# Hedging with an edge: parametric currency overlay

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**Abstract**

Campbell, Serfaty-De Medeiros, and Viceira (2010) propose an optimized method to hedge currency risk in portfolios of international equities. In a demanding out-of-sample test, incorporating transaction and rebalancing costs, and margin requirements we find their method reduces risk in real time, but also underperforms economically a naïve alternative or even a purely domestic portfolio. We propose modeling the currency hedging strategy as a function of characteristics proxying for expected returns and risk. We find that using currency momentum, value, carry, and autocorrelation significantly reduces the cost of hedging. Proxies for risk, such as volatility, skewness, beta on volatility, and equity sensitivity are irrelevant in our optimizations. Our optimal strategy is close to a fully hedged portfolio, but with a sizable 38% gain in Sharpe ratio.

**Keywords**: Foreign exchange, currency market, currency overlay.
**JEL classification**: F31, G11

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# 1 Introduction

There is no reason to be exposed to country-specific shocks, when these can be substantially diversified away by holding international portfolios instead. Unfortunately, international portfolios bring with them the unwelcome guest of currency risk, and it is not obvious how should be dealt with. An investor looking for guidance on how to manage currency exposure in an equity portfolio would find support in the literature for no hedging (Froot, 1993), half hedging (Gastineau, 1995), or full hedging (Perold & Schulman, 1988). This non-exhaustive list covers both the extremes (and the midpoint) of a reasonable spectrum of choices. To complicate things further, the benefits in terms of reducing portfolio volatility depend on the investor's reference currency (Cho, Choi, Kim, & Kim, 2016). This illustrates well the ambiguity surrounding the currency risk hedging decision. In this paper, we examine the hedging approach of Campbell, Serfaty-De Medeiros, and Viceira (2010) (CMV) in a realistic setting, incorporating transaction and rebalancing costs, margin requirements and estimation uncertainty. We find that the method is robust, but the resulting portfolios still underperform naïve hedging approaches in terms of mean-variance efficiency. As an alternative, we adapt the parametric portfolio policies of Brandt, Santa-Clara, and Valkanov (2009) to the issue of designing an optimal currency overlay[1]. Generally, we find statistical and economic evidence that this method achieves an enhanced risk-return profile, delivering on the promised benefits of international diversification. Furthermore, the approach provides practical and intuitive guidelines for handling currency risk.

Intuitively, if currency risk is not rewarded in terms of a larger return, then hedging it away should isolate the risk premium in equities, and result in unequivocal gains. If so, the case for hedging should be straightforward. Perold and Schulman (1988, p. 45) express this idea in a particularly clear manner:

> *"The key to our argument is that [...] investors should think of currency hedging as having zero expected return. Therein lies the free lunch: On average, currency hedging gives you substantial risk reduction at no loss of expected return."*

One problem with this statement is that over the past 31 years we have seen increasing evidence of predictability in the cross section of currency excess returns. For example, Lustig, Roussanov, and Verdelhan (2014) demonstrate that aggregated currency returns are highly predictable. Therefore the currency hedging overlay (currency overlay for short) can perfectly be expected to have a return that is different from zero. This does not invalidate the case for hedging per se. The currency overlay could still be, on average, neutral with respect to expected returns. However that is not typically the case. De Roon, Eiling, Gerard, and Hillion

[1] The hedging issue is typically formulated as finding an optimal currency strategy to complement a fixed portfolio of international equities. Our strategy is designated as the currency overlay.

(2012) demonstrate that an optimized hedging portfolio systematically shorts the currencies with higher expected returns. The shorted currencies are the opposite of safe-haven currencies: they depreciate the most in times of market turmoil, but also bear rewards for risk that go beyond what is justifiable by their exposure to the stock market alone[2]. The authors find that this effect in expected returns is so large that it outweighs any benefits from risk reduction. As a result, hedged portfolios display worser economic performance than unhedged counterparts. This underscores the need to design an optimal hedging strategy – a currency overlay – that takes predictability into consideration with regard to currency returns. On the other hand, incorporating expected returns in an optimization is not self-evident. In fact, it is often found that optimizations perform better if one delibertely ignores information on expected returns (Eun & Resnick, 1988; Glen & Jorion, 1993; Jorion, 1985, 1994). Estimation error is a pervasive problem in portfolio optimization, especially in expected returns, which suggests that naïve approaches to portfolio construction work better (see e.g. DeMiguel, Garlappi, and Uppal (2009)).

In this paper we propose using parametric portfolio policies (PPPs) – a method developed by Brandt et al. (2009) – to design an optimal currency overlay. We build on previous work which demonstrates that this method successfully addresses estimation issues in forming portfolios of equities (Brandt et al., 2009; DeMiguel, Martin-Utrera, Nogales, & Uppal, 2017), currencies (Barroso & Santa-Clara, 2015) and options (Faias & Santa-Clara, 2017). Our contribution to this literature is an application of parametric portfolio policies for currency overlays.

One advantage of parametric portfolio policies is that they bypass the problem of estimating the conditional distribution of returns by modeling weights directly as a function of each asset characteristic. However, the parametric portfolio policy relies on prior knowledge of relevant characteristics for risk and returns. In our main optimization we use carry, momentum, and value as characteristics proxying for expected returns in the currency market. The selection of these characteristics is based on previous research which illustrates the importance of these characteristics for the currency market (see Lustig et al. (2011) for carry; Okunev and White (2003), and Menkhoff, Sarno, Schmeling, and Schrimpf (2012b) for momentum; Menkhoff, Sarno, Schmeling, and Schrimpf (2016) for value; and Asness, Moskowitz, and Pedersen (2013), and Koijen, Moskowitz, Pedersen, and Vrugt (2013) for evidence in other asset classes). Many other characteristics have been proposed as predictors of currency returns or risk, but we elect these as our main choices given the extensive evidence supporting their relevance.

To motivate our approach, we start by testing the performance of the optimal hedging method

[2]Possible justifications for this extra-market premium include exposure to crash risk (Brunnermeier, Nagel, & Pedersen, 2008), to innovations in volatility (Menkhoff, Sarno, Schmeling, & Schrimpf, 2012a), to the carry trade (Lustig, Roussanov, & Verdelhan, 2011), and an external imbalances factor (Corte, Riddiough, & Sarno, 2016). Either way safe haven currencies (or their opposite) do not earn returns in line with the predictions of the CAPM.

proposed by Campbell et al. (2010) for a U.S. investor holding an equal-weighted portfolio of equities in 11 developed markets, i.e. Australia, Canada, Denmark, Europe, Japan, New Zealand, Norway, Sweden, Switzerland, the United Kingdom and the United States. The data set spans from 1976 to 2016. Only the ten currencies of the developed markets are available for currency overlay positions[3]. We test their method in a realistic setting with plausible margin requirements, after transaction and rebalancing costs, and in an out-of-sample (OOS) period of 31 years.

We find the method is robust OOS, achieving significant reductions in risk in real time. This is in contrast with the usual results of OOS performance for optimized portfolios - however not atypical for parametric portfolio policy. Therefore, the equity sensitivity of each currency – the variable introduced by CMV – displays little evidence of major issues with estimation error. The reduction in risk comes at such a high cost that an investor with mean-variance utility still prefers to do without hedging. The CMV method reduces the OOS volatility by up to 8.94%, but it also reduces the average excess returns by 1.10%. The Sharpe ratio falls from 0.47 for an unhedged portfolio to 0.12 or less for the CMV portfolios. The optimal hedging of currency risk, in terms of risk minimization, effectively removes (almost entirely) the positive drift of holding equities.

Besides this dismal economic performance, the CMV portfolios also imply absolute cumulative currency positions that are more than twice the size of the equity portfolio. These positions consume capital, which must be pledged as collateral, and this further reduces the risk premium of the overall portfolio as a result. A naïve fully hedged portfolio performs better, with a Sharpe ratio of 0.33, but this does not solve the hedging problem. Its performance is still substantially below that achieved by an unhedged portfolio. As result, in our realistic setting, a U.S. investor holding a 100% domestic portfolio finds that none of these international portfolios (unhedged, fully-hedged or CMV-optimally-hedged) outperforms a purely domestic one. This lends support, in our setting, to the possibility that the benefits of international diversification are not necessarily evident to investors – an explanation for home bias proposed by Bekaert and Urias (1996).

In our parametric currency overlay, we keep the same realistic setting and add a restriction to the tracking error of the portfolio with respect to a benchmark. This restriction forces the optimization to achieve a solution that is not too different from a fully hedged portfolio. To the best of our knowledge, incorporating a benchmark risk restriction in the PPP method is a novel approach. This distinguishes our work from previous research into optimal combinations of currencies with stocks (Barroso & Santa-Clara, 2015; Kroencke, Schindler, & Schrimpf, 2013). As a result, our optimal portfolios are essentially a passive portfolio of international equities, combined with an active currency overlay. This currency overlay has

[3]In the robustness section we vary the investment and currency universe. However, the selected currencies are those from the corresponding investment universe.

as its first aim the achievement of a risk reduction such as that obtained by a full hedge. The optimization procedure has only limited freedom to reduce risk in the least costly manner it can find. Furthermore, our optimization approach allows considering margin requirements, and transaction and rebalancing costs. This means that the risk-return trade-off between equity and currency positions is implicitly incorporated in the analysis. Furthermore, a trade-off exists between first-order transaction and rebalancing costs when entering a currency position and expected returns. Both trade-offs are addressed in our currency overlay optimization process. Moreover, we incorporate a tracking error constraint, so that the currency overlay does not cause a large deviation from the designated benchmark.

By restricting benchmark risk to only 2% with respect to a fully hedged equity portfolio, the portfolios with optimized currency overlays achieve the same reduction in risk with higher returns. The optimal portfolios demonstrate statistically significant Jensen-$\alpha$s between 110 and 129 basis points (bps) with respect to the benchmark. Therefore, the PPP method systematically provides a less expensive way to hedge currency risk in a global equity portfolio. The size of the positions assumed in the currency market is also quite sensible. This contrasts with the aggressive currency positions of Campbell et al. (2010) or Barroso and Santa-Clara (2015)[4].

We combine currency value, momentum, and carry with other characteristics too – some specially related to risk. We examine the sign of the forward discount, equity sensitivity (of the CMV method), autocorrelation, skewness, volatility, and loading on FX-volatility risk. The equity sensitivity variable provides a direct test of the appeal of the CMV method for our mean-variance investor. We find this variable is not statistically significant in our optimizations. Therefore, despite their robustness in reducing risk, the equity sensitivity ratios of CMV are not interesting for our investor. We find similar results for skewness, volatility, and FX-volatility risk.

Okunev and White (2003) find that the success of a momentum strategy in currency markets is related to the autocorrelation. Motivated by this, we incorporate a newly proposed variable that interacts the autocorrelation of one currency with its previous month's return. It is equivalent to a trend-following trading strategy for currencies with positive autocorrelation and, simultaneously, contrarian for those with negative autocorrelation. We find this strategy is distinct from momentum and value, and demonstrates strong statistical significance that is robust to controlling for these two well-known effects. To the best of our knowledge this is a new variable and showing its relevance is an additional contribution of our paper.

Black (1989) derives universal hedge ratios that are not affected by the reference currency of each investor. To emulate this feature, we create global characteristics that are not dependent on the domicile of the investor. This is not a standard element of the PPP method and this

[4]Campbell et al. (2010) imply currency positions of up to 317% of the equity portfolio, while Barroso and Santa-Clara (2015) report an average position of 594%. Ours are in the range of 90.50% to 93.14%.

adaptation in our paper takes advantage of the flexibility of PPP in defining characteristics. Our method therefore produces universal hedge ratios.
We test the robustness of our method on the basis of subperiods, benchmark risk restriction, domicile of the investor, selection of benchmarks and margin requirements. Across all examined subperiods and investor domiciles we observe a significant increase in Sharpe ratio, and a significant positive Jensen-$\alpha$ and information ratio. We simulate a more aggressive investor and set the benchmark risk to 5%. The greater benchmark risk results in a larger currency exposure and an additional increase in Sharpe ratio and Jensen-$\alpha$, with the result that the unhedged, fully hedged, and purely domestic equity portfolios are outperformed. In an additional robustness test, we restrict the benchmark risk to only 2% with respect to an unhedged equity portfolio. The empirical investigation reveals robust outperformance the parametric currency overlay. Lastly, we examine the influence of different margin requirements, and set them between 0% and 15%. The result of this analysis shows that the significant outperformance of PPP currency overlay is not restricted by the choice of margin requirements.
The return of the currency overlay is divided into a hedging and a speculative component. The investigation in this decomposition reveals that the parametric currency overlay provide a significant positive speculative return.

Our paper is closely related to recent work demonstrating the benefits of investing in currencies that combine several characteristics and styles for diversified investors who hold equities (Barroso & Santa-Clara, 2015; Kroencke et al., 2013). However, the related work does not examine the issue of hedging currency risk. Other work incorporates estimated expected returns in the hedging problem (e.g. Glen and Jorion (1993)). Our approach is very different, using the PPP method, and simultaneously examining multiple possible determinants of risk and return for currencies that became known after previous findings.

The paper is organized as follows. Section 2 provides a brief overview of the related literature. Section 3 introduces the empirical framework used in our analysis, and the applied currency overlay strategies. Section 4 presents the empirical analysis. This section discusses the calculation of the currency characteristics, the considered data set, and the empirical analysis. Section 5 summarizes our findings.

## 2 Related Literature

An extensive literature documents that investors have a substantial home bias in their equity portfolios (see for example Levy and Sarnat (1970), Lewis (1999)). In an extended sample of 140 years, Rangvid, Santa-Clara, and Schmeling (2016) demonstrate that risk sharing in the international economy is at times quite low, and this has relevant utility costs. Our method provides investors willing to pursue the benefits of international diversification with an effective method to manage currency risk in their portfolios.

From a risk-management perspective, currency positions are used to reduce volatility. If an investor wants to capture the entire currency risk, then his portfolio is unhedged, and the foreign currency exposure equals the equity holdings. Conversely, if the investor has a net-zero position in foreign currency, then the foreign exchange risk is neutralized and the portfolio is fully hedged. Solnik (1974) demonstrates that a neutralization of currency risk is only optimal if equity and currency returns are uncorrelated. If equity and currency returns are correlated, then a deviation from the entire neutralization of currency risk can lead to less risk. Campbell et al. (2010) illustrate that currency positions equal to the negative sensitivity of equity and currency cause a significant smaller portfolio volatility than a fully hedged portfolio.

De Roon et al. (2012) demonstrate that currency hedging leads to a larger reduction in portfolio return than in volatility. Currency hedging is therefore not a free lunch, as Sharpe ratios decline. Furthermore, currency hedging also increases the portfolio's skewness and kurtosis, which indicates a larger tail risk. Glen and Jorion (1993) find that an optimized hedging strategy does not improve the mean-variance efficiency of a passive portfolio of equities. Rather, they propose using the predictability in currency returns to create a conditional hedging strategy using interest rate differentials (i.e. a carry trade). Our method builds on this insight, using other variables with predictive power for expected returns and / or risk to design an optimal conditional currency overlay. Studying a combination of variables, instead of carry alone – as Glen and Jorion (1993) do – increases the problem of estimation error. This is an issue we address using the ability of PPP to reduce the dimensionality in the estimation procedure.

Opie and Dark (2015) demonstrate that the benefits of hedging are sensitive to the reference currency of the investor. We test the robustness of our approach and find similar benefits, irrespective of the domicile of the investor. Black (1989) proposes a method where the exposure of optimal currency hedging is independent of the investor's reference currency. This means that an investor independent of his domicile profits from the same currency exposure.

The carry trade strategy is closely related to the forward premium puzzle (Engel, 1996; Fama, 1984), which states that, on average, high-yielding currencies do not experience depreciations large enough to offset their higher interest rates. As a result, a strategy that buys high-yielding currencies (and sells low-yielding ones) achieves positive returns that constitute a violation of uncovered interest parity (Bakshi & Panayotov, 2013; Burnside, Eichenbaum, Kleshchelski, & Rebelo, 2010). Possible explanations for the profitability of the strategy include exposure to rare disasters and peso problems (Burnside et al., 2010; Farhi & Gabaix, 2015), consumption risk (Lustig & Verdelhan, 2007), crashes and liquidity spirals (Brunnermeier et al., 2008) or global FX volatility risk (Menkhoff et al., 2012b). In our setting we simultaneously test a carry related variable, the implied interest rate, and the loading on FX volatility risk, and find the latter is not relevant. One should mention two caveats when interpreting this result. First, the PPP is not an asset pricing test. A characteristic can be found relevant even if it does not predict expected returns in the cross section (it can predict co-skewness, for example). Conversely, a characteristic that predicts returns can still be irrelevant to form portfolios if it simultaneously captures contributions to the overall risk of the portfolio. Second, Menkhoff et al. (2012b) shed light on the important question of why the carry trade is priced in the first place. Our analysis does not address this question directly. It simply demonstrates that an investor provided with information on both variables simultaneously, only finds relevance in carry to form the currency overlay.

Our approach to determine a currency overlay strategy employs the method introduced by Brandt et al. (2009). This procedure does not estimate any moments, with the result that the estimation risk is reduced. Brandt et al. (2009) empirically implement a U.S. equity portfolio with equity characteristics, and are able to double the Sharpe ratio in an out-of-sample framework. Barroso and Santa-Clara (2015) apply this optimization approach for currency portfolios, and find a significant enhancement in the risk-return profile.
To apply the parametric portfolio policy we define currency characteristics to derive the currency overlay. Besides characteristics related to expected returns, we seek to incorporate risk explicitly in the optimization. We examine volatility, skewness, and sensitivity to equity markets and to innovations in foreign exchange volatility. The last two characteristics are used by Ranaldo and Söderlind (2010) as defining elements of safe haven currencies. Skewness is potentially relevant for optimization, because it is a direct measure of crash risk for currencies. Moreover, the relevance of skewness for asset returns in equities is established in the literature (Conrad, Dittmar, & Ghysels, 2013; Harvey & Siddique, 2000). This motivates testing the relevance of realized skewness in currencies. We do not find relevance for this variable in our optimizations. One possible explanation is that realized skewness may be a poor proxy for ex-ante expected skewness.

# 3 Currency Overlay

We follow Campbell et al. (2010) for the basic return calculation, and assume a global equity investor with an investment universe consisting of $n$ foreign currencies, one domestic and $n$ foreign equity markets. We define that $F_{c,t}$ and $S_{c,t}$ equal the forward and spot FX rates in units of reference currency per unit of foreign currency $c$ at time $t$, respectively. By convention, we assume that $c = 1$ denotes the reference currency, such that $c = 2, ...n + 1$ represents the foreign currencies. We define the domestic forward and spot rate as constant over time and equal to one.

### 3.1 Global equity return

The portfolio return of a global equity investor ($R_{p,t+1}$) consists of the equity and foreign exchange (FX) return, where the FX return corresponds to the currency overlay strategy $\boldsymbol{\Theta}_t$, i.e.

$$R_{p,t+1} = \boldsymbol{\omega}_t' \boldsymbol{R}_{t+1}^{E} (\boldsymbol{S}_{t+1} \div \boldsymbol{S}_t) + \boldsymbol{\Theta}_t' \boldsymbol{R}_{t+1}^{FX}, \tag{1}$$

such that $\boldsymbol{R}_{t+1}^{E}$ equals a $(n+1 \times 1)$-vector of gross equity return measured in the local currency. $\boldsymbol{R}_{t+1}^{FX}$ denotes a vector of FX overlay return defined as

$$\boldsymbol{R}_{t+1}^{FX} = (\boldsymbol{F}_t - \boldsymbol{S}_{t+1}) \div \boldsymbol{S}_t, \tag{2}$$

where $\div$ is an element operator and $\boldsymbol{F}_t$ and $\boldsymbol{S}_t$ capture a $(n+1 \times 1)$-vector of one-period forward and FX spot rates at time $t$, respectively. $\boldsymbol{\omega}_t = \{\omega_{c,t}\}_c$ and $\boldsymbol{\Theta}_t = \{\theta_{c,t}\}_c$ are $(n+1 \times 1)$-weight vectors, which denote the equity weights and the currency overlay at time $t$.
The foreign currency exposure of the equity portfolio is fully hedged, if the currency overlay equals the global equity weights $\boldsymbol{\omega}_t$, i.e. $\boldsymbol{\Theta}_t = \boldsymbol{\omega}_t \forall t$. By contrast, an unhedged foreign currency exposure, where the investor consumes the whole FX risk, corresponds to

$$\theta_{c,t} = \begin{cases} 1 & \text{if } c = 1 \\ = 0 & \text{if } c = 2, ..., n+1 \end{cases},$$

Campbell et al. (2010) employ currencies to minimize the portfolio's volatility. The differences between $\boldsymbol{\omega}$ and $\boldsymbol{\Theta}$ correspond to a deviation from the full hedge. To change the view from a weight perspective towards a currency exposure, we define $\boldsymbol{\Psi}_t = \boldsymbol{\omega}_t - \boldsymbol{\Theta}_t$, such that the portfolio return equals

$$R_{p,t+1} = \boldsymbol{\omega}_t' \boldsymbol{R}_{t+1}^{E} (\boldsymbol{S}_{t+1} \div \boldsymbol{S}_t) + \boldsymbol{\omega}_t \boldsymbol{R}_{t+1}^{FX} - \boldsymbol{\Psi}_t \boldsymbol{R}_{t+1}^{FX}. \tag{3}$$

To determine the currency exposure $\boldsymbol{\Psi}_t$, such that the portfolio return $R_{t+1}^{h,PF}$ has a minimal risk, Campbell et al. (2010) rewrite Equation (3) with log return and regress

$$\boldsymbol{\omega}_t' (\boldsymbol{r}_{t+1}^{e} - \boldsymbol{i}_t) = \alpha + \tilde{\boldsymbol{\Psi}}_t' (\Delta \tilde{\boldsymbol{s}}_{t+1} + \tilde{\boldsymbol{i}}_t - \tilde{\boldsymbol{i}}_t^1) + \epsilon, \tag{4}$$

where $\tilde{\boldsymbol{\Psi}}_t = (\tilde{\Psi}_{2,t}, ..., \tilde{\Psi}_{n+1,t})'$, $\boldsymbol{r}_{t+1}^{e} = log(\boldsymbol{R}_{t+1}^{E})$, $\Delta \boldsymbol{s}_{t+1} = log(\boldsymbol{S}_{t+1}) - log(\boldsymbol{S}_t)$, $\boldsymbol{i}_t = log(1+\boldsymbol{I}_t)$, $\boldsymbol{i}_t^1 = log(1 + I_{1,t}) \mathbb{1}_{n+1\times 1}$, $\mathbb{1}_{n+1\times 1}$ is an unit vector of length $n + 1$, and $\boldsymbol{I}_t = (I_{1,t}, ..., I_{n+1,t})$ denotes the vector of implied interest rates at which the investor can borrow and lend[5].

[5] All variables marked with $\tilde{}$ neglect the reference currency.

By definition, the domestic currency exposure is the negative cumulative sum of all foreign currency exposures, i.e. $\Psi_{1,t} = -\sum_{c=2}^{n+1} \Psi_{c,t}$. The currency overlay computed with Regression (4) corresponds to CMV Optimal (CMV Opt) and switches the sign of $\boldsymbol{\Psi}_t$.
The limitation of this method is that it reduces the portfolio's volatility in an in-sample environment, and has a forward-looking bias. We expand this method in two ways to an out-of-sample application and only historical data is employed to determine $\boldsymbol{\Psi}_t$.
First, we estimate $\boldsymbol{\Psi}_t$ on a rolling window of length $l$[6] (henceforth called CMV RW). Second, we adopt a time-expanding window with initial length $l$ (henceforth CMV TE). For each time step $t$, we determine $\boldsymbol{\Psi}_t$ by Regression (4) based on the introduced historical observation windows. Both currency overlays $\boldsymbol{\Psi}_t$ are applied between $t$ and $t+1$. It is expected, that CMV TE and CMV Opt have a similar impact on the global equity portfolio, as the currency overlay of CMV TE converts towards CMV Opt. Generally, the economic interpretation of CMV Opt, CMV RW and CMV TE is that equity has a certain sensitivity to currencies, which is captured by $\boldsymbol{\Psi}_t$. By taking the negative of $\boldsymbol{\Psi}_t$, the FX sensitivity of equity is entirely neutralized. The currency exposure is therefore estimated from sample data. Consequently, this method faces estimation issues, with the result that the true currency exposure is not observable.

### 3.2 Parametric currency overlay

We now introduce a novel approach to design the currency overlay. The currency overlay strategy determines its time-varying currency exposure with a proxy for currency expected return and risk. As characteristics, we use momentum and forward discounts, for example. This parametric currency overlay defines the currency exposure $\boldsymbol{\Psi}_t$ as a function of the currency characteristics. The advantage of this approach is that the currency overlay depends only on the currency characteristic and does not require any explicit estimation of expected returns from the sample. The currency exposure follows an optimization process introduced by Brandt et al. (2009), and is defined as a linear function, i.e.

$$f(\kappa_{c,t}; \eta) = \frac{\eta \kappa_{c,t}}{n+1}, \tag{5}$$

where $\kappa_{c,t}$ denotes the characteristic of currency $c = 1, ..., n+1$ at time $t$. $\eta \in \mathbb{R}$ equals the coefficient on the sensitivity of the characteristic. The coefficients on the characteristics are constant over the sample period and considered currencies, allowing their estimation from the data. The log portfolio return equals

$$r^h_{p,t+1} = \boldsymbol{\omega}_t(\boldsymbol{r}^e_{t+1} + \boldsymbol{i}^1_t - \boldsymbol{i}_t) + f(\boldsymbol{\kappa}_t; \eta)'(\Delta \boldsymbol{s}_{t+1} + \boldsymbol{i}_t - \boldsymbol{i}^1_t), \tag{6}$$

[6] As we later set the initial window for our parametric currency overlay to 120 months, we define $l$ equal to 120.

which is an approximation for $\log(R^h_{p,t+1})$. As the optimization method of parametric portfolio policies maximizes the utility of the portfolio return after the sensitivity of the characteristic, $\eta$ is determined as:

$$\begin{aligned}\hat{\eta} &= \arg\max_{\eta} \frac{1}{t+1}\sum_{\tau=0}^{t} U\Big(r^h_{p,\tau+1}\Big) \\ &= \arg\max_{\eta} \frac{1}{t+1}\sum_{\tau=0}^{t} U\Big(\boldsymbol{\omega}_\tau(\boldsymbol{r}^e_{\tau+1} + \boldsymbol{i}^1_\tau - \boldsymbol{i}_\tau) + f(\boldsymbol{\kappa}_\tau;\eta)'(\Delta\boldsymbol{s}_{\tau+1} + \boldsymbol{i}_\tau - \boldsymbol{i}^1_\tau)\Big) \qquad (7)\end{aligned}$$

where $U(\cdot)$ is a quadratic utility function, i.e.

$$U(x) = x - \frac{\lambda}{2}x^2. \qquad (8)$$

The $(n+1)\times 1$-vector $\boldsymbol{\kappa}_t$ denotes the characteristics. It is important to mention that the applied optimization process maximizes the portfolio's utility. The approach does not necessarily minimize the distance between realized and forecasted returns. Even if the currency characteristic has no insight with regard to the future return, it could enhance the portfolio's risk-return profile, because it may reduce extreme events and / or reduce its volatility. Conversely, a characteristic that does predict returns can still be irrelevant in the optimization if it offers an unappealing risk-return trade-off.

Our optimization approach is able to handle transaction costs, which can also vary across time and currency pair. To incorporate transaction costs (TC), we define these costs for currency $c$ at time $t$ as the bid-ask-spread:

$$TC_{c,t} = \log\Big(\frac{F^{ask}_{c,t,t+1} - F^{bid}_{c,t,t+1}}{F^{mid}_{c,t,t+1}}\Big),$$

where the indices $ask, bid$ and $mid$ correspond to ask, bid and mid rates, respectively. The assumption is that the investor buys (sells) the forward contract at the ask (bid) rate. The optimization process with transaction costs equals

$$\hat{\eta} = \arg\max_{\eta} \frac{1}{t+1}\sum_{\tau=0}^{t} U\Big(\boldsymbol{\omega}_\tau(\boldsymbol{r}_{\tau+1} + \boldsymbol{i}^1_\tau - \boldsymbol{i}_\tau) + f(\boldsymbol{\kappa}_\tau;\eta)'(\Delta\boldsymbol{s}_{\tau+1} + \boldsymbol{i}_\tau - \boldsymbol{i}^1_\tau) - |\omega_\tau - f(\boldsymbol{\kappa}_\tau;\eta)|'\boldsymbol{TC}_\tau\Big), \qquad (9)$$

where the transaction costs are proportional to the currency positions[7], and $\boldsymbol{TC}_t$ equals a $(n+1\times 1$-vector, which chapters currency transaction costs. The implementation implies that transaction costs are proportional to the absolute currency exposure.

Besides trading costs, entering a forward contract also requires a certain margin. Campbell

[7]As $f(\boldsymbol{\kappa}_\tau;\eta)$ defines the derivation from the full hedge, $\omega_\tau - f(\boldsymbol{\kappa}_\tau;\eta)$ equals the currency overlay strategy $\boldsymbol{\Theta}_t$. Thus,, transaction costs accrue for the entire currency overlay.

et al. (2010) assume implicitly that the margin requirements for forward contracts is zero. As market standards for institutional investors require margins of between 5% and 15% for liquid currencies, the investor faces an additional trade-off. He needs to decide whether an investment in currencies or equity offers a larger utility. We follow industry standard and reserve the margin requirements equivalent to the foreign currency overlay exposure in cash. In order to address the corresponding circularity problem between the margin requirement and the equity investment, we redefine the portfolio weight $\boldsymbol{\omega}_t$ as $\boldsymbol{\Omega}_t = \{\Omega_{c,t}\}_c$, and equals:

$$\Omega_{c,t} = (1 - \rho \sum_{i=2}^{n+1} |\omega_{i,t} - f(\kappa_{i,t}; \eta)|)\omega_{c,t}, \forall c \tag{10}$$

Then, the optimization equals:

$$\hat{\eta} = \arg\max_{\eta} \frac{1}{t+1} \sum_{\tau=0}^{t} U\Big(\boldsymbol{\Omega}_\tau(\boldsymbol{r}_{\tau+1} + \boldsymbol{i}_\tau^1 - \boldsymbol{i}_\tau) + f(\boldsymbol{\kappa}_\tau; \eta)(\Delta \boldsymbol{s}_{\tau+1} + \boldsymbol{i}_\tau - \boldsymbol{i}_\tau^1) - |\boldsymbol{\Omega}_\tau - f(\boldsymbol{\kappa}_\tau; \eta)| \boldsymbol{TC}_\tau\Big), \tag{11}$$

where $\rho \in [0, 1]$ denotes the margin requirement.

Furthermore, the currency overlay has a direct impact on the equity portfolio, due to the trade-off that exists between the volume of currency overlay and equity investment. This trade-off is caused by margin requirements of forward contracts. Therefore, the equity positions have to be rebalanced. We assume constant rebalancing costs equal to $\zeta$. The portfolio's rebalancing costs at time $t$ equal:

$$RBC_t = \sum_{i=1}^{n+1} |\Omega_{i,t} - \Omega_{i,t}^{hold}|\zeta, \tag{12}$$

and $\Omega_{i,t}^{hold}$ is the previous period portfolio weight adjusted by margins, and the equity return between $t - 1$ and $t$, i.e.

$$\Omega_{i,t}^{hold} = \Omega_{i,t-1} \cdot \exp(r_{i,t} - r_{p,t}), \tag{13}$$

where $r_{i,t}$ ($r_{p,t}$) is the return of asset $i$ (the portfolio return). Thus, the final optimization equals

$$\begin{aligned} \hat{\eta} = \arg\max_{\eta} \frac{1}{t+1} \sum_{\tau=0}^{t} U\Big( \quad & \boldsymbol{\Omega}_\tau(\boldsymbol{r}_{\tau+1} + \boldsymbol{i}_\tau^1 - \boldsymbol{i}_\tau) + f(\boldsymbol{\kappa}_\tau; \eta)(\Delta \boldsymbol{s}_{\tau+1} + \boldsymbol{i}_\tau - \boldsymbol{i}_\tau^1) \\ & - |\boldsymbol{\Omega}_\tau - f(\boldsymbol{\kappa}_\tau; \eta)| \boldsymbol{TC}_\tau - RBC_t\Big), \end{aligned} \tag{14}$$

Theoretically, the optimization process of Equation (14) can suggest to allocate the entire capital to currency exposure, such that no equities are purchased. The results in Barroso and Santa-Clara (2015) and Kroencke et al. (2013) illustrate that the unconstrained optimal currency overlay has an absolute exposure multiple times larger than the value of the underlying portfolio. The unconstrained currency overlay therefore dominates the risk-return profile of the underlying portfolio. In our setting, this violates the basic idea of the currency overlay. Therefore, we introduce a tracking error constraint following Jorion (2003). We define the tracking error constraint as

$$\sigma(r^b_{p,t+1} - r_{p,t+1}(\hat{\eta})) \leq \mathcal{C},$$

where $r^b_{p,t+1}$ and $r_{p,t+1}(\hat{\eta})$ are the return of the designated benchmark portfolio and optimized portfolio, respectively. $\mathcal{C}$ is the threshold of maximal deviation from the benchmark portfolio.

### 3.3 Currency characteristics

We now turn to the definition of currency characteristics. Black (1989) and Campbell et al. (2010) derive currency exposures that are independent from the reference currency, and each investor holds an identical currency portfolio. We adapt the method of Brandt et al. (2009) to obtain a currency overlay that is also independent of the reference currency. To the best of our knowledge, we are the first to design global currency characteristics for parametric currency overlay in a two-step process. First, the characteristics are calculated for each possible currency pair. Second, characteristics at the currency pair level are merged to global characteristics for each currency.

The first two currency characteristics are based on the forward discount, i.e.

- $fd_{qc,bc,t}$ is the forward discount between quoted ($qc$) and base ($bc$) currency at time $t$.
- $sign_{qc,bc,t}$ is the sign of the forward discount at time $t$ between the quoted and base currency. If the foreign currency is at a discount, i.e. $F > S$, then the sign equals 1. If the forward is traded at a premium, the sign is -1.

The motivation for these two variables is that the forward discount is frequently used as a predictor for currency returns (see for example Fama (1976) and Wolff (1987)). Furthermore, the carry trade strategy purchases (sells) currencies with high (low) forward discounts. The extensive literature on carry trade documents its profitability. Using characteristics such as forward discount, or its sign, implies that a carry trade is incorporated in the currency overlay. Next, we define currency characteristics that capture historical return properties. The return characteristics are as follows:

- $mom_{qc,bc,t}$ is the cumulative currency return over the previous three months at time $t$ between the quoted and base currency. This variable investigates the persistence of currency returns in the short term. There is evidence that a three-month momentum provides persistence at the portfolio level especially for this period. Menkhoff et al. (2012a) demonstrate that a momentum with a longer time horizon offers no additional gain.

- $rev_{qc,bc,t}$ is the long-term reversal. It quantifies the cumulative real currency depreciation between quoted and base currency. This measure is comparable with the currency value in Asness et al. (2013). The currency deprecation over the past five years is defined as:

$$rev_{qc,bc,t} = \frac{S_{qc,bc,t} CPI_{qc,t-60} CPI_{bc,t}}{S_{qc,bc,t-60} CPI_{qc,t} CPI_{bc,t-60}},$$

  where $CPI_{qc,t}$ ($CPI_{bc,t}$) is the consumer price index at time $t$ associated with the quoted (base) currency. A positive value of $rev_{qc,bc,t}$ implies that the quoted currency has a larger real depreciation against the base currency over the past five years and vice versa, if $rev_{qc,bc,t-60,t}$ is negative.

- $AC_{qc,bc,t}$ denotes the first lag of the autocorrelation function, estimated on the previous 24-month spot returns, and multiplied by the last realized return of a currency at time $t$. This is a newly proposed currency characteristic in our study. For example, a positive coefficient in this characteristic suggests the investor should buy currencies with positive (negative) previous return and with positive (negative) autocorrelation in the past 24 months. It essentially conditions trend-following on evidence of return persistence for a currency. Hence, Okunev and White (2003) state that the success of a currency momentum strategy depends on autocorrelation. That is why we estimate the first lag of autocorrelation on a medium-term period.

Lastly, we introduce characteristics that capture risk properties of currencies. De Santis and Gerard (1998) demonstrate that currency risk is important for equity portfolios. Therefore, the following risk measures aim to quantify currency risk, and thus enhance the currency overlay. The risk characteristics are as follows:

- $\mathcal{S}_{qc,bc,t}$ is the currency sensitivity with respect to the excess equity return, measured in local currency. The sensitivity is calculated following Campbell et al. (2010), by regressing the excess equity return $\mathbb{1}'_{n+1\times1}\boldsymbol{\omega_t}(\boldsymbol{r}_{t+1} - \boldsymbol{i}_t)$ on a constant and the excess currency return $\Delta \boldsymbol{s}_{qc,bc,t+1} + \boldsymbol{i}_{qc,t} - \boldsymbol{i}_{bc,t}$. The main difference between our approach and that of Campbell et al. (2010) is that we run this regression on daily spot returns on a rolling window of 60 months. We follow Dimson (1979), and incorporate two lags of the equity sensitivity into the regression.

- $\sigma_{qc,bc,t}$ equals the FX volatility at time $t$, introduced by Menkhoff et al. (2012a) and defined as:

$$\sigma_{qc,bc,t} = \frac{1}{T_t} \sum_{\tau \in T_t} |r_\tau^{qc,bc}|,$$

  where $r_\tau^{qc,bc}$ is the daily log return at time $\tau$ and $T_t$ equals the number of trading days in month $t$. The measure $\sigma_{qc,bc,t}$ is a proxy for the realized volatility (Andersen, Bollerslev, Diebold, & Labys, 2001).

- $\beta_{\sigma_{qc,bc,t}}$ is the loading of volatility innovation. We follow Menkhoff et al. (2012a) and regress:
$$r_t^{qc,bc} = \alpha - \beta_{DOL} DOL_{bc,t} - \beta_{\sigma_{qc,bc,t}} \Delta\sigma_t^{FX} + \epsilon_t.$$
$\sigma_t^{FX} = \frac{1}{n(n-1)} \sum_{qc,bc \in C_t} \sigma_{qc,bc,t}$. $C_t$ and $n$ denote the set and number of available currencies at time $t$. Lustig et al. (2011) introduce a dollar factor, which is the cumulative return of all foreign currencies measured in U.S. dollars. The factor $DOL_{bc,t}$ is the dollar factor with respect to the base currency $bc$. This regression is calculated on a 60-month rolling window. Menkhoff et al. (2012a) demonstrate that the loading on the innovation in FX volatility is priced in the cross section of currencies, and this partially explains the carry premium. Furthermore, we follow Dimson (1979) and incorporate into the regression two lags of the dollar and innovation in volatility factor.

- $skew_{qc,bc,t}$ is the skewness of the spot return. This variable captures the skewness of each month based on daily observations. This variable measures the crash risk of currencies.

We now convert the currency characteristics on FX pair level into global characteristics. We follow Black (1989) and average across investors. The global currency characteristic of each currency $c$ is therefore the mean of the currency characteristic quoted against currency $bc$, i.e.

$$\kappa_{c,t}^{global} = \frac{1}{n} \sum_{bc=2}^{n+1} \kappa_{bc,c,t}, \tag{15}$$

Finally, the global characteristics are cross-sectionally standardized, so that the parametric currency overlay is a zero investment strategy, i.e $\sum_c \kappa_{c,t}^{global} = 0 \forall t$.

# 4 Empirical Analysis

Our empirical analysis is based on a global equity investor holding an equally weighted portfolio of developed economies. We follow Lustig et al. (2011) and define developed economies as Australia, Canada, Denmark, Europe, Japan, New Zealand, Norway, Sweden, Switzerland, the United Kingdom (UK) and the United States (USA). Each economy is represented by the corresponding index of Morgan Stanley Capital International. We assume that the global equity investor has a currency risk against the following currencies: Australian dollar, British pound, Canadian dollar, Danish krona, Euro, Japanese Yen, New Zealand dollar, Norwegian krona, Swiss franc, Swedish krona and U.S. dollar[8]. All exchange rate data is downloaded from Thomson Reuters DataStream. The frequency of the data sample is monthly, and spans the period from January 1976 to December 2016. Following Burnside et al. (2010), we use

[8]We follow the weighting scheme of the Bank of England (2015) to design an artificial Euro rate before 2000. In a robustness test we vary the currency and equity universe to demonstrate that the results are not driven by a certain selection of equity and currencies.

forward rates quoted against USD and GBP, and merge them to obtain the longest samples. We follow Campbell et al. (2010), and use Europe as a proxy for the European monetary union. This implies a look-ahead bias, as in 1976 there was only a small indication of this eventual union. However, from the perspective of a present-day investor, it makes sense to assume such a look-ahead bias, and to regard the European monetary union as one market.

Table 1 reflects the implied interest rates and excess equity returns between 1976 and 2016. The annual implied interest rates vary across the selected countries. Switzerland and Japan have the lowest interest rates of ≈2%, while New Zealand and Norway are regarded as high-yield countries with interest rate levels of approximately ≈7%. The excess equity returns are primarily in the range of 5% to 10%, with a standard deviation of 15% to 24%[9].

## 4.1 Alternative hedging methods

In the following we assume a U.S. investor – the reference currency is therefore the U.S. dollar[10], and margin requirements for forward contracts are 15%. Table 2 sets out the summary statistics of the international equity portfolio, following classical currency overlay strategies[11]. We assume constant rebalancing costs equal to 50bps. The overlay strategy 'unhedged' ('full hedge') bears (entirely neutralizes) the currency risk. Due to the construction of an equally weighted equity portfolio, the investor holds $\frac{10}{11}$ in foreign equity. To implement a full hedge, he purchases a volume of $\frac{10}{11}$ for forward contracts. As margin requirements of 15% are assumed, the investor purchases only a cumulative volume relative to the underlying portfolio of 77.27% ( $= \frac{10}{11} \cdot$ (1-0.15)). Therefore, 13.63% is held in cash to back the currency overlay, and the cumulative non-domestic exposure equals 90.90% ($= \frac{10}{11} =$ 77.27% + 13.63%). The unhedged and fully hedged strategies have a significant impact on the first two momenta. The fully hedged strategy leads to a significant reduction in the excess return and standard deviation. The annual excess return and standard deviation of the fully hedged (unhedged) portfolio equal 3.97% (7.61%) and 12.00% (16.33%), respectively. The neutralization of the currency risk leads to a larger tail risk measured by skewness and kurtosis. This observation is consistent with De Roon et al. (2012). For subsequent comparisons, we adopt the fully hedged portfolio as the benchmark.

We also examine the universal hedging approach introduced by Black (1989). The universal hedging identifies a hedging ratio for each currency, which is applicable independent of the reference currency. The hedge ratio quantifies relatively to the currency exposure the amount of required forward contracts. The empirical results demonstrate that the universal hedging is

[9]New Zealand has an excess return of -0.64%. This is due to the fact that the MSCI Standard Index of New Zealand is heavily concentrated in a few stocks.

[10]In section 4.3.3 we examine the case for investors domiciled in different economies.

[11]The internet appendix indicates the same summary statistics for other domiciled investors.

able to increase the excess return to 4.54% in a statistically significant manner. However, the increase in Sharpe ratio to 0.36 is not significant. The last three columns of Table 2 indicate the impact of the currency overlay strategy following Campbell et al. (2010) (CMV), and their expansions (CMV RW, CMV TE). We set the initial and rolling window of CMV RW and CMV TE to a length of 60 months. The idea of the CMV method is to use currencies to minimize the volatility of the international equity portfolio. The average weights allocated to each currency are set out in the internet appendix. It is primarily the Australian dollar, British pound and Canadian dollar that are sold, while Danish krona, Euro, Japanese Yen, Swiss franc and U.S. dollar are purchased.

We find the CMV method recommends extremely large currency positions that are not feasible once margin requirements are taken into account. To study implementable versions of the CMV method, we rescale the currency positions in such a way that the margin requirements are compatible with equity holdings. For example, in the column CMV, the investor holds 17.53% (=166.84·0.15) in cash, as collateral for the currency positions, and the remaining 82.47% in the equity portfolio. We find the CMV approach results in a significant reduction in excess return and standard deviation, of approximately 2.90 percentage points (pp) and 3.00pp, respectively. The reduction in volatility is not sufficient to improve the Sharpe ratios. In fact, the CMV approaches have a maximum Sharpe ratio of 0.12, which is significantly smaller than the benchmark portfolio. The empirical results reveal that the CMV method is able to reduce a portfolio's volatility under margin requirements, and this reduction is robust to OOS estimation uncertainty. However, this decline in risk comes at an expensive price, and the method does not appeal to investors who care about both return and risk. It is clear that the certainty equivalents are much smaller for the three CMV methods than those of the unhedged and fully hedged portfolio.

In comparison to the CMV method, the parametric portfolio policy (PPP) approach, introduced by Equation (14), provides several advantages, which are not addressed by CMV. The PPP currency overlay is able to optimize several trade-offs simultaneously. First, there is a trade-off between volume of currency overlay and investment in risky assets, due to margin requirements. Second, the currency position must provide a higher return than the first-order transaction costs. These two trade-offs are directly implemented in Equation (14). Third, the currency overlay should not dominate the entire portfolio, i.e. the volume of the currency overlay, and hence, the corresponding reserved margin, should have a minor quantity. The last trade-off is considered indirectly, as the currency overlay should cause a maximal tracking error of 2% annually.

## 4.2 Parametric currency overlay

We follow Brandt et al. (2009) and Barroso and Santa-Clara (2015), and set the length of the initial window at 120 months. The observation period is therefore between January 1986 and December 2016. All out-of-sample statistics are constructed in the following way. Suppose the parametric currency overlay should be defined at time $t$ for the trading period from $t$ to $t+1$. Then, the optimization of Formula (14) is applied on the historical window between January 1976 and time $t$. The optimization estimates $\hat{\eta}$, which captures the loadings of each characteristic. The characteristics observed at time $t$ are weighted linearly with $\hat{\eta}$, as defined in Formula (5). The result of this calculation is the currency overlay between $t$ and $t+1$. Table 3 sets out the summary statistics and the factor loadings of the international equity portfolio, following a PPP currency overlay strategy. The portfolio performance figures in Table 3 are adjusted for transaction and rebalancing costs.

The first column of Table 3 (Panel A) depicts the portfolio performance of the equally weighted, fully hedged portfolio[12]. The benchmark portfolio has an annual return of 3.97%, with a standard deviation of 12.00%. The Sharpe ratio equals 0.33. The second column illustrates our PPP base currency overlay, in which the deviation from the fully hedged strategy uses the momentum (mom), forward discount (fd) and long-term reversal (rev) characteristics. These are the characteristics used in Barroso and Santa-Clara (2015), and rely on extensive evidence of the carry, value, and momentum as predictors of currency returns (see e.g. Lustig and Verdelhan (2007), Menkhoff et al. (2016)). The PPP base currency overlay achieves a statistically significant increase in the annual excess return to 5.24%, which is 1.3pp higher than the fully hedged strategy. However, the standard deviation is at 12.29%, which is almost identical to the fully hedged portfolio. The Sharpe ratio therefore rises by 0.10 to 0.43[13]. The information ratio equals 0.65, and the Jensen-$\alpha$ is 1.23% with respect to the fully hedged portfolio. Both quantities are highly significant[14]. Additionally, the certainty equivalent[15] increases from 3.43 to 4.50. This is higher than the certainty equivalent achieved by the fully hedged benchmark or the unhedged portfolio. All discussed measures demonstrate that the PPP base currency overlay results in a significant improvement in the risk-return profile and an additional excess return, exceeding white noise. The currency overlay has an average position in currencies of 91.81%. This is much more reasonable than the more than 166.84% for the CMV methods examined. The investor therefore needs to reserve only 13.77%[16] of his capital as margin for

[12] The chapter appendix includes portfolio performances for other domiciled investors.

[13] The test for differences in Sharpe ratio is the bootstrap method, introduced by Ledoit and Wolf (2008). The applied bootstrap method examines two time series for differences in Sharpe ratio. It provides a robust estimate under autocorrelation, heteroscedasticity and heavy tails.

[14] To determine the p-Value of the information ratio, we apply the bootstrap method and count the frequency of a negative information ratio. For the Jenson-$\alpha$, we follow White (1980) to adjust the standard errors.

[15] The certainty equivalent is defined via a power utility function with CRRA of 5 as in Barroso and Santa-Clara (2015).

[16] The required margin is calculated as volume of currency overlay times margin requirements.

currency positions – a value close to the requirement of the fully hedged strategy (13.63%).
Panel B of Table 3 shows the loading of each currency characteristic. Momentum, forward discount and long-term reversal have loadings of 0.27, 0.43 and 0.20, respectively. All loadings are statistically significant[17]. The significance of all characteristics means that each characteristic provides a significant improvement in the currency overlay. The positive loading of the momentum characteristic implies that currencies with a high (low) momentum are purchased (sold), i.e. a classical momentum strategy. The characteristic forward discount is also positively loaded, and high (low)-yield currencies are bought (sold), i.e. a typical carry trade strategy. Lastly, the loading of the long-term reversal means that currencies with the largest (smallest) real depreciation are purchased (sold), i.e. a standard value strategy.

The three characteristics of the PPP base currency overlay build on the basic properties of currencies. Next, we examine whether an additional fourth currency characteristic is able to provide any improvement. This fourth characteristic denotes risk or propensity for trend-following.

As a first characteristic, we add the sign of the forward discount to the PPP base currency overlay. These four characteristics create a smaller annual excess return than the PPP base currency overlay. Moreover, the characteristic forward discount loses its statistical significance. In this combination, the forward discount and its sign have a loading of 0.00 and 0.45, respectively. These two variables have a similar economical interpretation, and are highly correlated. The PPP base currency overlay with the sign has a smaller excess return, information ratio and Jensen-$\alpha$. In this case, it seems that the multicollinearity has a negative effect on the currency overlay.

Next, we add the sensitivity of equity returns ($\mathcal{S}_{FX}$) as another variable to the PPP base currency overlay. The positive slope (0.02) of $\mathcal{S}_{FX}$ leads to a contrary interpretation, as Campbell et al. (2010) suggest, i.e. an increase in risk consumption. As this characteristic has a p-Value of 0.42, it indicates that this measure does not contribute to an enhanced risk-return profile. This observation is in line with the empirical results of Table 2, i.e. the sensitivity of equity returns does not provide an enhancement of risk-return profile under margin requirements, transactions, and rebalancing costs. Hence, the risk-return profile is similar to the PPP base currency overlay. This provides direct evidence that $\mathcal{S}_{FX}$, the only variable used in the CMV method, is not relevant to our investor who cares about the overall risk-return trade-off.

We find that autocorrelation (AC) – our newly proposed characteristic – has a positive loading of 0.23. The characteristic is highly significant. This is the most significant improvement on the base PPP of all characteristics examined. The result suggests that trend-following is particularly interesting in currencies with recent evidence of persistence in returns. The statistical significance of this characteristic demonstrates that it is both distinct from and robust

[17] The statistical significance is an in-sample test, based on a bootstrap method with 1’000 random samples, and considers data from January 1976 to December 2016. The p-Values equal the quantity of the sign opposite to the expected one.

in controlling for momentum.
Motivated by the literature on skewness and its relation to the cross section of equity returns (Conrad et al., 2013; Harvey & Siddique, 2000), we examine the relevance of this characteristic for currencies. Skewness is a measure of crash risk, i.e. the smaller the skewness, the larger the crash risk. To the extent that investors dislike currencies prone to crashes, they should, ceteris paribus, underweight currencies with high skewness. These crashes are especially pronounced in high-yield currencies (Brunnermeier et al., 2008). The positive loading of 0.05 of this characteristic implies that currencies with a large (small) crash risk are sold (purchased). However, the crash risk characteristic is not significant, and this variable does not lead to an enhancement of the risk-return profile. One possibility is that skewness realized in the past is a poor proxy for true expected skewness, and as such it is irrelevant in the optimization. Another possible explanation is that even if realized skewness predicts crash risk, it may offer the investor a risk-return trade-off that leaves him indifferent.
Lustig et al. (2011) and Menkhoff et al. (2012a) form several currency portfolios sorted by volatility. The currency portfolio with the highest volatility consists of high-yield currencies. Low volatility portfolios consist of mid-yield currencies. The characteristic currency volatility has a loading of 0.13 and is not statistically significant. This loading results in highly (lowly) volatile currencies being purchased (sold). Therefore, this characteristic replicates a quasi-carry trade strategy, and provides a small improvement in excess return.
The last characteristic added to the PPP base currency overlay is the sensitivity of global FX volatility innovation. Menkhoff et al. (2012a) show that high-yield currencies are negatively related to innovations in global FX variation. In times of unexpected high variation, high-yield currencies have small returns. Conversely, low-yield currencies act as a hedge and generate high returns. In those periods, we observe that the characteristic has a positive loading, with the result that currencies with a positive (negative) sensitivity to FX volatility innovations are purchased (sold). However, the loading is not significant. In our setting, the loading on FX-volatility risk does not improve performance once controlling for carry, value, and momentum.
The empirical results demonstrate that the three base characteristics of momentum, forward discount, and long-term reversal provide a significantly larger excess return. The only characteristic that shows a significant contribution controlling for these is autocorrelation.

## 4.3 Robustness tests

### 4.3.1 Subperiods

Jylhä and Suominen (2011) demonstrate that the profitability of carry strategies has declined as more speculative capital attempts to exploit the strategy. McLean and Pontiff (2016) indicate a general decline in anomalies after discovery. As a result, it is pertinent to assess whether the benefits of our hedging overlay decline in a later sample. To test for this, we divide the entire sample period into two equal sub samples – first and second sub samples cover the time periods January 1986 to December 2000, and January 2001 to December 2016, respectively. Table 4 sets out these summary statistics for the sub sample periods. Again, these summary statistics are out-of-sample, and adjusted for margin requirement, and transaction and rebalancing costs. The fully hedged portfolio has an annualized excess return of 4.74%, a volatility of 12.32%, a Sharpe ratio of 0.38, and a certainty equivalent of 6.07% between January 1986 and December 2000. The PPP base currency overlay is able to improve the risk-return profile significantly. The excess return and Sharpe ratio increase significantly to 6.17% and 0.49, respectively. Jensen-$\alpha$ and certainty equivalent equal 1.42% and 7.30%, respectively. The remaining PPP currency overlays with four currency characteristics provide a similar significant increase in the risk-return profile, which is why we refrain from a detailed discussion.

The second sub period, from January 2001 to December 2016, is illustrated in Panel B of Table 4. This period includes the Dot-Com bubble, the recent financial crisis and the European debt crisis. The empirical results reveal the economic benefits of the PPP currency overlay during turbulent financial times. The fully hedged portfolio has a Sharpe ratio of 0.28, and a certainty equivalent of 1.03%. The PPP base currency overlay is able to increase the Sharpe ratio to 0.36. The information ratio stands at 0.70, and Jensen-$\alpha$ equals 1.05%. All mentioned quantities are statistically significant. Again, the other PPP currency overlay strategies have a similar enhancement and significance with regard to the risk-return profile. The standard deviation is not affected, and remains at 12.06%. This empirical investigation demonstrates that the parametric approach has a positive contribution under financial stress.

We also examine the contribution of our hedging overlay under stress. For this purpose we calculate the historical average of the VIX index between 1986 and 2016, which is approximately 20%. Panel C of Table 4 sets out the empirical results for the subsample when the VIX index is larger than 20%. The fully hedged portfolio has an annual return of -6.77%, a volatility of 15.04%, and a Sharpe ratio of -0.45. Applying the PPP base currency overlay to the equally weighted portfolio causes a significant reduction in losses of approximately 1.3pp to -5.49%. During this subsample, the Jensen-$\alpha$ is at 1.37%, and significantly different from zero. This analysis illustrates that the parametric currency overlay is able to enhance the portfolio risk-return profile significantly in a later period, and during financial stress levels that are higher than average.

The subplots in Figure 1 display the time-varying information ratio for the PPP base currency overlay and CMV TE method. These plots indicate the time-varying short-, mid- and long-term contribution of the currency overlay strategy to the global equity portfolio. Not surprisingly, the six-month rolling information ratio shows a strong fluctuation for both currency overlays. Approximately 65% of the observed CMV TE information ratios are negative between January 1986 and December 2016, a period of 241 months. Meanwhile, only 32% of the PPP base currency overlay information ratios are negative. This underpins the positive contribution of the PPP base currency overlay. The 60- and 120-month rolling information ratios demonstrate the different contributions of the two overlay strategies. The longer the rolling window, the more negative (positive) the information ratio for the CMV TE (PPP base currency overlay) becomes. This emphasizes that the PPP base currency overlay is able to provide a higher excess return in the mid- and long-term. This analysis demonstrates that the return of the parametric currency overlay is not correlated with financial stress. It is able to provide a currency hedge without compromising profitability. The plots also highlight the time period of financial crunch according to the National Bureau of Economic Research (NBER) business cycle. During this subperiod, the 60- and 120-month rolling information ratio is always positive of the PPP base currency overlay, while the CMV TE has a negative information ratio. The CMV TE has a slightly larger positive impact on the underlying portfolio, as this overlay has a tendency to short high-yield currencies which generally depreciate sharply during times of financial crisis.

### 4.3.2 Tracking error

Until now, we assume that the PPP currency overlay is allowed to have an annual tracking error (TE) of 2%. This tracking error assumption is in-line with passive index funds such as the db x-trackers MSCI World (TE: 1.44%) or JPMorgan Equity Index Fund A (TE: 0.61%)[18]. In our main analysis, we assume a passive investor, who tracks a certain benchmark closely. This setting does not allow the optimization to harvest the full potential of the currency overlay. To better illustrate the potential gains of the approach we loosen the tracking error restriction to consider the case of a more aggressive investor. We therefore set the threshold of maximal tracking error to 5%. The corresponding summary statistics of portfolio performances are set out in Table 5. Overall, the PPP currency overlays are able to increase the excess return by ≈2.5pp and Sharpe ratio by ≈0.18 in a statistical significant manner. The information ratio and Jensen-$\alpha$ are approximately 0.50 and 2.50%, respectively. Consistent with this, the certainty equivalent increases by ≈2.1pp and equals ≈5.50%. Therefore, the PPP currency overlay does not cause a significant rise in standard deviation. However, the larger tracking error leads to a hike in the currency overlay volume, with an average volume of ≈130%. This means that 19.50% of the investor's capital is blocked for margins. The equity investment is therefore diminished to 81.50%. The main message from this analysis is that the larger the tracking error, the larger the volume of the parametric currency overlay. It seems that,

[18]Both tracking errors cover the observation period 2014-2016. Retrieved from the factsheet of these funds. Source: ThomsonReuters Eikon, as of March 17, 2017.

to a certain degree, a substitution of equity positions by the parametric currency overlay is beneficial.

To compare the fully hedged portfolio, CMV TE and the PPP currency overlay with 2% and 5%, Figure 2 indicates the cumulative portfolio return. It is clearly observable that the PPP currency overlay dominates the fully hedged portfolio over the entire sample period, and establishes a long-term positive drift. The CMV TE does not outperform the fully hedged portfolio in a single month, and the cumulative return is a sideward movement. This demonstrates that the reduction in volatility afforded by the CMV method comes at the remarkable price of removing the drift from a global equity portfolio.

#### 4.3.3 Robustness to domestic currency

The previous analysis shows that the parametric currency overlay has a statistical and robust contribution for a U.S. investor. We now relax the assumption of a U.S. domicile, and consider various other investors such as an Australian or European investor. This means that the reference currency is other than the U.S. dollar. Such an analysis demonstrate the robustness of the parametric currency overlay against the reference currency. Table 6 indicates the information ratio and Jensen-$\alpha$ for various reference currencies. The equity composition remains unchanged, and we therefore still consider an equally weighted international equity portfolio. Again, an annual tracking error of 2% is assumed. The main message this table conveys is that each investor earns a positive, significant Jensen-$\alpha$ and information ratio. Furthermore, each investor acquires a similar Jensen-$\alpha$. This analysis reveals that the parametric currency overlay is applicable to all investors, independent of their reference currencies. However, information ratio and Jensen-$\alpha$ are sensitive to the reference currency, which is consistent with Opie and Dark (2015). It is able to outperform the benchmark portfolio in each reference currency, and the parametric currency overlay is therefore applicable globally and independently from the reference currency.

#### 4.3.4 Robustness to alternative investment universe

We now analyze the parametric currency overlay on a different investment universe. The first alternative investment universe contains Australia, Canada, Europe, Japan, New Zealand, Switzerland, Sweden, the United Kingdom and the United States. These economies are chosen as they represent the 10 most liquid currencies according to the Triennial Central Bank Survey by the Bank for International Settlements (2016)[19]. This investment universe is therefore called the most liquid universe.

[19]China is excluded due to lack of data.

In the second investment universe we follow Campbell et al. (2010). This includes Australia, Canada, Europe, Japan, Switzerland, the United Kingdom and the United States. We call this the CMV universe.

Table 7 illustrates the portfolio performance of the alternative investment universes for the corresponding equally weighted portfolios following a full hedge, or the PPP base currency overlay. The empirical analysis demonstrates that the PPP base currency overlay provides a positive, significant contribution for all alternative investment universes. This means that the excess returns significantly increase by at least 89bps, the Sharpe ratios increase by 20% on average, and the information ratios are between 0.48 and 0.90. The strategies display statistically significant Jensen-$\alpha$ between 85 and 123bps. We conclude that the benefits of the approach are robust to alternative investment universes.

### 4.4 Robustness to unhedged portfolio and margin requirements

Until now, the benchmark has been a fully hedged portfolio. To evaluate the robustness to the benchmark, that is not hedged against currency risk, for the next analysis we consider an unhedged portfolio, where the demand for forward contracts is zero. The excess return over the entire sample period of the unhedged portfolio is 7.61%, with a standard deviation of 16.33%, and a certainty equivalent of 3.65%.

Panel A of Table 8 indicates the empirical results for the parametric currency overlay following the unhedged portfolio, with a tracking error of 2%. The PPP base currency overlay provides an excess return of 8.21%, and a portfolio volatility of 16.07%. The Sharpe ratio therefore equals 0.51. Furthermore, the Jensen-$\alpha$ is 0.77% and the certainty equivalent is 4.50%. These portfolio measures reveal that the PPP base currency overlay can also outperform the unhedged portfolio in economic terms. The associated test statistics are significant, and the added value is underpinned statistically.

The remaining characteristics exhibit an economic outperformance with respect to the unhedged portfolios. However, the variables capturing the sign of the forward discount ($sign$) and the sensitivity between currency and equity ($S_{FX}$) have a negative impact on the parametric currency overlay, as the excess return decreases to 7.98% and 7.90%, respectively. Therefore, for $sign$ and $S_{FX}$, the outperformance in the case of the suggested currency overlay is not underpinned statistically. The remaining characteristics return significant test statistics.

An additional central assumption is a margin requirement of 15%, with the result that the investor faces a trade-off between currency overlay and equity investment. In the following examinations we relax this assumption, and set the margin requirements to 0%. The investor is therefore not limited with regard to the volume of the currency overlay, and faces no trade-off between currency overlay and equity investment. Panel B of Table 8 illustrates the results

of the parametric currency overlay, which follows the unhedged portfolio and a margin requirement of 0%. The empirical investigation reveals that all parametric currency overlays significantly outperform the unhedged portfolio. The PPP base currency overlay has an annual excess return of 8.59%, with a Sharpe ratio of 0.51, and a certainty equivalent of 4.12%. The portfolio volatility equals 16.80%, which is insignificantly different from the volatility of the unhedged portfolio.
The parametric currency overlay can outperform the unhedged portfolio significantly, and the economic benefit is therefore not related to the full hedge.

To illustrate the impact of margin requirements on the other currency overlay, Panel A of Table 9 indicates the performances of the following currency overlays: Full hedge, the various CMV approaches, the universal hedging approach and the PPP base currency overlay following the full hedge. All considered currency overlays assume a margin requirement of 0%. The fully hedged portfolio has an annual excess return of 5.44%, a volatility of 13.90%, and a Sharpe ratio of 0.39. Moreover, the universal hedging ratio of Black (1989) provides a larger excess return of 5.74% relative to the fully hedged portfolio. However, the corresponding improved Sharpe ratio of 0.41 finds no statistical evidence.
The results of the hedging approach, following Campbell et al. (2010), create an excess return of 3.28%, a volatility of 11.95%, and a Sharpe ratio of 0.27. Consistent with Campbell et al. (2010), the reduction in volatility is highly significant. The decline in Sharpe ratio finds no statistical evidence. It is important to mention that the reduction in Sharpe ratio is driven by the transaction and rebalancing costs, as the Sharpe ratio for CMV, without trading costs, equals 0.36. With regard to the other two CMV approaches: CMV TE provides a result similar to the CMV. The reduction in volatility is smaller, and the test statistics therefore provide weaker statistical evidence. The CMV RW does not have a significant impact on the risk-return profile.
Lastly, we examine the contribution of PPP base currency overlay. The test results reveal that the PPP base currency overlay is able to outperform the fully hedged portfolio in terms of excess return and Sharpe ratio. Jensen-$\alpha$ and information ratios are positive. All portfolio measures are underpinned by highly significant test results. The parametric currency overlay is therefore robust to different margin requirements.

## 4.5 Speculative return

According to Jorion (1994) and Kroencke et al. (2013), the return of a currency overlay consists of a hedging and a speculative component. Given a mean-variance investor with a unity risk aversion ($\lambda = 1$), as considered in this empirical study, the portfolio return equals

$$r_p = (\boldsymbol{\mu}_E - B'\boldsymbol{\mu}_{FX})\boldsymbol{\omega} + \boldsymbol{\mu}'_{FX}\Sigma^{-1}_{FX,FX}\boldsymbol{\mu}_{FX}, \tag{16}$$

where $\boldsymbol{\mu}_E$ ($\boldsymbol{\mu}_{FX}$) is the expected equity (currency) return, $\Sigma^{-1}_{FX,FX}$ denotes the inverse of the currency covariance matrix and $B$ are the currency weights suggested by Campbell et al. (2010). Thus, the terms $-B'\boldsymbol{\omega}$ and $\Sigma^{-1}_{FX,FX}\boldsymbol{\mu}_{FX}$, are related to the hedging and speculative components, respectively. We follow Kroencke et al. (2013), and present the exclusive speculative return of each currency overlay in Panel B of Table 9. It is important to mention that the regression-based approach of Campbell et al. (2010) implicitly assumes that the speculative return is zero (Anderson & Danthine, 1981). The empirical results indicate that all currency overlays have a positive speculative annual return. The unhedged and fully hedged portfolios achieve a speculative return of 4.33% and 2.16%, respectively. Furthermore, the PPP base currency overlay has a return of at least 3.42%. The test statistics reveal that the speculative return of PPP base currency overlay and unhedged portfolio is significant, in that these three currency overlay strategies display a significant, positive speculative return. Furthermore, the speculative return is adjusted for transaction and rebalancing cost. As the hedging component is identical for all currency overlays, the contribution of this component is implicitly presented in Panel A of Table 9. By definition, the hedging component equals the currency overlay approach of Campbell et al. (2010). Therefore, the contribution of the hedge component ($-B\boldsymbol{\omega}$) corresponds to the test statistics of CMV, and only the excess return is influenced on a weak statistical basis. This analysis indicates that the proposed parametric currency overlay is able to provide a positive and significant speculative return.

# 5 Conclusion

This study proposes adapting parametric portfolio policies (PPP) to the problem of designing a currency overlay strategy. The weights of the currencies are modeled as a function of currency characteristics. The relevance of characteristics is estimated by maximizing the investor's quadratic utility of the associated portfolio returns over a given sample period. The currency characteristics momentum, forward discount and long-term reversal form our PPP base currency overlay.

Over the entire sample period, from 1986 to 2016, the PPP overlay strategy generates a positive Jensen-$\alpha$ and information ratio with respect to the fully hedged portfolio. The Sharpe ratio and average excess return increase as well. All enhancements are underpinned by highly significant test statistics. Furthermore, the outperformance is quantified after transaction and rebalancing costs, incorporating margin requirement and in an out-of-sample setting.
We include additional characteristics proxying for risk and expected returns to the PPP base currency overlay and analyze its contribution to the risk-return trade-off. We find that autocorrelation is the only supplementary characteristic able to marginally enhance the PPP base currency overlay. These empirical results emphasize the importance of the three base charac-

teristics, and the mixture of these three characteristics creates a good proxy for future currency returns.

To test for robustness, we apply the parametric currency overlay under the following specifications: First, we split the sample into several sub-samples. Second, we study the time-varying contribution of the parametric currency overlay to the overall portfolio performance. Third, we investigate the parametric currency overlay under various reference currencies. Fourth, we vary the tracking error from a passive to an aggressive investor. Fifth, we apply different the currency universe. Sixth, we restrict the benchmark risk relative to a fully hedged and unhedged equity portfolio. Seventh, we differ the margin requirements. All examinations reveal that the parametric currency overlay enhances the risk-return profile of the designated benchmark portfolios in a robust and statistically significant manner. Moreover, we reveal significant positive speculative return of the parametric currency overlay.

The parametric currency overlay provides a practical guideline on how to handle currency risk. First, the investor decides which properties or characteristics are important for the currency overlay. Second, each property or characteristic is weighted in the overall currency overlay. One of the unique advantages of this applied method is its flexibility. Other methods of estimating exchange rate returns or risk (e.g. private forecasts) could also be tested as characteristics.

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# Tables

Table 1: Summary Statistics

Stock market return data are from Morgan Stanley Capital International database. The frequency of the data is monthly. Excess stock returns are quantified in local currency adjusted by the corresponding interest rate. The interest rates are implied interest rates computed from forward discounts quoted against the U.S. dollar. The U.S. dollar interest rate equals the treasury bill rate, and is from IMF IFS database. Foreign exchange data are sourced from Thomson Reuters Datastream. ret, vol, and SR stand for annualized return, volatility, and Sharpe Ratio, respectively. The sample period is between January 1976 and December 2016.

| | Interest rates | | Excess stock returns | | |
|---|---|---|---|---|---|
| | ret | vol | ret | vol | SR |
| Australia | 6.35 | 2.61 | 7.80 | 17.41 | 0.45 |
| Canada | 5.28 | 1.92 | 5.58 | 16.00 | 0.35 |
| Denmark | 5.85 | 2.56 | 7.21 | 18.05 | 0.40 |
| Europe | 5.00 | 1.96 | 6.88 | 15.33 | 0.45 |
| Japan | 1.69 | 1.38 | 5.33 | 18.36 | 0.29 |
| New Zealand | 7.40 | 3.23 | −0.64 | 15.42 | −0.04 |
| Norway | 6.53 | 2.19 | 6.14 | 23.75 | 0.26 |
| Sweden | 6.14 | 2.50 | 10.36 | 22.72 | 0.46 |
| Switzerland | 1.94 | 1.28 | 7.65 | 15.32 | 0.50 |
| UK | 6.18 | 2.08 | 6.01 | 16.03 | 0.38 |
| USA | 4.55 | 1.70 | 6.80 | 14.77 | 0.46 |

Table 2: Volatility Minimization with Margin Requirements

This table reports the summary statistics of several currency overlay strategies from a U.S. investor's perspective. The currency risk of the global equity portfolio is not (Unhedged) or entirely neutralized (Full Hedge). CMV refers to the approach of Campbell et al. (2010) using currencies to minimize the volatility of the global equity portfolio. CMV TE and CMV RW are an imitation of CMV using a time expanding or rolling window, respectively. The column Uni. Hedge refers to the universal hedging ratio introduced by Black (1989). ex ret, vol, and SR stand for annualized excess return, volatility, and Sharpe Ratio, respectively. skew and kurt denote skewness and kurtosis, respecitvely. The certainty equivalent (CE) is expressed in annualized percentage points. Fwd Size refers to the volume of the currency overlay strategy. The numbers in brackets are the p-Values examining the differences in excess return (correlated t-test), volatility (f-Test), Sharpe ratio (boot-TS of Ledoit and Wolf (2008)) to the fully hedged portfolio. We assume currency margin requirements of 15%. The sample period is from January 1986 to December 2016.

| | Unhedged | Full Hedge | Uni. Hedge | CMV | CMV TE | CMV RW |
|---|---|---|---|---|---|---|
| ex ret | 7.61 | 3.97 | 4.54 | 1.10 | 1.02 | 0.01 |
| | [0.00] | | [0.01] | [0.01] | [0.01] | [0.00] |
| vol | 16.33 | 12.00 | 12.53 | 8.94 | 9.10 | 7.82 |
| | [0.00] | | [0.41] | [0.00] | [0.00] | [0.00] |
| SR | 0.47 | 0.33 | 0.36 | 0.12 | 0.11 | 0.00 |
| | [0.18] | | [0.15] | [0.06] | [0.04] | [0.01] |
| skew | −0.84 | −1.13 | −1.09 | −0.67 | −1.08 | 0.01 |
| kurt | 5.52 | 6.40 | 6.21 | 5.31 | 8.03 | 7.99 |
| CE | 3.65 | 3.43 | 3.65 | 2.39 | 2.17 | 1.84 |
| Fwd Size | 0.00 | 90.91 | 76.88 | 166.84 | 188.23 | 317.43 |

## Table 3: Parametric Currency Overlay

This table reports the out-of-sample (Panel A) summary statistics of a global equity portfolio following a parametric currency overlay. Each column refers to a certain parametric currency overlay. The parametric currency overlay is estimated under a 2% tracking error constraint. Full Hedge refers to the currency overlay strategy to neutralized the currency risk entirely.
ex ret, vol, and SR stand for annualized excess return, volatility, and Sharpe Ratio, respectively. skew and kurt denote skewness and kurtosis, respectively. $\alpha$ equals the annualized Jensen-$\alpha$. The certainty equivalent (CE) is expressed in annualized percentage points. Fwd Size refers to the volume of the currency overlay strategy. The numbers in brackets are the p-Values examining the differences in excess return (correlated t-test), volatility (f-Test), Sharpe ratio (boot-TS of Ledoit and Wolf (2008)) to the fully hedged portfolio. The p-Value of the information ratio (IR) is computed by a bootstrap method counting the frequency of a negative sign. The standard errors of Jensen-$\alpha$ are adjusted as suggested in White (1980). A margin requirement of 15% is assumed. The economic quantities are measured in U.S. dollar. The sample period between January 1986 to December 2016.
Panel B illustrates the statistical significance of the examined characteristics in an in-sample test. The displayed coefficient maximizes the quadratic utility over wealth with risk aversion of 1. The numbers in brackets are the corresponding p-Values. The p-Values are computed by a bootstrap method, which generates 1000 random samples and captures the percentage of random samples, where the sign of the estimate varies from the expected sign.

| Panel A: Summary Statistic | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Full Hedge | mom, fd rev | mom, fd rev, sign | mom, fd rev, $\mathcal{S}_{FX}$ | mom, fd rev, AC | mom, fd rev, skew | mom, fd rev, vol | mom, fd rev, $\beta_{\sigma_{FX}}$ |
| ex ret | 3.97 | 5.24 | 5.15 | 5.14 | 5.31 | 5.20 | 5.24 | 5.29 |
| | | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| vol | 12.00 | 12.29 | 12.38 | 12.36 | 12.31 | 12.29 | 12.27 | 12.33 |
| | | [0.64] | [0.54] | [0.56] | [0.62] | [0.64] | [0.66] | [0.59] |
| SR | 0.33 | 0.43 | 0.42 | 0.42 | 0.43 | 0.42 | 0.43 | 0.43 |
| | | [0.01] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| IR | | 0.65 | 0.63 | 0.59 | 0.68 | 0.61 | 0.65 | 0.65 |
| | | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| $\alpha$ | | 1.23 | 1.10 | 1.11 | 1.29 | 1.18 | 1.23 | 1.27 |
| | | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| skew | −1.13 | −1.22 | −1.19 | −1.22 | −1.25 | −1.20 | −1.21 | −1.22 |
| kurt | 6.40 | 7.00 | 6.82 | 6.93 | 7.12 | 6.85 | 6.94 | 6.91 |
| CE | 3.43 | 4.50 | 4.35 | 4.34 | 4.55 | 4.46 | 4.52 | 4.52 |
| Fwd Size | 90.91 | 91.81 | 90.50 | 93.08 | 92.13 | 92.00 | 92.04 | 93.14 |
| TE | | 1.96 | 1.87 | 1.98 | 1.97 | 1.99 | 1.96 | 2.04 |
| **Panel B: Loadings of Characteristics** | | | | | | | | |
| mom | | 0.27 | 0.25 | 0.26 | 0.24 | 0.26 | 0.27 | 0.26 |
| | | [0.01] | [0.01] | [0.01] | [0.01] | [0.01] | [0.01] | [0.01] |
| fd | | 0.43 | 0.00 | 0.44 | 0.41 | 0.41 | 0.41 | 0.43 |
| | | [0.00] | [0.46] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| rev | | 0.20 | 0.17 | 0.21 | 0.21 | 0.21 | 0.17 | 0.28 |
| | | [0.04] | [0.05] | [0.04] | [0.05] | [0.04] | [0.06] | [0.07] |
| sign | | | 0.45 | | | | | |
| | | | [0.01] | | | | | |
| $\mathcal{S}_{FX}$ | | | | 0.02 | | | | |
| | | | | [0.42] | | | | |
| AC | | | | | 0.23 | | | |
| | | | | | [0.02] | | | |
| skew | | | | | | 0.05 | | |
| | | | | | | [0.36] | | |
| vol | | | | | | | 0.13 | |
| | | | | | | | [0.12] | |
| $\beta_{\sigma_{FX}}$ | | | | | | | | 0.09 |
| | | | | | | | | [0.30] |

## Table 4: Sub Period Analysis

This table reports the out-of-sample summary statistics of a global equity portfolio following a parametric currency overlay. Each column refers to a certain parametric currency overlay. The parametric currency overlay is estimated under a 2% tracking error constraint. Full Hedge refers to the currency overlay strategy to neutralized the currency risk entirely.
ex ret, vol, and SR stand for annualized excess return, volatility, and Sharpe Ratio, respectively. skew and kurt denote skewness and kurtosis, respectively. $\alpha$ equals the annualized Jensen-$\alpha$. The certainty equivalent (CE) is expressed in annualized percentage points. Fwd Size refers to the volume of the currency overlay strategy. The numbers in brackets are the p-Values examining the differences in excess return (correlated t-test), volatility (f-Test), Sharpe ratio (boot-TS of Ledoit and Wolf (2008)) to the fully hedged portfolio. The p-Value of the Information Ratio (IR) is computed by a bootstrap method counting the frequency of a negative sign. The standard errors of Jensen-$\alpha$ are adjusted as suggested in White (1980). A margin requirement of 15% is assumed. The economic quantities are measured in U.S. dollar. The sample period between January 1986 to December 2016.
Panel A covers the sample period between January 1986 to December 2000, Panel B the sample period between January 2001 to December 2015. Panel C shows the empirical results for the subsample, when the VIX index is larger than 20% between January 1986 and December 2016.

| Panel A: January 1986 - December 2000 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Full Hedge | mom, fd rev | mom, fd rev, sign | mom, fd rev, $\mathcal{S}_{FX}$ | mom, fd rev, AC | mom, fd rev, skew | mom, fd rev, vol | mom, fd rev, $\beta_{\sigma_{FX}}$ |
| ex ret | 4.74 | 6.17 | 6.14 | 6.01 | 6.22 | 6.13 | 6.09 | 6.20 |
| | | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| vol | 12.32 | 12.56 | 12.62 | 12.63 | 12.58 | 12.52 | 12.55 | 12.60 |
| | | [0.64] | [0.54] | [0.56] | [0.62] | [0.64] | [0.66] | [0.59] |
| SR | 0.38 | 0.49 | 0.49 | 0.48 | 0.49 | 0.49 | 0.49 | 0.49 |
| | | [0.01] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| IR | | 0.63 | 0.64 | 0.56 | 0.64 | 0.60 | 0.60 | 0.63 |
| | | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| $\alpha$ | | 1.42 | 1.36 | 1.23 | 1.47 | 1.40 | 1.34 | 1.44 |
| | | [0.02] | [0.02] | [0.04] | [0.02] | [0.03] | [0.03] | [0.02] |
| skew | −1.43 | −1.66 | −1.61 | −1.65 | −1.66 | −1.63 | −1.65 | −1.62 |
| kurt | 8.40 | 9.87 | 9.58 | 9.71 | 9.88 | 9.66 | 9.79 | 9.64 |
| CE | 6.07 | 7.30 | 7.23 | 7.07 | 7.33 | 7.29 | 7.22 | 7.31 |
| Fwd Size | 90.91 | 90.72 | 89.54 | 93.10 | 90.91 | 91.19 | 90.57 | 90.81 |
| TE | | 2.28 | 2.17 | 2.29 | 2.32 | 2.34 | 2.26 | 2.32 |
| **Panel B: January 2001 - December 2016** | | | | | | | | |
| ex ret | 3.24 | 4.36 | 4.23 | 4.32 | 4.45 | 4.31 | 4.44 | 4.43 |
| | | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| vol | 11.72 | 12.06 | 12.18 | 12.13 | 12.08 | 12.10 | 12.04 | 12.11 |
| | | [0.64] | [0.54] | [0.56] | [0.62] | [0.64] | [0.66] | [0.59] |
| SR | 0.28 | 0.36 | 0.35 | 0.36 | 0.37 | 0.36 | 0.37 | 0.37 |
| | | [0.01] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| IR | | 0.70 | 0.64 | 0.66 | 0.77 | 0.66 | 0.73 | 0.68 |
| | | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| $\alpha$ | | 1.05 | 0.88 | 0.99 | 1.14 | 0.99 | 1.14 | 1.11 |
| | | [0.01] | [0.02] | [0.02] | [0.00] | [0.01] | [0.01] | [0.01] |
| skew | −0.83 | −0.78 | −0.78 | −0.79 | −0.85 | −0.78 | −0.77 | −0.82 |
| kurt | 4.34 | 4.16 | 4.16 | 4.18 | 4.38 | 4.14 | 4.11 | 4.21 |
| CE | 1.03 | 1.95 | 1.74 | 1.86 | 2.01 | 1.88 | 2.05 | 1.98 |
| Fwd Size | 90.91 | 92.84 | 91.40 | 93.06 | 93.28 | 92.76 | 93.43 | 95.33 |
| TE | | 1.61 | 1.54 | 1.64 | 1.58 | 1.61 | 1.63 | 1.75 |
| **Panel C: VIX > 20%** | | | | | | | | |
| ex ret | −6.77 | −5.49 | −5.48 | −5.68 | −5.50 | −5.65 | −5.51 | −5.56 |
| | | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| vol | 15.04 | 15.40 | 15.54 | 15.50 | 15.43 | 15.38 | 15.38 | 15.42 |
| | | [0.64] | [0.54] | [0.56] | [0.62] | [0.64] | [0.66] | [0.59] |
| SR | −0.45 | −0.36 | −0.35 | −0.37 | −0.36 | −0.37 | −0.36 | −0.36 |
| | | [0.01] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| IR | | 0.57 | 0.61 | 0.47 | 0.56 | 0.49 | 0.56 | 0.51 |
| | | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| $\alpha$ | | 1.37 | 1.45 | 1.22 | 1.36 | 1.20 | 1.34 | 1.30 |
| | | [0.03] | [0.01] | [0.06] | [0.03] | [0.06] | [0.03] | [0.05] |
| skew | −0.83 | −0.96 | −0.93 | −0.95 | −0.99 | −0.94 | −0.95 | −0.96 |
| kurt | 4.59 | 5.11 | 4.96 | 5.03 | 5.17 | 5.00 | 5.06 | 5.06 |
| CE | −8.95 | −8.15 | −8.24 | −8.41 | −8.21 | −8.27 | −8.15 | −8.23 |
| Fwd Size | 90.91 | 92.86 | 90.95 | 94.11 | 93.08 | 93.13 | 93.08 | 94.82 |
| TE | | 2.26 | 2.12 | 2.34 | 2.25 | 2.27 | 2.26 | 2.38 |

Table 5: Parametric Currency Overlay - Tracking Error 5%

This table reports the out-of-sample summary statistics of a global equity portfolio following a parametric currency overlay. Each column refers to a certain parametric currency overlay. The parametric currency overlay is estimated under a 5% tracking error constraint.
ex ret, vol, and SR stand for annualized excess return, volatility, and Sharpe Ratio, respectively. skew and kurt denote skewness and kurtosis, respectively. $\alpha$ equals the annualized Jensen-$\alpha$. The certainty equivalent (CE) is expressed in annualized percentage points. Fwd Size refers to the volume of the currency overlay strategy. The numbers in brackets are the p-Values examining the differences in excess return (correlated t-test), volatility (f-Test), Sharpe ratio (boot-TS of Ledoit and Wolf (2008)) to the fully hedged portfolio. The p-Value of the information ratio (IR) is computed by a bootstrap method counting the frequency of a negative sign. The standard errors of Jensen-$\alpha$ are adjusted as suggested in White (1980). A margin requirement of 15% is assumed. The economic quantities are measured in U.S. dollar. The sample period between January 1986 to December 2016.

| | Full Hedge | mom, fd rev | mom, fd rev, sign | mom, fd rev, $\mathcal{S}_{FX}$ | mom, fd rev, AC | mom, fd rev, skew | mom, fd rev, vol | mom, fd rev, $\beta_{\sigma_{FX}}$ |
|---|---|---|---|---|---|---|---|---|
| ex ret | 3.97 | 6.50 | 6.18 | 5.82 | 6.69 | 6.38 | 6.36 | 6.51 |
| | | [0.00] | [0.00] | [0.02] | [0.00] | [0.00] | [0.00] | [0.00] |
| vol | 12.00 | 12.64 | 12.79 | 12.76 | 12.66 | 12.66 | 12.59 | 12.72 |
| | | [0.31] | [0.21] | [0.23] | [0.29] | [0.29] | [0.35] | [0.25] |
| SR | 0.33 | 0.51 | 0.48 | 0.46 | 0.53 | 0.50 | 0.51 | 0.51 |
| | | [0.01] | [0.03] | [0.05] | [0.01] | [0.02] | [0.02] | [0.02] |
| IR | | 0.53 | 0.49 | 0.39 | 0.57 | 0.49 | 0.50 | 0.51 |
| | | [0.00] | [0.00] | [0.02] | [0.00] | [0.00] | [0.00] | [0.00] |
| $\alpha$ | | 2.63 | 2.22 | 1.91 | 2.81 | 2.51 | 2.51 | 2.64 |
| | | [0.00] | [0.01] | [0.03] | [0.00] | [0.01] | [0.00] | [0.00] |
| skew | −1.13 | −1.22 | −1.18 | −1.22 | −1.27 | −1.16 | −1.20 | −1.24 |
| kurt | 6.40 | 7.46 | 6.98 | 7.26 | 7.69 | 6.93 | 7.36 | 7.31 |
| CE | 3.43 | 5.53 | 5.10 | 4.73 | 5.69 | 5.42 | 5.43 | 5.47 |
| Fwd Size | 90.91 | 129.03 | 126.54 | 138.70 | 131.13 | 129.78 | 131.06 | 140.80 |
| TE | | 4.77 | 4.47 | 4.79 | 4.81 | 4.87 | 4.79 | 4.97 |

Figure 1: Rolling Window Information Ratio

The first row of plots displays the time-varying information ratio of the parametric base currency overlay with a tracking error of 2% (PPP TE 2) and 5% (PPP TE 5), and the method of Campbell et al. (2010) applied in a time expanding window (CMV TE). The information ratio (IR) is calculated with respect to the fully hedged portfolio. The second row of plots corresponds the frequency of negative and positive information ratios. Each column reports the time-varying information ratio for a certain estimation window (EW). The gray hatched areas indicate crises according to NBER business calendar. The sample period is between January 1986 and December 2015.

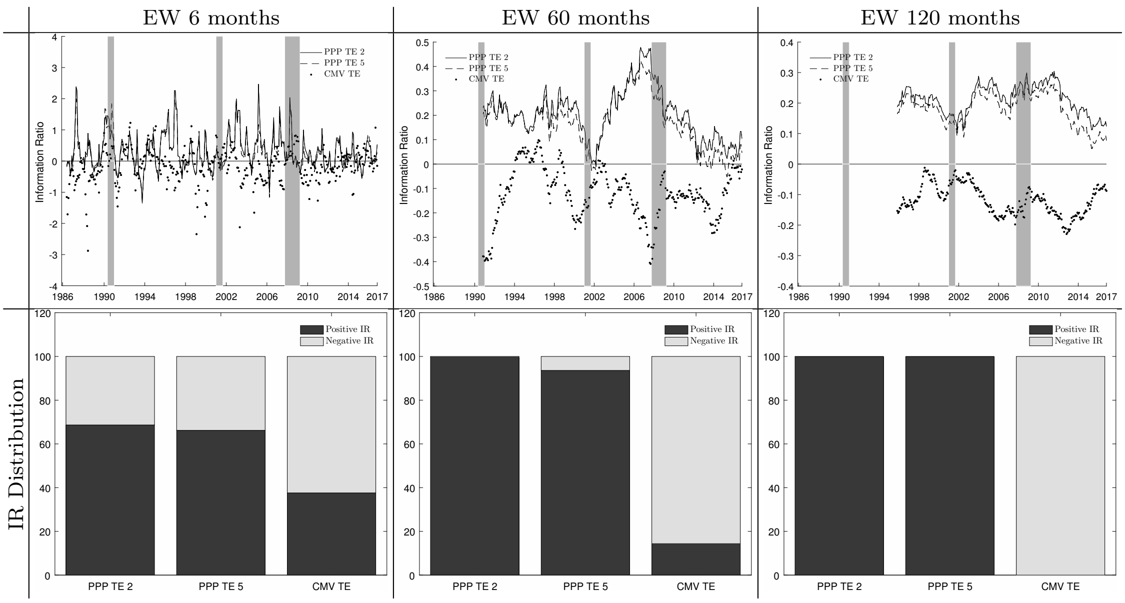

Table 6: Currency Overlay for Different Reference Currencies

This table reports the out-of-sample and transaction, and rebalancing cost adjusted Jensen-$\alpha$ (Panel A) and information ratio (Panel B). The sample period is between January 1986 and December 2016. Each column refers to a certain parametric currency overlay. The parametric currency overlay is estimated under a 2% tracking error constraint. The row name refers to the country, where the investor is domiciled. The numbers in brackets are the p-Values with respect to the corresponding fully hedged portfolio. The p-Value of the information ratio (IR) is computed by a bootstrap method counting the frequency of a negative sign. The standard errors of Jensen-$\alpha$ are adjusted as suggested by White (1980).

| Panel A: Information Ratio | | | | | | | |
|---|---|---|---|---|---|---|---|
| | mom, fd rev | mom, fd rev, sign | mom, fd rev, $\mathcal{S}_{FX}$ | mom, fd rev, AC | mom, fd rev, skew | mom, fd rev, vol | mom, fd rev, $\beta_{\sigma FX}$ |
| Australia | 0.59 | 0.56 | 0.53 | 0.62 | 0.56 | 0.58 | 0.58 |
| | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| Canada | 0.62 | 0.59 | 0.56 | 0.65 | 0.59 | 0.62 | 0.61 |
| | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| Euroland | 0.64 | 0.62 | 0.61 | 0.67 | 0.61 | 0.65 | 0.63 |
| | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| Japan | 0.72 | 0.71 | 0.65 | 0.74 | 0.69 | 0.69 | 0.71 |
| | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| Switzerland | 0.69 | 0.69 | 0.66 | 0.72 | 0.66 | 0.69 | 0.69 |
| | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| UK | 0.60 | 0.57 | 0.56 | 0.63 | 0.57 | 0.60 | 0.59 |
| | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| USA | 0.65 | 0.63 | 0.59 | 0.68 | 0.61 | 0.65 | 0.65 |
| | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| Panel B: Jensen Alpha | | | | | | | |
| Australia | 1.13 | 1.01 | 1.01 | 1.19 | 1.10 | 1.12 | 1.16 |
| | [0.00] | [0.00] | [0.01] | [0.00] | [0.00] | [0.00] | [0.00] |
| Canada | 1.19 | 1.05 | 1.06 | 1.25 | 1.14 | 1.19 | 1.22 |
| | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| Europe | 1.22 | 1.09 | 1.14 | 1.28 | 1.19 | 1.24 | 1.25 |
| | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| Japan | 1.32 | 1.21 | 1.20 | 1.38 | 1.29 | 1.29 | 1.36 |
| | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| Switzerland | 1.30 | 1.20 | 1.22 | 1.36 | 1.27 | 1.30 | 1.35 |
| | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| UK | 1.16 | 1.02 | 1.07 | 1.21 | 1.12 | 1.17 | 1.19 |
| | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| USA | 1.23 | 1.10 | 1.11 | 1.29 | 1.18 | 1.23 | 1.27 |
| | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |

Table 7: Alternative Investment Universe

This table reports the out-of-sample (Panel A) summary statistics of a equity portfolio invested in developed market (Dev. Market), the most liquid market (Most Liq) and CMV(following Campbell et al. (2010)) from January 1986 to December 2016. Panel B highlights the out-of-sample result of the corresponding equity portfolio following a PPP base currency overlay. The parametric currency overlay is estimated under a 2% tracking error constraint.
ex ret, vol, and SR stand for annualized excess return, volatility, and Sharpe Ratio, respectively. skew and kurt denote skewness and kurtosis, respectively. $\alpha$ equals the annualized Jensen-$\alpha$. The certainty equivalent (CE) is expressed in annualized percentage points. Fwd Size refers to the volume of the currency overlay strategy. The numbers in brackets are the p-Values examining the differences in excess return (correlated t-test), volatility (f-Test), Sharpe ratio (boot-TS of Ledoit and Wolf (2008)) to the fully hedged portfolio. The p-Value of the information ratio (IR) is computed by a bootstrap method counting the frequency of a negative sign. The standard errors of Jensen-$\alpha$ are adjusted as suggested in White (1980). A margin requirement of 15% is assumed. The economic quantities are measured in U.S. dollar.

| Panel A: Benchmark Portfolios | | | |
|---|---|---|---|
| | Dev. Market | Most Liq | CMV |
| ex ret | 3.97 | 4.88 | 3.96 |
| vol | 12.00 | 11.68 | 11.73 |
| SR | 0.33 | 0.42 | 0.34 |
| Panel B: Parametric Portfolio Policy | | | |
| ex ret | 5.24 | 6.27 | 4.87 |
| | [0.00] | [0.00] | [0.00] |
| vol | 12.29 | 12.14 | 12.04 |
| | [0.64] | [0.44] | [0.60] |
| SR | 0.43 | 0.52 | 0.40 |
| | [0.01] | [0.00] | [0.03] |
| IR | 0.65 | 0.90 | 0.48 |
| | [0.00] | [0.00] | [0.00] |
| $\alpha$ | 1.23 | 1.24 | 0.85 |
| | [0.00] | [0.00] | [0.02] |
| skew | −1.22 | −1.08 | −1.38 |
| kurt | 7.00 | 6.16 | 8.81 |
| CE | 4.50 | 5.73 | 4.19 |
| Fwd Size | 91.81 | 88.94 | 85.44 |
| TE | 1.96 | 1.55 | 1.90 |

Table 8: Parametric Currency Overlay - Unhedged

This table reports the out-of-sample summary statistics of a global equity portfolio following a parametric currency overlay. Each column refers to a certain parametric currency overlay. The parametric currency overlay is estimated under a 2% tracking error constraint. The benchmark of the parametric portfolio policy is the equally weighted portfolio, which is unhedged against currency risk.
ex ret, vol, and SR stand for annualized excess return, volatility, and Sharpe Ratio, respectively. skew and kurt denote skewness and kurtosis, respectively. $\alpha$ equals the annualized Jensen-$\alpha$. The certainty equivalent (CE) is expressed in annualized percentage points. The numbers in brackets are the p-Values examining the differences in excess return (correlated t-test), volatility (f-Test), Sharpe ratio (boot-TS of Ledoit and Wolf (2008)) to the unhedged portfolio. The p-Value of the information ratio (IR) is computed by a bootstrap method counting the frequency of a negative sign. The standard errors of Jensen-$\alpha$ are adjusted as suggested in White (1980). Panel A assumes a margin requirement of 15%, while Panel B supposes 0%. The economic quantities are measured in U.S. dollar. The sample period between January 1986 to December 2016.

Panel A: Margin 15%

| | Unhedged | mom, fd rev | mom, fd rev, sign | mom, fd rev, $\mathcal{S}_{FX}$ | mom, fd rev, AC | mom, fd rev, skew | mom, fd rev, vol | mom, fd rev, $\beta_{\sigma_{FX}}$ |
|---|---|---|---|---|---|---|---|---|
| ex ret | 7.61 | 8.21 | 7.98 | 7.90 | 8.30 | 8.15 | 8.17 | 8.15 |
| | | [0.03] | [0.11] | [0.19] | [0.02] | [0.05] | [0.05] | [0.05] |
| vol | 16.33 | 16.07 | 16.09 | 16.08 | 16.07 | 16.07 | 16.04 | 16.06 |
| | | [0.76] | [0.79] | [0.77] | [0.76] | [0.76] | [0.74] | [0.76] |
| SR | 0.47 | 0.51 | 0.50 | 0.49 | 0.52 | 0.51 | 0.51 | 0.51 |
| | | [0.08] | [0.18] | [0.22] | [0.04] | [0.11] | [0.09] | [0.07] |
| IR | 0.47 | 0.33 | 0.23 | 0.16 | 0.37 | 0.29 | 0.30 | 0.29 |
| | | [0.03] | [0.12] | [0.18] | [0.02] | [0.05] | [0.04] | [0.06] |
| $\alpha$ | | 0.77 | 0.52 | 0.45 | 0.86 | 0.71 | 0.74 | 0.72 |
| | | [0.02] | [0.08] | [0.17] | [0.01] | [0.04] | [0.03] | [0.04] |
| skew | −0.84 | −0.90 | −0.88 | −0.92 | −0.93 | −0.89 | −0.90 | −0.91 |
| kurt | 5.52 | 5.61 | 5.59 | 5.70 | 5.77 | 5.57 | 5.59 | 5.66 |
| CE | 3.65 | 4.50 | 4.24 | 4.14 | 4.56 | 4.44 | 4.48 | 4.42 |
| TE | 7.80 | 1.84 | 1.66 | 1.84 | 1.86 | 1.87 | 1.86 | 1.88 |

Panel B: Margin 0%

| | Unhedged | mom, fd rev | mom, fd rev, sign | mom, fd rev, $\mathcal{S}_{FX}$ | mom, fd rev, AC | mom, fd rev, skew | mom, fd rev, vol | mom, fd rev, $\beta_{\sigma_{FX}}$ |
|---|---|---|---|---|---|---|---|---|
| ex ret | 7.61 | 8.59 | 8.44 | 8.25 | 8.62 | 8.47 | 8.44 | 8.68 |
| | | [0.00] | [0.00] | [0.03] | [0.00] | [0.01] | [0.01] | [0.00] |
| vol | 16.33 | 16.80 | 16.91 | 16.57 | 16.81 | 16.78 | 16.74 | 16.89 |
| | | [0.58] | [0.50] | [0.77] | [0.58] | [0.60] | [0.63] | [0.51] |
| SR | 0.47 | 0.51 | 0.50 | 0.50 | 0.51 | 0.50 | 0.50 | 0.51 |
| | | [0.04] | [0.09] | [0.12] | [0.03] | [0.09] | [0.08] | [0.02] |
| IR | 0.29 | 0.52 | 0.48 | 0.33 | 0.53 | 0.44 | 0.44 | 0.54 |
| | | [0.00] | [0.00] | [0.03] | [0.00] | [0.01] | [0.01] | [0.00] |
| $\alpha$ | | 0.81 | 0.60 | 0.59 | 0.84 | 0.70 | 0.69 | 0.86 |
| | | [0.02] | [0.05] | [0.10] | [0.02] | [0.04] | [0.05] | [0.02] |
| skew | −0.84 | −0.93 | −0.91 | −0.94 | −0.95 | −0.90 | −0.93 | −0.95 |
| kurt | 5.52 | 5.70 | 5.74 | 5.58 | 5.84 | 5.55 | 5.74 | 5.72 |
| CE | 3.65 | 4.12 | 3.85 | 4.01 | 4.11 | 4.04 | 4.02 | 4.09 |
| TE | 7.40 | 1.89 | 1.73 | 1.95 | 1.92 | 1.94 | 1.90 | 1.97 |

Table 9: Currency Overlay Comparison

Panel A reports the out-of-sample summary statistics of several currency overlay strategies from an U.S. investor's perspective. The currency risk of the global equity portfolio is not (Unhedged) or entirely neutralized (Full Hedged). CMV refers to the approach of Campbell et al. (2010) using currencies to minimize the volatility of the global equity portfolio. CMV TE and CMV RW are an imitation of CMV using a time expanding or rolling window, respectively. The column Uni. Hedge refers to the universal hedging ratio introduced by Black (1989). PPP TE2 (PPP TE5) refers to the base currency overlay following a parametric portfolio policy with a tracking error constraint of 2% (5%). The benchmark portfolio of the base currency overlay is the fully hedged portfolio. A margin requirement of 0% is assumed. ex ret, vol, and SR stand for annualized excess return, volatility, and Sharpe Ratio, respectively. skew and kurt denote skewness and kurtosis, respectively. The certainty equivalent (CE) is expressed in annualized percentage points. Fwd Size refers to the volume of the currency overlay strategy. The numbers in brackets are the p-Values examining the differences in excess return (correlated t-test), volatility (f-Test), Sharpe ratio (boot-TS of Ledoit and Wolf (2008)) to the fully hedged portfolio.
Panel B depicts the exclusively the speculative return (spec ret) for each currency overlay, such that the hedging component is already subtracted. The hedging component is defined by the CMV approach. The sample period is between January 1986 and Decmeber 2016.

Panel A: Summary Statistic

| | Unhedged | Full Hedged | Uni. Hedge | CMV | CMV TE | CMV RW | PPP TE2 | PPP TE5 |
|---|---|---|---|---|---|---|---|---|
| ex ret | 7.61 | 5.44 | 5.74 | 3.28 | 3.67 | 4.90 | 6.70 | 8.26 |
| | [0.05] | | [0.08] | [0.07] | [0.10] | [0.12] | [0.00] | [0.00] |
| vol | 16.33 | 13.90 | 14.14 | 11.95 | 12.66 | 14.98 | 14.22 | 15.27 |
| | [0.00] | | [0.74] | [0.00] | [0.07] | [0.82] | [0.65] | [0.07] |
| SR | 0.47 | 0.39 | 0.41 | 0.27 | 0.29 | 0.33 | 0.47 | 0.54 |
| | [0.47] | | [0.40] | [0.30] | [0.31] | [0.25] | [0.01] | [0.02] |
| IR | 0.29 | | 0.25 | −0.26 | −0.23 | −0.04 | 0.64 | 0.57 |
| | [0.05] | | [0.08] | [0.07] | [0.10] | [0.12] | [0.00] | [0.00] |
| $\alpha$ | 1.90 | | 0.23 | −0.50 | −0.49 | 1.65 | 1.18 | 2.59 |
| | [0.16] | | [0.31] | [0.70] | [0.69] | [0.48] | [0.00] | [0.00] |
| skew | −0.84 | −1.13 | −1.11 | −0.64 | −1.02 | 0.13 | −1.26 | −1.34 |
| kurt | 5.52 | 6.42 | 6.34 | 5.25 | 7.61 | 7.19 | 7.24 | 8.00 |
| CE | 3.65 | 3.47 | 3.59 | 2.91 | 2.64 | 2.62 | 4.39 | 4.91 |
| TE | 7.40 | | 1.22 | 8.22 | 7.62 | 13.67 | 1.98 | 4.92 |

Panel B: Speculative Return

| | Unhedged | Full Hedged | Uni. Hedge | CMV | CMV TE | CMV RW | PPP TE2 | PPP TE5 |
|---|---|---|---|---|---|---|---|---|
| spec ret | 4.33 | 2.16 | 2.47 | | 0.39 | 1.62 | 3.42 | 4.98 |
| | [0.04] | [0.14] | [0.11] | | [0.62] | [0.37] | [0.03] | [0.01] |

Figure 2: Cumulative Return

This figure plots the cumulative portfolio return. Full Hedge refers to a global equity portfolio, which entirely neutralize the currency risk. PPP TE 2 (PPP TE 5) corresponds to the global equity portfolio, which follows the parametric base currency overlay with a tracking error of 2% (5%). CMV TE corresponds to the currency management strategy of Campbell et al. (2010), but in an out-of-sample setting and with a time expanding window.