</td>
<td>0.119</td>
<td>0.120</td>
<td>0.120</td>
<td>0.117</td>
<td>0.124</td>
<td>0.121</td>
<td></td>
<td></td>
</tr>
<tr>
<td>t-stat</td>
<td>(2.04)</td>
<td>(2.18)</td>
<td>(1.91)</td>
<td>(2.04)</td>
<td>(2.03)</td>
<td>(2.10)</td>
<td>(2.12)</td>
<td></td>
</tr>
<tr>
<td>t-stat_{(total-unh)}</td>
<td>(0.09)</td>
<td>(-0.27)</td>
<td>(0.46)</td>
<td>(0.46)</td>
<td>(0.34)</td>
<td>(-0.06)</td>
<td>(0.22)</td>
<td>(0.878)</td>
</tr>
</tbody>
</table>

Panel D: Impact on portfolio skewness

| Skew_{spec} | -0.810 | -1.158 | -1.319 | -0.951 | -1.228 | -0.963 | -1.220 |
| t-stat | (-2.15) | (-2.34) | (-2.53) | (-2.10) | (-3.19) | (-2.91) | (-2.36) |
| t-stat_{(spec-unh)} | (-0.71) | (0.43) | (-2.52) | (-2.90) | (0.49) | (1.56) | (-1.10) | (0.002) |
| Add speculative demand to an unhedged portfolio | | | | | | | | |
| Skew_{total} | -1.446 | -1.516 | -1.495 | -1.547 | -1.325 | -1.591 | -1.161 |
| t-stat | (-2.72) | (-2.70) | (-2.22) | (-2.78) | (-2.92) | (-2.90) | (-2.81) |
| t-stat_{(total-unh)} | (-1.91) | (-1.97) | (-2.12) | (-3.46) | (-0.02) | (-2.22) | (-0.26) | (0.006) |

Panel E: Impact on portfolio kurtosis

| Kurt_{spec} | 3.804 | 4.677 | 5.491 | 4.163 | 4.857 | 2.822 | 5.194 |
| t-stat | (3.24) | (1.36) | (1.47) | (1.54) | (2.18) | (1.37) | (1.44) |
| t-stat_{(spec-unh)} | (3.06) | (0.27) | (1.46) | (2.48) | (-0.42) | (-1.39) | (1.16) | (0.001) |
| Add speculative demand to a hedged portfolio | | | | | | | | |
| t-stat | (1.58) | (1.65) | (1.49) | (1.67) | (1.78) | (1.67) | (1.61) |
| t-stat_{(total-unh)} | (1.19) | (2.67) | (1.49) | (1.99) | (0.02) | (2.01) | (-0.51) | (0.052) |
Table IV. Calibration

Panel A reports the parameter values of the model that are chosen such that the squared difference between the implied and empirical moments in Panel B is minimized and the Feller condition has a minimum value of 10. We calibrate the parameter values for each of the six foreign currencies, using the US dollar as the home currency. Panel A reports the average parameter values over all currencies. Panel B reports the implied and empirical moments, which are also averaged over all home currencies. The fourth column reports the cross-currency standard deviation of the differences between implied and empirical moments.

<table>
<thead>
<tr>
<th>Panel A: Parameter values</th>
</tr>
</thead>
</table>
| $\lambda_v$ | 0.0009  
| $\lambda_m$ | 0.0000  
| $\lambda_w$ | 1.2842  
| $\alpha$ | 0.0133  
| $\chi$ | 2.6607  
| $\gamma$ | 0.4074  
| $\kappa$ | 10.7894  
| $\phi$ | 0.9165  
| $\theta$ | 0.0010  
| $\sigma$ | 0.0040  
| $\delta$ | 18.8365  
| $\delta_{\text{min}}$ | 14.141  
| $\delta_{\text{max}}$ | 30.712  

| Panel B: Implied and empirical moments |  
|----------------------------|----------------------------|----------------------------|  
| mean $[rf]$ | 5.84% | 5.71% | 0.81%  
| std $[rf]$ | 0.73% | 0.89% | 0.05%  
| AR $[rf]$ | 0.916 | 0.920 | 0.002  
| mean $[re]$ | 5.28% | 4.79% | 0.26%  
| std $[re]$ | 15.62% | 15.91% | 0.25%  
| stdev $[rs]$ | 10.10% | 10.49% | 0.81%  
| mean $[rf_i]$ | 4.54% | 5.98% | 0.92%  
| std $[rf_i]$ | 0.84% | 0.90% | 0.07%  
| std $[rf-rf_i]$ | 0.43% | 0.65% | 0.09%  
| mean $[rx]$ | -1.29% | -0.94% | 0.48%  
| std $[rx]$ | 10.12% | 10.57% | 0.82%  
| slope hedge regression | -0.355 | -0.606 | 0.061  
| slope UIP regression $rx$ on $rf_i-rf$ | 2.322 | 2.369 | 0.027  
| slope UIP regression $rs$ on $rf_i-rf$ | -1.322 | -1.369 | 0.027  

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Table V. Simulations

This table reports the impact of currency risk hedging on the portfolio standard deviation (Panel A), mean returns (Panel B), Sharpe ratios (Panel C), skewness (Panel D) and kurtosis (Panel E), based on simulated returns from the model. We use the parameter values as reported in Table IV Panel A. The only parameter that varies across currencies is the global factor exposure, $\delta_i$, which is varied from $\delta_{\min}$ to $\delta_{\max}$ in seven equal steps. This gives us seven different values of $\delta_i$, representing the different currencies. In each column, we choose another currency as the home currency, ranging from the minimum value of $\delta_i$ in the second column to its maximum value in the eighth column. The results are based on 5000 simulations. Each panel reports the relevant statistic for unhedged and hedged returns, and below that the $t$—statistic of the difference. The table is directly comparable to the empirical results in Table II.

Panel A: Impact on portfolio standard deviation

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stdev unhedged</td>
<td>4.76%</td>
<td>6.57%</td>
<td>7.15%</td>
<td>7.69%</td>
<td>8.18%</td>
<td>8.93%</td>
<td>9.37%</td>
</tr>
<tr>
<td>Stdev hedged</td>
<td>3.73%</td>
<td>3.73%</td>
<td>3.73%</td>
<td>3.73%</td>
<td>3.73%</td>
<td>3.73%</td>
<td>3.73%</td>
</tr>
<tr>
<td>$t$-stat (hedged—unh)</td>
<td>(21.18)</td>
<td>(29.56)</td>
<td>(32.69)</td>
<td>(33.44)</td>
<td>(33.87)</td>
<td>(33.96)</td>
<td>(37.10)</td>
</tr>
</tbody>
</table>

Panel B: Impact on portfolio mean returns

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean unhedged</td>
<td>0.51%</td>
<td>0.79%</td>
<td>0.91%</td>
<td>1.02%</td>
<td>1.11%</td>
<td>1.29%</td>
<td>1.37%</td>
</tr>
<tr>
<td>Mean hedged</td>
<td>0.15%</td>
<td>0.12%</td>
<td>0.09%</td>
<td>0.06%</td>
<td>0.04%</td>
<td>0.01%</td>
<td>-0.01%</td>
</tr>
<tr>
<td>$t$-stat (hedged—unh)</td>
<td>(-7.30)</td>
<td>(-8.35)</td>
<td>(-9.17)</td>
<td>(-9.78)</td>
<td>(-10.07)</td>
<td>(-10.88)</td>
<td>(-11.06)</td>
</tr>
</tbody>
</table>

Panel C: Impact on portfolio Sharpe ratio

<table>
<thead>
<tr>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR unhedged</td>
<td>0.107</td>
<td>0.120</td>
<td>0.128</td>
<td>0.133</td>
<td>0.135</td>
<td>0.145</td>
<td>0.146</td>
</tr>
<tr>
<td>SR hedged</td>
<td>0.040</td>
<td>0.031</td>
<td>0.023</td>
<td>0.017</td>
<td>0.011</td>
<td>0.004</td>
<td>-0.002</td>
</tr>
<tr>
<td>$t$-stat (hedged—unh)</td>
<td>(-5.96)</td>
<td>(-6.34)</td>
<td>(-7.13)</td>
<td>(-7.76)</td>
<td>(-8.14)</td>
<td>(-9.00)</td>
<td>(-9.28)</td>
</tr>
</tbody>
</table>

Panel D: Impact on stock portfolio skewness

<table>
<thead>
<tr>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skew unhedged</td>
<td>0.110</td>
<td>0.157</td>
<td>0.187</td>
<td>0.201</td>
<td>0.221</td>
<td>0.275</td>
<td>0.181</td>
</tr>
<tr>
<td>Skew hedged</td>
<td>0.025</td>
<td>0.023</td>
<td>0.027</td>
<td>0.025</td>
<td>0.019</td>
<td>0.014</td>
<td>0.019</td>
</tr>
<tr>
<td>$t$-stat (hedged—unh)</td>
<td>(-1.83)</td>
<td>(-2.05)</td>
<td>(-2.69)</td>
<td>(-2.73)</td>
<td>(-2.86)</td>
<td>(-3.32)</td>
<td>(-2.58)</td>
</tr>
</tbody>
</table>

Panel E: Impact on stock portfolio kurtosis

<table>
<thead>
<tr>
<th></th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kurt unhedged</td>
<td>0.201</td>
<td>0.785</td>
<td>0.570</td>
<td>0.686</td>
<td>0.774</td>
<td>0.989</td>
<td>0.595</td>
</tr>
<tr>
<td>Kurt hedged</td>
<td>0.159</td>
<td>0.157</td>
<td>0.161</td>
<td>0.152</td>
<td>0.163</td>
<td>0.162</td>
<td>0.148</td>
</tr>
<tr>
<td>$t$-stat (hedged—unh)</td>
<td>(-0.22)</td>
<td>(-2.25)</td>
<td>(-1.67)</td>
<td>(-1.94)</td>
<td>(-1.92)</td>
<td>(-2.00)</td>
<td>(-1.68)</td>
</tr>
</tbody>
</table>
This table reports out-of-sample results of currency hedging in equally weighted international bond portfolios. We add a minimum variance hedge to an equally weighted country portfolio. Hedging portfolio weights are estimated based on an overlay strategy, using the past 60 months of data. In each column the unhedged international bond portfolio is expressed in a different home currency. Panel A reports the impact of currency risk hedging on the standard deviation of the overall portfolio returns. The panel shows standard deviations of unhedged and hedged portfolios, as well as the corresponding \(t\)-statistics in parentheses. Below, the panel reports \(t\)-statistics of the null hypotheses that the standard deviation remains unchanged after adding currency hedging positions \(t(\text{hedged}-\text{unh})\). The final column reports the \(p\)-values of the Wald test that the changes in standard deviations across all home currencies are jointly equal to zero. Panel B reports the results for portfolio mean returns and Panel C reports the results for portfolio Sharpe ratios. Finally, Panels D and E report the impact of hedging on the skewness and kurtosis of the portfolio returns.

### Panel A: Impact on portfolio standard deviation

<table>
<thead>
<tr>
<th>Home currency:</th>
<th>US$</th>
<th>Euro</th>
<th>Aus$</th>
<th>Cd$</th>
<th>Yen</th>
<th>SwF</th>
<th>BP</th>
<th>Wald test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unhedged bond portfolio</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Stdev(_{ unhedged } )</td>
<td>2.38%</td>
<td>1.82%</td>
<td>3.25%</td>
<td>2.48%</td>
<td>2.75%</td>
<td>2.30%</td>
<td>2.33%</td>
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</tr>
<tr>
<td>(t)-stat</td>
<td>(26.50)</td>
<td>(24.56)</td>
<td>(21.35)</td>
<td>(24.63)</td>
<td>(20.42)</td>
<td>(23.61)</td>
<td>(18.15)</td>
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</tr>
<tr>
<td>Add minimum variance hedge</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Stdev(_{ hedged } )</td>
<td>1.44%</td>
<td>1.45%</td>
<td>1.45%</td>
<td>1.45%</td>
<td>1.44%</td>
<td>1.45%</td>
<td>1.45%</td>
<td></td>
</tr>
<tr>
<td>(t)-stat</td>
<td>(19.73)</td>
<td>(19.27)</td>
<td>(18.06)</td>
<td>(19.70)</td>
<td>(19.19)</td>
<td>(18.65)</td>
<td>(19.35)</td>
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</tr>
<tr>
<td>(t)-stat(_{ (hedged-unh) } )</td>
<td>(-8.19)</td>
<td>(-4.29)</td>
<td>(-9.06)</td>
<td>(-8.13)</td>
<td>(-7.29)</td>
<td>(-6.98)</td>
<td>(-5.69)</td>
<td>(0.000)</td>
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</table>

### Panel B: Impact on portfolio mean returns

<table>
<thead>
<tr>
<th>Home currency:</th>
<th>US$</th>
<th>Euro</th>
<th>Aus$</th>
<th>Cd$</th>
<th>Yen</th>
<th>SwF</th>
<th>BP</th>
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<tbody>
<tr>
<td>Unhedged bond portfolio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean(_{ unhedged } )</td>
<td>0.32%</td>
<td>0.42%</td>
<td>0.14%</td>
<td>0.20%</td>
<td>0.34%</td>
<td>0.43%</td>
<td>0.30%</td>
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<tr>
<td>(t)-stat</td>
<td>(2.52)</td>
<td>(4.32)</td>
<td>(0.79)</td>
<td>(1.53)</td>
<td>(2.30)</td>
<td>(3.55)</td>
<td>(2.42)</td>
</tr>
<tr>
<td>Add minimum variance hedge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean(_{ hedged } )</td>
<td>0.17%</td>
<td>0.22%</td>
<td>0.20%</td>
<td>0.19%</td>
<td>0.22%</td>
<td>0.23%</td>
<td>0.22%</td>
</tr>
<tr>
<td>(t)-stat</td>
<td>(2.26)</td>
<td>(2.89)</td>
<td>(2.56)</td>
<td>(2.46)</td>
<td>(2.82)</td>
<td>(2.93)</td>
<td>(2.86)</td>
</tr>
<tr>
<td>(t)-stat(_{ (hedged-unh) } )</td>
<td>(-1.31)</td>
<td>(-2.51)</td>
<td>(0.36)</td>
<td>(-0.11)</td>
<td>(-0.89)</td>
<td>(-1.89)</td>
<td>(-0.74)</td>
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</table>

### Panel C: Impact on portfolio Sharpe ratios

<table>
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<th>US$</th>
<th>Euro</th>
<th>Aus$</th>
<th>Cd$</th>
<th>Yen</th>
<th>SwF</th>
<th>BP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unhedged bond portfolio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR(_{ unhedged } )</td>
<td>0.134</td>
<td>0.230</td>
<td>0.042</td>
<td>0.082</td>
<td>0.123</td>
<td>0.189</td>
<td>0.129</td>
</tr>
<tr>
<td>(t)-stat</td>
<td>(2.52)</td>
<td>(4.39)</td>
<td>(0.81)</td>
<td>(1.54)</td>
<td>(2.24)</td>
<td>(3.48)</td>
<td>(2.52)</td>
</tr>
<tr>
<td>Add passive minimum variance hedge</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR(_{ hedged } )</td>
<td>0.120</td>
<td>0.154</td>
<td>0.136</td>
<td>0.131</td>
<td>0.150</td>
<td>0.156</td>
<td>0.152</td>
</tr>
<tr>
<td>(t)-stat</td>
<td>(2.21)</td>
<td>(2.80)</td>
<td>(2.47)</td>
<td>(2.39)</td>
<td>(2.72)</td>
<td>(2.83)</td>
<td>(2.78)</td>
</tr>
<tr>
<td>(t)-stat(_{ (hedged-unh) } )</td>
<td>(-0.26)</td>
<td>(-1.58)</td>
<td>(1.42)</td>
<td>(0.89)</td>
<td>(0.45)</td>
<td>(-0.57)</td>
<td>(0.44)</td>
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</tbody>
</table>
Table VI - continued

<table>
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<tr>
<th>Home currency:</th>
<th>US$</th>
<th>Euro</th>
<th>Aus$</th>
<th>Cd$</th>
<th>Yen</th>
<th>SwF</th>
<th>BP</th>
<th>Wald test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unhedged bond portfolio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skew$^{unhedged}$</td>
<td>0.026</td>
<td>0.252</td>
<td>0.713</td>
<td>0.178</td>
<td>-0.390</td>
<td>-0.104</td>
<td>0.697</td>
<td></td>
</tr>
<tr>
<td>$t$-stat</td>
<td>(0.20)</td>
<td>(1.91)</td>
<td>(4.83)</td>
<td>(1.24)</td>
<td>(-1.45)</td>
<td>(-0.55)</td>
<td>(2.38)</td>
<td></td>
</tr>
<tr>
<td>Add minimum variance hedge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skew$^{hedged}$</td>
<td>-0.314</td>
<td>-0.311</td>
<td>-0.423</td>
<td>-0.302</td>
<td>-0.341</td>
<td>-0.343</td>
<td>-0.298</td>
<td></td>
</tr>
<tr>
<td>$t$-stat</td>
<td>(-0.97)</td>
<td>(-0.91)</td>
<td>(-1.06)</td>
<td>(-0.93)</td>
<td>(-0.98)</td>
<td>(-0.93)</td>
<td>(-0.88)</td>
<td></td>
</tr>
<tr>
<td>$t$-stat$^{(hedged– unh)}$</td>
<td>(-0.99)</td>
<td>(-1.61)</td>
<td>(-2.62)</td>
<td>(-1.40)</td>
<td>(0.11)</td>
<td>(-0.60)</td>
<td>(-2.33)</td>
<td>(0.000)</td>
</tr>
</tbody>
</table>

Panel D: Impact on portfolio skewness

<table>
<thead>
<tr>
<th>Panel E: Impact on portfolio kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unhedged bond portfolio</td>
</tr>
<tr>
<td>Kurt$^{unhedged}$</td>
</tr>
<tr>
<td>$t$-stat</td>
</tr>
<tr>
<td>Add minimum variance hedge</td>
</tr>
<tr>
<td>Kurt$^{hedged}$</td>
</tr>
<tr>
<td>$t$-stat</td>
</tr>
<tr>
<td>$t$-stat$^{(hedged– unh)}$</td>
</tr>
</tbody>
</table>
Table VII. The determinants of changes in skewness due to hedging

This table tests changes in portfolio skewness due to hedging, setting one of the three components equal to zero. The table starts with the total change in skewness, taking into account all three components. Next, the skewness of the hedged portfolio is calculated leaving out $CoSkew_{curr, unh}$. We subtract the skewness of the unhedged portfolio and test whether the resulting change in skewness is statistically significant. We perform similar calculations leaving out $CoSkew_{unh, curr}$ and $Skew_{curr}$ from the skewness measure of the hedged portfolio. The table reports the difference between the skewness of the hedged and unhedged portfolios in the various specifications ($\Delta Skew$) and below the corresponding $t$-statistic for the null hypothesis that the difference equals zero ($t$-stat($hedged-unh$)). Each column reports the results for a different home currency.

<table>
<thead>
<tr>
<th>Home currency:</th>
<th>US$</th>
<th>Euro</th>
<th>Aus$</th>
<th>Cd$</th>
<th>Yen</th>
<th>SwF</th>
<th>BP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base case incl. all components</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta Skew$</td>
<td>-0.548</td>
<td>-0.100</td>
<td>-0.844</td>
<td>-0.614</td>
<td>0.041</td>
<td>-0.190</td>
<td>-0.171</td>
</tr>
<tr>
<td>$t$-stat($hedged-unh$)</td>
<td>(-1.46)</td>
<td>(-0.52)</td>
<td>(-2.45)</td>
<td>(-2.55)</td>
<td>(0.11)</td>
<td>(-0.78)</td>
<td>(-0.88)</td>
</tr>
<tr>
<td>Excl. $CoSkew_{curr, unh}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta Skew$</td>
<td>-0.663</td>
<td>-0.357</td>
<td>-0.392</td>
<td>-0.369</td>
<td>-0.663</td>
<td>-0.530</td>
<td>-0.425</td>
</tr>
<tr>
<td>$t$-stat($hedged-unh$)</td>
<td>(-2.36)</td>
<td>(-1.72)</td>
<td>(-1.99)</td>
<td>(-2.26)</td>
<td>(-2.19)</td>
<td>(-1.94)</td>
<td>(-2.13)</td>
</tr>
<tr>
<td>Excl. $CoSkew_{unh, curr}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta Skew$</td>
<td>-0.237</td>
<td>-0.043</td>
<td>-1.000</td>
<td>-0.444</td>
<td>0.728</td>
<td>-0.054</td>
<td>-0.111</td>
</tr>
<tr>
<td>$t$-stat($hedged-unh$)</td>
<td>(-0.36)</td>
<td>(-0.19)</td>
<td>(-3.19)</td>
<td>(-1.45)</td>
<td>(1.01)</td>
<td>(-0.18)</td>
<td>(-0.45)</td>
</tr>
<tr>
<td>Excl. $Skew_{curr}$</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta Skew$</td>
<td>-1.188</td>
<td>-0.041</td>
<td>-0.461</td>
<td>-1.149</td>
<td>-0.810</td>
<td>-0.277</td>
<td>0.044</td>
</tr>
<tr>
<td>$t$-stat($hedged-unh$)</td>
<td>(-2.87)</td>
<td>(-0.15)</td>
<td>(-1.11)</td>
<td>(-4.98)</td>
<td>(-2.23)</td>
<td>(-0.98)</td>
<td>(0.12)</td>
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</table>