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International Diversification Benefits with Foreign Exchange Investment Styles

Tim A. Kroencke, Felix Schindler, and Andreas Schrimpf

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Non-technical Summary

Style-based investments and their role for portfolio allocation have been widely studied by researchers in stock markets. By contrast, there exists considerably less knowledge about the portfolio implications of *style investing* in *foreign exchange markets*. Indeed, style-based investing in foreign exchange markets is nowadays very popular and arguably accounts for a considerable fraction in trading volumes in foreign exchange markets. This study aims at providing a better understanding of the characteristics and behavior of style-based foreign exchange investments in a portfolio context. We provide a comprehensive treatment of the most popular foreign exchange investment styles over the period from January 1985 to December 2009. We go beyond the well known carry trade strategy and investigate further foreign exchange investment styles, namely foreign exchange momentum strategies and foreign exchange value strategies. We use traditional mean-variance spanning tests and recently proposed multivariate stochastic dominance tests to assess portfolio investment opportunities from foreign exchange investment styles. We find statistically significant and economically meaningful improvements through style-based foreign exchange investments. An internationally oriented stock portfolio augmented with foreign exchange investment styles generates up to 30% higher return per unit of risk within the covered sample period. The documented diversification benefits broadly prevail after accounting for transaction costs due to rebalancing of the style-based portfolios, and also hold when portfolio allocation is assessed in an out-of-sample framework.

Das Wichtigste in Kürze (Non-technical Summary in German)

Für internationale Aktienmärkte wurden Anlagestile und ihre Rolle für die Portfolio-Allokation in zahlreichen wissenschaftlichen Untersuchungen umfassend analysiert. Dahingegen existieren nur geringe Erkenntnisse bezüglich der Implikationen von *Anlagestilen* auf *Devisenmärkten* für die Portfolio-Allokation. Gleichwohl sind dieser Tage stil-basierte Investment-strategien mit Währungen weit verbreitet und für bedeutsame Anteile der Handelsvolumina auf den Devisenmärkten verantwortlich. Ziel dieser Untersuchung ist es, die Charakteristika und das Verhalten von währungsbasierten Anlagestilen im Portfolio-Kontext besser zu verstehen. Die Studie bietet eine umfassende Betrachtung der prominentesten währungsbasierten Anlagestile für den Zeitraum von Januar 1985 bis Dezember 2009. Als Grundlage dient dabei zum einen die bekannte „Carry Trade“ Strategie sowie darüber hinausgehende Anlagestile in Devisenmärkten, insbesondere sog. „FX Momentum“ und „FX Value“ Strategien. Die Untersuchung beruht auf traditionellen Spanning-Tests und jüngst entwickelten multivariaten Tests auf stochastische Dominanz, um die Vorteilhaftigkeit von währungsbasierten Anlagestilen zu quantifizieren. Diese Arbeit zeigt auf, dass die Diversifikationsvorteile durch währungsbasierte Anlagestile statistisch signifikant und ökonomisch bedeutsam sind. Ein international diversifiziertes Aktienportfolio – erweitert um devisenbasierte Anlagestile – generiert eine bis zu 30% höhere Rendite pro Risikoeinheit innerhalb des Untersuchungszeitraums. Die dokumentierten Diversifikationsvorteile bleiben weitgehend auch existent, wenn Transaktionskosten aufgrund Portfolio-Umschichtungen berücksichtigt werden, und haben ebenfalls im Kontext einer „Out-of-Sample“-Analyse Bestand.

International Diversification Benefits with Foreign Exchange Investment Styles*

Tim A. Kroencke‡ **Felix Schindler**§ **Andreas Schrimpf****

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Abstract

This paper provides a comprehensive analysis of portfolio choice with popular foreign exchange (FX) investment styles such as carry trades and strategies commonly known as FX momentum, and FX value. We investigate if diversification benefits can be achieved by style investing in FX markets relative to a benchmark allocation consisting of U.S. bonds, U.S. stocks, and international stocks. Overall, our results suggest that there are significant improvements in international portfolio diversification due to style-based investing in FX markets (both in the statistical, and most importantly, in the economic sense). These results prevail for the most important investment styles after accounting for transaction costs due to re-balancing of currency positions, and also hold in out-of-sample tests. Moreover, these gains do not only apply to a mean-variance investor but we also show that international portfolios augmented by FX investment styles are superior in terms of second and third order stochastic dominance. Thus, even an investor who dislikes negatively skewed return distributions would prefer a portfolio augmented by FX investment styles compared to the benchmark.

JEL-Classification: G11, G12, G15
Keywords: International Diversification, Foreign Exchange Speculation and Hedging, Carry Trades,
Stochastic Dominance, Investment Styles

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‡Centre for European Economic Research (ZEW), Mannheim, Germany, Email: kroencke@zew.de.

§Centre for European Economic Research (ZEW), Mannheim, Germany, and Steinbeis University Berlin, Berlin, Germany, Email: schindler@zew.de.

**Corresponding Author. Aarhus University and CREATES, School of Economics and Management, Bartholins Alle 10, DK-8000 Aarhus C, Denmark, Email: aschrimpf@creates.au.dk.

I. Introduction

Over the past decades the empirical finance literature has found evidence that several investment strategies in stock markets generate substantial profits. Arguably the most prominent and most widely studied strategies are so-called "value" strategies (taking a long position in stocks with low market value relative to book value while shorting stocks with a high market value relative to book value) and "momentum" strategies (taking a long position in stocks with recently large cumulative returns, referred to as "winners", while shorting past "losers", i.e. stocks with low recent cumulative returns). Capital market phenomena such as value and momentum effects have typically been referred to as "anomalies" due to the difficulty of explaining their high returns by canonical asset pricing models, such as the capital asset pricing model (see e.g. the seminal papers by Fama and French, 1993, Fama and French, 1996, or Jegadeesh and Titman, 1993).[1] This has spurred an ongoing debate and a voluminous literature on the question whether the high returns obtained from exploiting these "anomalies" reflect a compensation for risk or whether alternative explanations should be pursued.[2] Importantly, these capital market phenomena have also generated considerable interest in the asset management industry, where "investment styles" such as value and momentum nowadays play a vital role and are commonly practiced.

While style-based investments and their role for portfolio allocation have been widely studied by academic researchers in stock markets (e.g. Eun, Huang, and Lai, 2008, or Eun, Lai, de Roon, and Zhang, 2010), there exists considerably less knowledge about the portfolio implications of style investing in foreign exchange markets. Yet, style-based investing in foreign exchange markets is nowadays very popular and accounts for a large fraction in trading volumes in foreign exchange markets (Galati, Heath, and McGuire, 2007). Hence, a deeper knowledge of the most popular styles and their implications for optimal portfolio allocation is of substantial interest from both an academic and a practical perspective. This paper aims at providing a better understanding of these issues.

We provide a comprehensive treatment of three different FX investment styles over

[1]Recently, Asness, Moskowitz, and Pedersen (2009) document that there are considerable value and momentum profits in several asset classes and many countries worldwide.

[2]See, among others, Chen, Novy-Marx, and Zhang (2010) and Avramov, Chordia, Jostova, and Philipov (2010) for recent prominent contributions in this literature.

the period from January 1985 to December 2009. We go beyond well known carry trades and investigate two further popular foreign exchange investment styles, namely FX momentum, and FX value. Among the foreign exchange investment styles that we study in this paper, the most prominent strategy is arguably the currency carry trade. The carry trade is the trading strategy derived from the "forward premium puzzle" (Fama, 1984) and consists of long positions in high interest rate currencies that are financed by borrowing in low interest rate currencies. If the interest differential is not offset by corresponding exchange rate movements (i.e. if uncovered interest rate parity, UIP, does not hold), there are considerable gains to be made from this form of currency speculation. Carry trades have shown to be highly profitable (see for instance the seminal paper by Lustig and Verdelhan, 2007), are widely used among professional currency fund managers (Pojarliev and Levich, 2008), and also show up in actual FX transactions data (Galati, Heath, and McGuire, 2007). The remaining two strategies we study – FX momentum, and FX value – have received less attention in the academic literature so far, but are also popular in the asset management industry (Pojarliev and Levich, 2008).[3] Existing empirical evidence (e.g. in recent papers by Asness, Moskowitz, and Pedersen, 2009 and Ang and Chen, 2010) suggests that these investment styles are also highly profitable, which is further confirmed and documented in this paper.[4] This paper, however, is the first to quantify in a comprehensive fashion the magnitude of portfolio diversification benefits that can be obtained from style-based foreign exchange market investments.

We assess the potential benefits for international portfolio diversification by means of classical tests of mean-variance efficiency as well as more recently developed tests that are based on the theoretically appealing concept of stochastic dominance. In our analysis we have to be careful to construct our international benchmark portfolios and our FX style portfolios adequately. As the benchmark allocation, we consider a portfolio of U.S. stocks and U.S. bonds as well as stock portfolios of developed countries and we thoroughly account for any possible exchange rate risk exposure in these portfolios to separate the

[3]Just to name a few real life examples which are even available for non-institutional investors: Deutsche Bank Carry ETF, Deutsche Bank Momentum ETF, and Deutsche Bank Valuation ETF (all based on the G10 currencies); Investment products with carry trade strategies including emerging market currencies are also available from UBS (V24 Carry TR Index).

[4]For a more detailed analysis of FX momentum see, for instance, Okunev and White (2003) or the recent study by Menkhoff, Sarno, Schmeling, and Schrimpf (2010). The latter paper provides a comprehensive analysis of FX momentum strategies, considers the role of transaction costs and discusses from an economic perspective why FX momentum strategies are profitable.

effects from style-based currency speculation. Our initial tests for the benchmark allocation suggest that international stock market investments are only beneficial for a U.S. investor if the exchange rate exposure is adequately hedged (Sharpe ratio rises from 0.29 p.m. in the unhedged case to 0.33 p.m. for the fully hedged case). Thus, we consider an international portfolio of bond and stock market investments where exchange rate risk is controlled for as our benchmark allocation for judging the additional diversification benefits from FX style investing. Our baseline results are obtained for FX style portfolios constructed from 24 very liquid and frequently traded currencies, and a reduced subset of the G10 currencies. Moreover, we consider the role of transaction costs which typically occur due to re-balancing of currency positions in the FX style portfolios in order to provide the most realistic analysis of diversification benefits possible.[5]

Based on this empirical setup we establish three important findings. First, we show that considerable improvements in the portfolio allocation can be achieved by style investing in foreign exchange markets. Considering all three baseline FX styles for international portfolio choice raises the Sharpe ratio to 0.44 p.m., which is a substantial increase relative to the benchmark case (Sharpe ratio: 0.33 p.m., benchmark of U.S. bonds and stocks plus fully hedged international stock market portfolios). Second, these results also hold after correcting for transaction costs (based on quoted bid-ask spreads) that are implied by rebalancing of the FX style portfolios. Third, we also find significant diversification benefits when judged by the stochastic dominance criterion (second and third order stochastic dominance), which is based on less restrictive assumptions compared to the traditional mean-variance framework. Importantly, our findings on third order stochastic dominance imply that even investors who dislike negatively skewed return distributions would prefer international portfolios augmented by FX style portfolios relative to the benchmark case. This is an important finding since some of the FX strategies (especially the carry trade, see e.g. Brunnermeier, Nagel, and Pedersen, 2009) are prone to occasional large losses, i.e. have quite negatively skewed return distributions.

Further, we extend our analysis by considering yield curve strategies in the spirit of Ang

[5]The vast majority of papers in the literature on international diversification typically neglect the role of transaction costs. Important exceptions are the papers by de Roon, Nijman, and Werker (2001) and Eun, Lai, de Roon, and Zhang (2010) who consider hypothetical transaction costs. A virtue of our FX dataset is that we have information on bid-ask spreads available, which allows us to directly consider the role of transaction costs on diversification benefits.

and Chen (2010) and study additional variants of the momentum strategies. From this analysis we conclude that four strategies are particularly successful. Substantial portfolio diversification benefits can be obtained by adhering to carry trades, the FX momentum strategy (based on 3-month cumulative returns prior to portfolio's formation), the FX value strategy and Ang and Chen's (2010) term spread strategy.

As a next step, we reassess our results for our baseline strategies in an out-of-sample setting. Using rolling windows, we apply portfolio optimization rules as well as naive formation rules for the benchmark assets and an augmented asset menu with FX investment styles.[6] Importantly, we find that the diversification benefits of the FX investment styles also show up in these out-of-sample setups. Overall, the results in this paper suggest that there are significant improvements in international portfolio diversification due to style-based investing in foreign exchange markets, both in the statistical and, most importantly, in the economic sense.

Our paper proceeds as follows. We briefly discuss the related literature in Section II.. In Section III., we provide a detailed description of the foreign exchange investment styles in a common framework. Section IV. describes our dataset and shows how our FX style portfolios and benchmark portfolios are constructed. In Section V., we lay out our methodology for studying diversification benefits, which relies on mean-variance efficiency tests as well as tests for stochastic dominance. Section VI. presents our major empirical results on the three investment strategies and illustrates the gains in international portfolio diversification that can be achieved by FX style investing. In Section VII., we look at strategies based on the whole yield curve. Section VIII. reassess our findings out-of-sample, and Section IX. concludes.

II. Related Literature

Ever since the classical studies of Grubel (1968) and Solnik (1974), researchers and practitioners have become aware of the potential benefits from international portfolio diversification. Most of the earlier studies were interested in the potential benefits from investing in international stock markets. Somewhat surprisingly, empirical studies aimed at as-

[6] Such out-of-sample evaluations are common in the related literature, e.g. Glen and Jorion (1993), de Roon, Nijman, and Werker (2003), DeMiguel, Garlappi, and Uppal (2009).

sessing international diversification often had trouble to establish statistically significant benefits. To our knowledge, there is not a single study – analyzing (non-style based) international stock market returns – which finds significant diversification benefits for the tangency portfolio and a recent time period (Britten-Jones, 1999, Errunza, Hogan, and Hung, 1999, Eun, Huang, and Lai, 2008, Kan and Zhou, 2008, Eun, Lai, de Roon, and Zhang, 2010, among others). A possible explanation for this finding discussed in the literature is the ongoing integration of global markets and thus the potentially increasing correlation between international assets and decreasing diversification benefits. Recently, Eun and Lee (2010) document convergence in the risk-return characteristics (measured with the Euclidean distance) of 17 developed stock markets. Bekaert, Hodrick, and Zhang (2009) come to a different finding, using a "parsimonious risk-based factor model". They cannot find evidence for an upward trend in return correlations, except for the European markets.

In contrast, style based stock market investing seems to provide distinguishable diversification benefits for international stocks. Eun, Huang, and Lai (2008) show that diversification benefits are significant and larger for international small cap stocks than for large cap stocks, and Eun, Lai, de Roon, and Zhang (2010) show that similar holds for stock portfolios based on value and momentum strategies in stock markets. However, all studies mentioned above use currency risk unhedged returns. So far, the literature has paid relatively little attention to the role of the foreign exchange rate component of international diversification, which is by construction an unavoidable element of foreign investing.[7] As we will show in this paper, the exchange rate component has a non-negligible impact on international diversification benefits. We can confirm that unhedged international stocks do not provide significant diversification benefits, but in contrast, fully hedged international stocks do provide significant diversification benefits, even when they are non-style based.

Notwithstanding, several studies carefully consider the exchange rate component in foreign investments, such as Glen and Jorion (1993), de Roon, Nijman, and Werker (2003), and most recently Campbell, de Medeiros, and Viceira (2010). However, these studies consider the role of single currency positions and their role for international portfolios.

[7] Interestingly, older studies like Solnik (1974) carefully discuss exchange rate risk problems, whereas more recent studies tend to ignore the foreign exchange component.

Glen and Jorion (1993), as well as de Roon, Nijman, and Werker (2003), do not find (significant) diversification benefits of simple currency positions that go beyond fully hedging the currency risk exposure of stock and bond portfolios. Campbell, de Medeiros, and Viceira (2010) report higher Sharpe ratios for fully hedged and optimally hedged portfolios than for unhedged portfolios. Interestingly, all three studies find further increased Sharpe ratios for portfolios following a hedging strategy conditional on the interest rate differential of the domestic country to the foreign (hence, mimicking a kind of carry trade strategy).[8] This result leads Campbell, de Medeiros, and Viceira (2010) to conclude that, given "the high historical returns to the currency carry trade, foreign currencies are likely to play an important role in such a portfolio choice analysis." Our study is motivated by these initial findings in the extant literature on diversification on simple carry trade investing as well as the considerable returns to other FX investment styles documented elsewhere (e.g. Asness, Moskowitz, and Pedersen, 2009; Ang and Chen, 2010; Menkhoff, Sarno, Schmeling, and Schrimpf, 2010). We go beyond the extant literature by conducting a comprehensive evaluation of the international diversification benefits with systematic foreign exchange positions according to several FX investment styles.[9]

III. FX Investment Styles

We study the diversification benefits of three FX investment styles which can be considered the most popular foreign exchange investment strategies by professional currency fund managers (see e.g. Pojarliev and Levich, 2008) and which have received the utmost attention in the recent academic literature. These foreign exchange investment strategies are known as the currency carry trade, FX momentum, and the FX value strategy. We will describe these strategies in the following.

All three FX investment strategies generally rely on long-short positions in foreign currencies conditional on the signal by a specific instrument available one period before. The difference between the strategies is the specific conditioning variable upon which

[8] Glen and Jorion (1993), de Roon, Nijman, and Werker (2003) also report this increase of the Sharpe ratio to be statistically significant, while Campbell, de Medeiros, and Viceira (2010) do not provide statistical inference for Sharpe ratios.

[9] Further contributions of our paper are testing for stochastic dominance as well as a comprehensive analysis of out-of-sample gains in the spirit of DeMiguel, Garlappi, and Uppal (2009).

the positions are formed. In our empirical analysis, we use monthly observations and re-balance the style portfolios at the start of every month. The end-of-month payoff on a long-forward position (denoted as "FX excess return" in the following) for currency $j = 1, ..., J$ is measured as

$$RX^j_{t+1} = \frac{S^j_{t+1} - F^j_t}{S^j_t}, \tag{1}$$

where S^j_t is the spot U.S. dollar (USD) price of one unit foreign currency j at time $t = 0, ..., T$ and F^j_t is the one period forward price. Computed this way, the FX return is an excess return since it is a zero net investment consisting of selling USD in the forward market for the foreign currency in t and buying USD at the future spot rate in $t+1$. We identify long ($\mathcal{L}^j_t$) and short ($\mathcal{S}^j_t$) positions in currency j, conditional upon the J-dimensional vector of conditioning variables z_t available at time t by

$$\mathcal{L}^j_t = \begin{cases} 1 \;\; if \; z^j_t \geq q(z_t)_{1-p}, \\ 0 \;\; if \; z^j_t < q(z_t)_{1-p}, \end{cases} \tag{2}$$

$$\mathcal{S}^j_t = \begin{cases} 1 \;\; if \; z^j_t \leq q(z_t)_{p}, \\ 0 \;\; if \; z^j_t > q(z_t)_{p}, \end{cases} \tag{3}$$

where $q\left(z_t\right)_p$ is the p-quantile of the elements of z_t. We use $p = 2/9$ throughout the study. Finally, for each FX trading strategy i we form equally weighted portfolios by vector multiplication

$$R^{FX}_{i;t+1}\left(z_t\right) = \mathcal{L}_t \left(\sum_{j=1}^{J} \mathcal{L}^j_t\right)^{-1} RX_{t+1} - \mathcal{S}_t \left(\sum_{j=1}^{J} \mathcal{S}^j_t\right)^{-1} RX_{t+1}, \tag{4}$$

where RX_{t+1} denotes the J-dimensional vector of individual FX excess returns and $R^{FX}_{i;t+1}\left(z_t\right)$ denotes the return on the style-based trading strategy that depends on the conditioning variable z_t. The choice of the instrument z_t determines the particular strategy and will be discussed in turn.

Carry trade strategy. The carry trade is a popular FX investment style which exploits the well-established empirical failure of uncovered interest rate parity (UIP) known as the "forward premium puzzle" (Fama, 1984). Following the seminal paper by Lustig and Verdelhan (2007), our carry trade strategy goes long in an equally weighted portfolio of currencies with the largest nominal short-term interest rates (investment currencies), and short in an equally weighted portfolio of currencies with the smallest nominal short-term interest rates (funding currencies). Thus, our conditioning variable z_t in the carry trade is the interest rate differential between the foreign and the U.S. money market, which we infer from the FX forward premium/discount $(F_t/S_t - 1)$.[10] The carry trade yields a positive return if the differential in interest rates is not offset by a corresponding depreciation of the foreign currency.

Carry trade strategies are very profitable, typically have quite attractive risk-return characteristics, are widely used by practitioners and even show up in turnover data of FX markets (see Galati, Heath, and McGuire, 2007). Of particular interest in the recent academic literature is whether the returns on carry trade strategies can be explained by a risk premium or whether they should be attributed to the presence of market frictions.[11] In distinction to this literature, we take the returns to the carry trade as given and analyze if there is a (significant) demand for carry trade investments in an internationally diversified portfolio, or in other words, if an investor can improve the investment opportunity set by an investment in a carry trade strategy.

FX momentum strategy. In fact, the carry trade is not the only FX investment style discussed in the academic literature and used by professional currency fund managers. Similar to the well-known momentum returns in stock markets (e.g. Jegadeesh and Titman, 1993), momentum profits have also been shown to exist in foreign exchange markets (cf. Okunev and White, 2003, Ang and Chen, 2010, Menkhoff, Sarno, Schmeling, and

[10]No arbitrage (covered interest rate parity) implies that the forward premium is approximately equal to the interest rate differential between the U.S. and the foreign money market. Since covered interest rate parity empirically holds very well at the frequencies studied here (see Akram, Rime, and Sarno, 2008), sorting on interest rate differentials is equivalent to sorting on forward premiums.

[11]See, for instance, Lustig and Verdelhan (2007), Bacchetta and van Wincoop (2010), Christiansen, Ranaldo, and Söderlind (2010), Lustig, Roussanov, and Verdelhan (2010), Verdelhan (2010), Burnside, Eichenbaum, Kleshchelski, and Rebelo (2011), Burnside, Han, Hirshleifer, and Wang (2011), Menkhoff, Sarno, Schmeling, and Schrimpf (2011), for recent contributions.

Schrimpf, 2010).[12] Menkhoff and Taylor (2007) and Pojarliev and Levich (2008) also report some evidence for the high popularity of trend following FX strategies by professional currency fund managers.

Our momentum portfolio goes long in an equally weighted portfolio of currencies with the highest past cumulative returns (so-called "winners") and short in a portfolio of currencies with the lowest past returns (so-called "losers"). We define momentum as the cumulative three-month past returns in the main part of our empirical study, which serves as the conditioning variable z_t for this strategy.[13]

FX value strategy. The basic idea behind the value strategy is to buy currencies considered to trade below a fundamental value and to sell currencies which trade above a fundamental value. This may be interpreted as a contrarian strategy. In the stock market literature, for example, the book-to-market ratio is typically used as a measure for value (Lakonishok, Shleifer, and Vishny, 1994, Fama and French, 1998). A widely used measure for fundamental values in currency markets is the real exchange rate defined as

$$Q_t^j = \frac{S_t^j P_t^j}{P_t^*}, \tag{5}$$

where P_t^j is the price level of consumer goods in country j in the local currency, and P_t^* the corresponding price level in USD. If purchasing power parity (PPP) holds between two countries, equation (5) should be equal to one. Hence, currencies with real exchange rates below unity may be regarded as "undervalued" and currencies traded above as "overvalued". PPP is a rather strong assumption, as an equilibrium real exchange rate can easily deviate from unity (Harrod-Balassa-Samuelson effects).[14] Thus, to avoid problems of defining an equilibrium real exchange rate, we use a measure of "value" defined as the cumulative five-year change of the (log) real exchange rate as our conditioning variable z_t.

[12] Most recently, Asness, Moskowitz, and Pedersen (2009) find that momentum (and value) strategies across countries and several asset classes (e.g. stocks, currencies, and commodities) generate substantial abnormal returns.

[13] We provide additional results for the momentum strategies defined over one- and twelve-month horizons in the robustness section of the paper.

[14] See Sarno and Taylor (2009) for a recent survey of the PPP literature.

IV. Data and Portfolio Construction

In this section we provide an overview of the dataset and outline how the FX style portfolios are constructed.

FX data. Spot and one-month forward exchange rates versus the USD are obtained from Barclays Bank International (BBI) and WM/Reuters (WMR). The FX sample covers 24 currencies of Australia, Brazil, Canada, Denmark, France, Germany, Hungary, India, Indonesia, Italy, Japan, Mexico, the Netherlands, New Zealand, Norway, Poland, Russia, Singapore, South Africa, South Korea, Sweden, Switzerland, Taiwan, and United Kingdom against the USD, which reflect the lion's share of global FX market turnover.[15] For robustness, we also perform tests based on a reduced set of currencies of developed countries, or "G10 currencies" (currencies of Australia, Canada, Germany, Japan, New Zealand, Norway, Sweden, Switzerland, and the United Kingdom to the USD). Some of the currencies are not available over the entire sample period. Thus, our style portfolios containing all currencies are based on 14 currencies in 01/1985 and on 21 currencies in 12/2009. The G10 currencies are available over the complete sample. The time series of the Deutschmark is spliced with the introduction of the Euro in 01/1999. All data are taken from Thomson Reuters Datastream, and span the period from 01/1985 to 12/2009, resulting in 300 monthly observations.[16]

We use CPI data from the IMF's International Financial Statistics (IFS) to calculate real exchange rates for the value strategy. Since the CPI has an arbitrary base year unrelated to PPP, we use the PPP estimate of Heston, Summers, and Aten (2009) for the year 2000 to determine the level of the real exchange rate.[17]

[15] According to BIS (2010), our set of currencies covers 94.99 percent of the global FX market turnover in April 2010. The G10 currencies account for 90.05 percent of the global FX market turnover, with an estimated amount of 3,981 billions USD per day.

[16] We apply the approach of Burnside, Eichenbaum, Kleshchelski, and Rebelo (2011) using exchange rate quotes from WMR against the British Pound swapped to the USD for the 5 year period before 01/1985 to obtain value and momentum conditioning variables starting in 01/1985. The Australian and New Zealand dollar forwards are not available in this dataset. Hence, these two currencies enter the momentum strategy with a delay of three months.

[17] We also tried different base years for the PPP estimate, e.g. 1985 and 2009. The resulting conditioning variable for the value strategy is quite robust, as we use changes in the real exchange rate.

Transaction costs. Our style-based investment strategies involve a re-allocation of the positions in the individual currencies in every month according to the signal by the corresponding conditioning variable. Since the monthly re-balancing of the portfolios potentially involves substantial transaction costs, we compute returns both with and without adjusting for bid-ask spreads. Since the bid-ask spreads in the Reuters/BBI dataset are indicative quotes and are known to overstate the true transaction costs of an investor (Lyons, 2001), our adjustment procedure is a conservative approach of accounting for transaction costs.[18] Also note that the existing literature on international diversification has largely ignored the effects of transaction costs on portfolio returns, most likely due to the fact that no adequate data are available for international stock markets which are the subject of most studies.[19] A virtue of our FX dataset with its information on bid and ask quotes is that we can provide a lower bound on the benefits of the FX style based trading strategies for internationally diversified portfolios after the consideration of transaction costs.

Returns without transaction cost adjustments are based on the mid exchange rate quotes, e.g. $S_{t+1}^{j} = S_{t+1}^{M;j}$. Our results for transaction cost adjusted portfolio returns make use of the ask (bid) exchange rate quotes, $S_{t+1}^{A;j}$ $\left(S_{t+1}^{B;j}\right)$, when a currency enters (leaves) the specific FX investment style portfolio. The same applies to the forward rates, $F_t^{A;j}$ $\left(F_t^{B;j}\right)$. For a currency that is already part of the portfolio and remains in the portfolio, we compute the currency return using the mid quotes and we use mid and ask (bid) exchange rate quotes when a currency enters (is already in) a portfolio and remains in a portfolio (leaves a portfolio). Formally, the computation of bid-ask spread adjusted returns can be expressed as

[18] Given that the quoted spread is likely to overstate the true transaction costs for an investor, another possibility to account for transaction costs could rely on effective spreads similar to Goyal and Saretto (2009).

[19] An exception is de Roon, Nijman, and Werker (2001) who incorporate transaction costs when studying diversification benefits from emerging market stocks. They adjust their test statistics by hypothetical transaction costs rather than adjusting the returns for observed transaction costs, and show that for most countries even a small amount of transaction costs is sufficient to keep investors out of market.

$$
RX^{j}_{t+1} = \begin{cases} \left(S^{M;j}_{t+1} - F^{M;j}_{t}\right)/S^{M;j}_{t} \;\; if\; \mathcal{L}^{j}_{t-1} = 1 \wedge \mathcal{L}^{j}_{t} = 1 \wedge \mathcal{L}^{j}_{t+1} = 1, \\ \left(S^{M;j}_{t+1} - F^{A;j}_{t}\right)/S^{A;j}_{t} \;\; if\; \mathcal{L}^{j}_{t-1} = 0 \wedge \mathcal{L}^{j}_{t} = 1 \wedge \mathcal{L}^{j}_{t+1} = 1, \\ \left(S^{B;j}_{t+1} - F^{M;j}_{t}\right)/S^{M;j}_{t} \;\; if\; \mathcal{L}^{j}_{t-1} = 1 \wedge \mathcal{L}^{j}_{t} = 1 \wedge \mathcal{L}^{j}_{t+1} = 0, \\ \left(S^{B;j}_{t+1} - F^{A;j}_{t}\right)/S^{A;j}_{t} \;\; if\; \mathcal{L}^{j}_{t-1} = 0 \wedge \mathcal{L}^{j}_{t} = 1 \wedge \mathcal{L}^{j}_{t+1} = 0, \end{cases} \tag{6}
$$

for the long positions and vice versa in the case of short positions, i.e. exchanging A for B, B for A, and $\mathcal{L}_{t-1}$, $\mathcal{L}_{t}$, $\mathcal{L}_{t+1}$ for $\mathcal{S}_{t-1}$, $\mathcal{S}_{t}$, $\mathcal{S}_{t+1}$.

Benchmark assets: U.S. bonds, U.S. stocks, and international stocks. Our empirical tests allow us to quantify the diversification benefits from style-based FX investing relative to a benchmark portfolio allocation. As our benchmark we consider a typical internationally diversified portfolio which consists of U.S. assets and international stocks. We use the Merrill Lynch U.S. Government Total Return index with 7 to 10 years to maturity to represent the U.S. bond market and the MSCI Total Return indices of the U.S., Australia, Canada, Germany, Japan, New Zealand, Norway, Sweden, Switzerland, and the United Kingdom for the equity markets. Hence, for all nine currencies which form the basis of our style portfolios based on the G10 currencies, there is a corresponding return on a broad stock portfolio of the respective country. Furthermore, the covered benchmarks provide the best possible comparison to the existing literature on international diversification in developed markets.[20] Stock and bond market returns are monthly returns in excess of the one-month U.S. Treasury bill rate from Ibbotson (available on the homepage of Kenneth R. French). Since we study diversification benefits from the perspective of a U.S. investor, we use international indices expressed in USD.

Controlling for FX exposure in the benchmark assets. The raw international stock returns in our benchmark portfolio are exposed to exchange rate risk, i.e. they are unhedged returns $R^{u;j}_{t+1}$. However, it is possible to counteract the foreign exchange rate risk by an arbitrary hedging strategy. The hedged return $R^{h;j}_{t+1}$ can be written as

[20]Glen and Jorion (1993), de Santis and Gerard (1997), Britten-Jones (1999), de Roon, Nijman, and Werker (2003), Kan and Zhou (2008), Eun, Lai, de Roon, and Zhang (2010), among others, cover similar assets and international markets.

$$R_{t+1}^{h;j} = R_{t+1}^{u;j} - \psi_{t+1} RX_{t+1}^{j}, \tag{7}$$

where ψ_{t+1} is the hedge ratio. Anderson and Danthine (1981) and Jorion (1994), for instance, derive optimal hedging strategies for a mean-variance investor. Such optimal hedge ratios consist of a speculative component and a hedging component. The speculative component is based on the risk-return ratio of the FX returns, whereas the hedging component depends on the correlation to the core assets. The unhedged strategy ($\psi_{t+1} = 0$) can be said to be mean-variance optimal if expected FX returns are zero and are uncorrelated with the foreign asset return measured in USD. On the other hand, the full hedge, or unitary hedge, ($\psi_{t+1} = 1$), turns out to be mean-variance optimal if expected FX returns are zero and are uncorrelated with the foreign asset return measured in the local currency. As argued by Jorion (1994), it is unlikely that the FX returns are uncorrelated with the foreign asset return since both contain the change of the spot exchange rate. Alas, the conditions behind the full hedge seem to be more realistic, which may explain the popularity of the full hedge strategy in several studies (e.g. Eun and Resnick, 1988, among others). In a recent empirical study, Campbell, de Medeiros, and Viceira (2010) focus on the hedging component for FX returns and conclude that an optimal hedge strategy for an international bond portfolio comes very close to the full hedge. However, they find quite large over/under-hedging demand for international stock portfolios. For example, their risk-minimizing hedging ratio is larger than unity for the Australian dollar and less than unity for the Swiss Franc, reflecting that many currencies are typically not uncorrelated with international stock market returns.

FX investment styles based on the yield curve. Recently, Ang and Chen (2010) find that the whole yield curve (i.e. not just the short end as in the carry trade) can provide predictive signals for future FX returns. They rationalize these findings by a no-arbitrage term structure model which allows for multiple risk factors. Based on the findings reported by Ang and Chen (2010), we analyze several additional yield curve-based FX trading strategies in order to assess their potential benefits for international portfolio diversification. The set of additional strategies is based on the level of long-term rates, changes of short-term rates, changes of long-term rates, and the term spread. Ang and Chen (2010) report more attractive (i.e. less negative) skewness characteristics and low correlation with carry trade returns for the strategies based on interest rate changes and term spreads. While they provide evidence from predictability regressions and univariate time series regressions on various explanatory variables, we show that their proposed strategies can be fruitfully employed in a portfolio context as well.

We calculate the returns on these strategies in a similar fashion as for our FX investment strategies based on the G10 currencies described above. We use one-month Eurodollar interest rates as short-term interest rates, and the IMF's International Financial Statistics (IFS) as our source for the long-term interest rates, available via Thomson Reuters Datastream. For Australia, New Zealand, Norway, and Sweden, Eurodollar interest rates are only available from 04/1997 onwards. In these cases, we use the IFS short-term interest rates for the periods before.

V. Methods

In this section, we lay out our methodology for quantifying the benefits from style-based FX investing for international portfolio diversification. First, we briefly discuss classical tests for mean-variance efficiency, and second, we turn to tests based on the theoretically appealing criterion of stochastic dominance.

A. Mean-Variance Efficiency Tests

Regression-based test. The economic question in our context is whether adding style-based FX portfolios to an international diversified portfolio allows for improvements of the mean-variance frontier and may thus be beneficial from an investor's perspective. In consequence of the optimality nature of mean-variance frontiers, the frontier of the augmented set of $N + K$ assets can only be improved with respect to the frontier spanned by the smaller set of K benchmark assets. The regression-based test of mean-variance efficiency proposed by Huberman and Kandel (1987) and Jobson and Korkie (1989) allows for formal statistical inference on whether a shift of the investment opportunity set is too large to be attributed by chance. With the ability to borrow and invest in a risk-free asset, a test of mean-variance efficiency comes down to a test of the shift of the tangency portfolio, or in other words, to testing if the two mean-variance frontiers intersect at the point with the maximum Sharpe ratio. The intersection hypothesis for the tangency portfolio implies that

$$R_{t+1}^{N} = \alpha + \beta R_{t+1}^{K} + \varepsilon_{t+1}, \tag{8}$$

where R_{t+1}^{N} is an N-dimensional vector of test asset excess returns, R_{t+1}^{K} is a K-dimensional vector of benchmark excess returns and the elements of the N-dimensional vector of intercepts are not significantly different from zero, $H_0 : \alpha = 0_N$. We report an exact F test, $F \sim F_{N,T-K-N}$, and an asymptotic Wald test, $W_{hac} \sim \chi_N^2$, which is robust against heteroscedasticity and autocorrelation (HAC).

Stochastic discount factor-based test. Bekaert and Urias (1996) propose an alternative to the regression-based mean-variance efficiency tests, which exploits the duality between Hansen and Jagannathan (1991) bounds and mean-variance frontiers. Consider the general asset pricing restriction for the $N + K$ asset excess returns, $R_{t+1} = \left[R_{t+1}^{N\prime}, R_{t+1}^{K\prime}\right]'$:

$$E\left[R_{t+1} m_{t+1}\right] = 0_{N+K}, \tag{9}$$

where m_{t+1} is the projection of a stochastic discount factor (SDF) with mean $v = E\left[m_{t+1}\right]$ onto the demeaned $N + K$ asset returns

$$m_{t+1} = v + \left[R_{t+1} - E\left(R_{t+1}\right)\right]' b. \tag{10}$$

The SDF given by equation (10) prices the $N + K$ asset returns correctly by construction. Bekaert and Urias (1996) show that mean-variance efficiency of the K benchmark assets is implied by the N restrictions $b^N = 0_N$. In words, only the benchmark assets are necessary to price the augmented set of $N + K$ assets correctly. This estimation problem can be cast in a typical Generalized Methods of Moments (GMM) framework. We set $v = 1$ which corresponds to testing the tangency portfolio in the mean-variance space, and we report a heteroscedasticity- and autocorrelation-robust asymptotic GMM Wald test, $SDF_{hac} \sim \chi_N^2$. As proposed by Kan and Zhou (2008), we correct the test statistic for errors-in-variables, since the mean of the $N + K$ asset returns also has to be estimated.[21]

B. Stochastic Dominance Efficiency Tests

As is well known, in the case of non-normally distributed asset returns, the mean-variance criterion for optimal portfolio decisions of investors can only be justified by quite unrealistic assumptions, such as a quadratic utility function (Mao, 1970, Samuelson, 1970), and thus a linear function for marginal utility (or stochastic discount factors) and the market return. An appealing framework to avoid the shortcomings of the mean-variance paradigm is the concept of stochastic dominance. We briefly outline our testing approach in the following.[22]

A portfolio is second-order stochastic dominance (SSD) efficient if, and only if, it is optimal for a non-satiable and risk-averse investor, and it is third-order stochastic dominance (TSD) efficient if, and only if, it is optimal for a non-satiable, risk-averse and skewness-loving investor (Fishburn, 1977, Levy, 2006). Formally, SSD can be represented by any utility function U with a non-negative first derivative ($U' \geq 0$) and a non-positive second derivative ($U'' \leq 0$), where the inequalities are strict at least at one point. TSD adds the restriction of a non-negative third derivative of the utility function ($U''' \geqslant 0$) corresponding to the skewness-loving property.

Thus, the exact specification of the utility function (and hence the stochastic discount factor) of the investor is left unspecified, but it is merely restricted to be economically sensible. Stochastic dominance tests have not been applied in empirical finance on a broad scale, most likely since most tests are pairwise comparisons between investment opportunities and do not apply for portfolio choice problems in a multivariate context.

Our testing approach follows Post and Versijp (2007). Post and Versijp (2007) overcome this problem by proposing a formal SSD and TSD test in the spirit of the mean-

[21]The sample moments for the GMM estimation are stated in Kan and Zhou (2008). Our test statistic SDF_{hac} corresponds to J_1 in their notation when testing for intersection rather than spanning and excess returns are used instead of gross returns. Kan and Zhou (2008) also present some evidence on the power and size of the SDF-Wald test and perform a comparison to the regression-based approach. They find no important differences between the asymptotic test statistics when returns follow a multivariate normal distribution. However, their simulation study shows that the regression-based version is favorable to the SDF-based test when returns follow a multivariate Student-t distribution, which exhibits fatter tails than the multivariate normal.

[22]This subsection briefly introduces the concept of stochastic dominance. Further details on empirical testing procedures are discussed in Appendix A.

variance efficiency tests described above. The mean-variance efficiency tests described in the previous section use a parametrically specified (marginal) utility function, or, in terms of the stochastic discount factors, the SDF is explicitly formulated as a linear function of a portfolio return which lies on the mean-variance frontier. The SSD and the TSD tests, by contrast, allow for non-quadratic utility and non-normal distributions, leaving the exact functional form of the utility function unspecified but restricted to the SSD and TSD criterion. Appendix A examines the computational issues of the SSD and TSD tests, which assign "pricing errors" to a set of test assets, given a benchmark allocation. Intuitively, a positive pricing error of a specific test asset can be interpreted as an investor's desire to increase her allocation with respect to the benchmark. If the pricing error is also statistically significant, one may reject the hypothesis of stochastic dominance efficiency of the benchmark allocation.

VI. Diversification Benefits with FX Investment Styles

Before we turn to the quantification of diversification benefits from FX style investing, we start by providing summary statistics of our benchmark and test assets. We discuss results from classical mean-variance efficiency tests and, subsequently, the findings obtained from multivariate stochastic dominance tests.

A. Descriptive Statistics

Table 1 reports summary statistics for our set of test and benchmark assets for the mean-variance and stochastic dominance efficiency tests.

Benchmark assets. Panel A shows monthly excess returns of U.S. assets. The mean return of U.S. stocks is 7.0% p.a. and thus larger than for U.S. bonds (4.1% p.a.). However, compared to U.S. stocks, bonds exhibit more return-per-risk measured by the Sharpe ratio, reflecting an extraordinary good performance of the bond markets over the past decades compared to the longer history (see Palazzo and Nobili, 2010, for a discussion). Panel B reports the returns of international stock market investments. The lowest unhedged excess stock return can be found for Japan (3.5% p.a.), and the highest for Sweden (13.8% p.a.). All international unhedged equity market returns are more volatile than U.S. stock market returns. In terms of Sharpe ratios, all nine unhedged stock markets on average perform similar to the U.S. stock market. With the exception of Japan, all international stock markets also show a negatively skewed return distribution similar to returns on U.S. equities.

– Insert TABLE 1 about here –

In general, a full hedge should reduce the risk of a position, since the uncertain exchange rate component is replaced by the certain forward premium/discount (known to the investor in t). However, the impact on the average return of the fully hedged position depends on the average FX excess return, which could generally be negative as well as positive. Turning to the middle block of Panel B, we find, as expected, considerably smaller standard deviations for the hedged returns in all nine international equity markets. Note that the average returns are also reduced for all nine fully hedged markets, reflecting a rather weak USD over our sample period. The effect on the risk-return characteristics of international equity markets can be quite substantial: for example, the Sharpe ratio of the New Zealand stock market drops from 0.08 p.m. to almost zero when the currency risk is fully hedged.

Turning to the right-hand side of Panel B, all nine FX excess returns have a positive average return and the standard deviations of the FX excess returns are lower than those of stock market returns, but higher than for U.S. bonds. FX excess returns with relatively low interest rates over a large part of the sample period, such as the Swiss Franc or the Japanese Yen (typical carry trade funding currencies), have a positively skewed return distribution, whereas the FX excess returns of high interest rate currencies such as the the Australian dollar (a typical carry trade investment currency) are considerably negatively skewed (see, e.g. Brunnermeier, Nagel, and Pedersen, 2009).

Test assets. Panel C reports summary statistics for the three FX investment styles (carry trade, momentum, and value) which are described in section III.. In the upper half, the currency strategies are based on all available currencies, and below they are only based on the currencies of the developed countries, or G10 currencies. All three strategies have positive average returns. Our carry trade portfolio (before transaction costs) has an average return of 9.1% p.a. and a standard deviation of 10.1% p.a. The FX momentum and the FX value strategy have average returns of 5.9% p.a. and 4.7% p.a., respectively, with comparable standard deviations, but in contrast to the carry trade, their returns are less negatively skewed. This may be an appealing characteristic for an investor who is concerned about higher moments (skewness or kurtosis) beyond mean and variance. The FX investment styles based on the smaller set of G10 currencies have qualitatively similar return-risk characteristics. However, the average return for the carry trade and FX momentum is smaller and the standard deviations of all three styles is larger than their counterparts based on the expanded currency set.

– Insert FIGURE 1 about here –

Figure 1 illustrates the cumulative returns on all three FX investment styles. All three of them show a heterogeneous behavior over time. Moreover, the sub-table with bid-ask spread-adjusted returns of Panel C shows that transaction costs affect the FX investment styles differently. While the carry trade return is only slightly reduced by 0.6% p.a., transaction costs eat up about 1.4% p.a. of the return to the FX momentum strategy.[23] This pattern is also illustrated in Figure 2 for the FX momentum and the carry trade strategies, and reflects that some strategies require more frequent portfolio re-balancing and that there are substantial differences in the characteristics of the funding and investment currencies (Menkhoff, Sarno, Schmeling, and Schrimpf, 2010). In line with Figure 1, the correlation matrix in Panel C shows that all three FX investment styles are not mere copies of each other. We find quite low correlations between the strategies, most of which are single digit.

– Insert FIGURE 2 about here –

B. Mean-Variance Efficiency Tests

Evaluating the benchmark frontier. We consider a domestic portfolio containing U.S. bonds and U.S. stocks plus international stock markets in order to characterize the

[23]See Menkhoff, Sarno, Schmeling, and Schrimpf (2010) for a detailed analysis of the differences between carry trade and momentum strategies.

benchmark investment universe. We carefully control for the foreign exchange rate component which is also present in the international equity market returns. The mean-variance frontier spanned by these traditional assets typically used for international portfolio diversification will be our benchmark allocation in the following. In our tests, we then formally evaluate if this benchmark allocation can be improved by augmenting the set of investment opportunities by FX style portfolios.

The existing evidence in the literature on the diversification benefits from international stocks is rather weak. To our knowledge, there is not a single study able to report significant diversification benefits from a broad set of unhedged and (non-style based) international stock market returns for the tangency portfolio and a recent time period (Britten-Jones, 1999, Errunza, Hogan, and Hung, 1999, Eun, Huang, and Lai, 2008, Kan and Zhou, 2008, Eun, Lai, de Roon, and Zhang, 2010, among others). Our results on the benchmark allocation in Table 2, Panel A, for unhedged international stocks are in line with these findings. Although we find a substantial increase of the Sharpe ratios from 0.21 p.m. (U.S. portfolio of stocks and bonds) to 0.29 p.m. for the same portfolio augmented with international stocks, the increase is insignificant according to the F and SDF_{hac} test at common significance levels. Only the p-value for the W_{hac} test is slightly below 10%. Clearly, the economically large but statistically insignificant diversification gains reflect quite a substantial magnitude of sampling error.

– Insert TABLE 2 about here –

As indicated by the descriptive statistics discussed above, the effect of the currency component of international assets seems to be quite influential. In the lower row of Panel A we repeat the mean-variance efficiency tests with fully hedged international stock returns instead of unhedged returns. In the full hedge setting, the mean-variance optimal U.S. portfolio augmented with international stocks increases the Sharpe ratio from 0.21 p.m. to 0.33 p.m. Remarkably, the increase of the Sharpe ratio for the hedged returns represents a statistically significant improvement in the mean-variance space. All three test statistics can reject intersection for the tangency portfolio at the 5% level. The effect of eliminating unintended currency positions in international equity markets is striking, as it reveals the true diversification benefits from international equities dissected from FX risk.

Next, we want to see if there are further benefits from simple FX excess returns, computed as in equation (1), beyond hedging. Table 2 presents results of when U.S. assets and international stocks represent the benchmark allocation and FX excess returns are considered additional test assets.[24] First, we take the unhedged international stocks as benchmark assets. As shown in Panel B, the FX excess returns significantly improve the mean-variance frontier (the highest p-value can be found for the SDF_{hac} test, 0.05). Most importantly, as soon as we replace the unhedged by fully hedged international stocks as the benchmark, the mean-variance efficiency tests turn insignificant. Hence, we conclude that simple FX excess returns are redundant assets as soon as they are used to unwind any unintended foreign currency exposure in the international stock positions.[25] Consequently, we will focus on the unhedged and the fully hedged strategy as our benchmark allocation in the remainder of the study, since it is statistically justified by the mean-variance efficiency tests. Furthermore, the unhedged and the fully hedged international portfolios are economically interesting benchmarks for the FX investment style portfolios, as they reveal how the results are affected when the benchmark portfolio either contains unintended foreign exchange risk or when almost all FX risk exposure in the benchmark portfolio has been eliminated.

International diversification with FX investment styles. Now, we consider if style based FX investments are able to provide diversification gains relative to the benchmark allocation. Table 3 presents results from mean-variance efficiency tests in order to assess the diversification benefits from FX investment styles quantitatively. The benchmark assets are U.S. bonds and U.S. stocks as well as international stocks. In Panel A, the FX investment styles are based on all available currencies, whereas Panel B shows results for the strategies based on the G10 currencies. The FX investment styles are adjusted for transaction costs.

Overall, we find economically large and statistically significant diversification benefits for several FX investment styles. When the currency risk of the benchmark assets is

[24]Only a handful of studies test the diversification benefits from simple FX excess returns (long forward positions), e.g. Glen and Jorion (1993), de Roon, Nijman, and Werker (2003), Eiling, Gerard, Hillion, and de Roon (2009), and most recently Campbell, de Medeiros, and Viceira (2010).

[25]These findings are broadly in line with Glen and Jorion (1993) who do not find any significant performance improvement for international stock portfolios from FX excess returns.

fully hedged (right hand side of the table) and the carry trade portfolio is added to the investment universe, we find a substantial increase of the Sharpe ratio from 0.33 p.m. to 0.41 p.m. Likewise, the value style increases the Sharpe ratio to 0.36, while the increase is slightly less for the momentum strategy (0.35). In statistical terms, it is possible to reject mean-variance efficiency for the benchmark in case of the carry trade at the 1% level and for the momentum and value style at the 5% level in case of the regression-based tests. Similar, the SDF-based test statistics confirm significant improvements (at least at the 10 % level). As shown in the last row of Panel A, considering all FX investment styles jointly yields a substantial increase in the portfolio's Sharpe ratio from 0.33 to 0.44 p.m., i.e. an increase of about 30% return per unit of risk on a monthly basis. This improvement in the portfolio allocation is significant at the 1% level for all three test statistics.

– Insert TABLE 3 about here –

The results in Panel A of Table 3 are confirmed when using *unhedged* international stocks as the benchmark. The increases of the Sharpe ratios are generally of a similar magnitude. For example, when adding all three FX investment styles to the benchmark, the Sharpe ratio is increased from 0.29 to 0.42. The p-values of the test statistics are below the ones in the fully hedged setting in almost all cases. Hence, our results for the FX investment styles are clearly not driven by simply unwinding the unintended currency risk in the first instance.

In Panel B of Table 3, we repeat the spanning tests with FX investment styles based on the smaller set of G10 currencies and draw qualitatively similar results. The increase in the Sharpe ratios is quite large, up to 18%, though the increase is generally less than in Panel A. Accordingly, we also see larger p-values for the test statistics. We can still reject spanning at the 10% level in all cases, with exception of the HAC robust tests for the value strategy.

– Insert FIGURE 3 about here –

Figure 3 summarizes the results and visualizes that the shift due to the FX investment styles of the investment opportunity set in the traditional mean-standard deviation space is not only statistically significant, but also highly interesting in economic terms.

As robustness check, Appendix Table A.1 presents results when we also include the simple FX excess returns as benchmark assets (i.e., we use the mean-variance frontier obtained in Table 2, Panel B as "*optimally hedged*" benchmark frontier to be beaten by the FX investment styles). In this setting, the notable increases in Sharpe ratios remain, and are highly significant for the carry trade (1% level), and the value style (5% level), but less for the momentum style (10% level). We conclude that the diversification benefits from FX investment styles are relatively independent from unconditional investments in single currencies.

In the face of the discussion provided in section IV. that quoted spreads in our data are likely to overstate true transaction costs of a typical investor (Lyons, 2001), our results based on transaction cost-adjusted returns provide a lower bound on the diversification benefits by FX investment styles and are hence conservative. The available supplementary Web Appendix to this paper also provides results without taking transaction costs into account, which serves as an indication of an upper bound of the diversification benefits.

C. Stochastic Dominance Efficiency Tests

In contrast to the mean-variance tests before, the stochastic dominance tests are based on relatively mild assumptions about investor preferences. We calculate the mean-lower partial moment tangency portfolio constructed from U.S. bonds/stocks and international stocks as our benchmark and test it for stochastic dominance efficiency against the FX investment styles.[26]

Panel A in Table 4 shows the results of the SSD and TSD tests. In the fully hedged setting, the SSD test (p-value 0.00) and TSD test (p-value 0.00) allow for the conclusion that the FX investment styles improve the investment opportunity under very general conditions and not only for mean-variance investors. The carry trade has, in every setting, by far the highest pricing error (implying that its portfolio share should be increased the most with respect to the mean-$LPM_2(0)$ tangency portfolio constructed from the benchmark assets), followed by the value and the momentum style portfolios with pricing errors similar in magnitude.

[26]According to Bawa (1975) and Fishburn (1977), the lower partial moment as risk criterion is in line with stochastic dominance efficiency. We use the second-order lower partial moment with a target rate of zero ($LPM_2(0)$) throughout the study. See Appendix A for a more detailed discussion.

– Insert TABLE 4 about here –

In Panel B of Table 4 we focus on the FX investment styles based on the smaller set of G10 currencies. Similar to the previous results, in this setting the SSD test (10% level) and the TSD test (5% level) also allow for rejection of stochastic dominance efficiency of the benchmark.

These results are important for the following reason. It is well known that portfolios based on carry trade strategies exhibit negative skewness and are prone to sudden large losses as documented by Brunnermeier, Nagel, and Pedersen (2009) and Farhi, Fraiberger, Gabaix, Rancière, and Verdelhan (2009). This raises the question of how robust the mean-variance criterion is for optimal portfolio decisions, since this framework does not take higher moments of returns into account. Figure 4 shows the SDFs (or marginal utilities) estimated from the SSD and TSD tests above.[27] We also report hypothetical SDFs of a mean-variance efficiency test with the same benchmark and the same test assets, which must be a straight line in the SDF-return space. We find only modestly kinked SDFs for the stochastic dominance efficiency tests that are well approximated by the mean-variance SDFs. As these figures imply, it seems that in our setting the mean-variance criterion is quite an applicable approximation for more complex utility functions which are in line with SSD and TSD. This also explains the conformity of the stochastic dominance tests with the previous mean-variance tests.[28] A possible explanation could be that high downside risk on the FX portfolios can be well diversified in a portfolio context, since co-movements between the FX investment styles and the stock markets are relatively low.[29]

– Insert FIGURE 4 about here –

[27]The shown pricing kernels are based on the setting with fully hedged stocks and FX styles based on all countries, differences to the unhedged and G10 setting are very small and almost not visible.

[28]Post and Versijp (2007) find highly kinked SDFs from the SSD and TSD test for U.S. portfolios sorted on beta, reflecting that the mean-variance criterion can indeed be potentially misleading in general.

[29]Fong (2010) uses pairwise stochastic dominance tests and compares yen carry trade portfolios with a global and a U.S. stock market portfolio. He finds that carry trades SSD- and TSD-dominate the stock market portfolios, even without accounting for diversification benefits.

VII. Other FX investment styles

Recently, Ang and Chen (2010) find that yield curve predictors other than short-term rates – as in conventional carry trade strategies – contain predictive signals for future foreign exchange returns. Drawing on their findings, we construct additional yield curve-based FX investment style portfolios based on long-term rates, the change of short-term rates, the change of long-term rates, and the term spread. In this section, we investigate the role of these yield curve strategies for optimal portfolio choice. Furthermore, since we showed above that strategies based on past returns (three-month momentum) are quite successful, we also consider in this section how robust the FX momentum strategy is when it is based on a one-month (momentum1) or twelve-month window (momentum12). Finally, another popular style for FX investments is based on FX volatility. Currency managers seek long positions when volatility decreases in FX markets and enter short positions when volatility is increasing (Pojarliev and Levich, 2008). To capture a pure volatility-based strategy, we construct a portfolio that goes long in an equally weighted portfolio of currencies with the lowest individual increase (or possibly decrease) in volatility and short in currencies with large increases in volatility. We proxy for volatility by the mean of the absolute FX returns of the past 66 trading days (approximately three months) of each individual currency j. To be precise, our conditioning variable z_t is computed as the difference of the volatility measure over the three months before portfolio formation.[30] For all additional FX investment styles in this section, we use the smaller set of G10 currencies.

Table 5 shows summary statistics of the additional FX investment style portfolios together with our baseline portfolios. In line with the findings of Ang and Chen (2010), we find respectable excess returns for all four additional yield curve strategies ranging from 3.0% p.a. for the long-term rate to 6.0% p.a. for the term spread portfolio. However, after accounting for transaction costs, the returns for the change of short-term rate and the change of long-term rate strategy decrease substantially, possibly due to frequent portfolio re-balancing. A similar decrease can be observed for the additional momentum strategies, in particular for the one-month momentum portfolio, where almost 3/4 of the returns

[30] Hence, the strategy we study here is based on a measure of idiosyncratic FX volatility. This differs from the analysis in Menkhoff, Sarno, Schmeling, and Schrimpf (2011) who show that an aggregate volatility risk factor performs well in explaining the cross-section of carry trade portfolios and beyond. They also show that sorting on volatility-betas generates portfolios which are remarkably similar to carry trade portfolios.

are lost due to transaction costs (Menkhoff, Sarno, Schmeling, and Schrimpf, 2010). The loss from transaction costs is much less pronounced for the three-month momentum and twelve-month momentum strategies.

Panel B reports correlations among the returns of the augmented set of FX trading strategies. The long-term rate strategy is highly correlated with the carry trade (correlation of 0.87), which is not surprising since both are based on the level of the yield curve. Similarly, a quite high correlation to the carry trade can be observed for the term spread strategy (correlation of 0.64). Nearly uncorrelated with the baseline FX investment style returns are the strategies based on the change in short-term and long-term rates.

– Insert TABLE 5 about here –

Panel A of Table 6 shows mean-variance efficiency tests for the additional FX investment strategies based on yield curve variables. For the sake of a better overview and to provide the most conservative assessment, we focus on transaction cost-adjusted returns. In addition to the carry trade, we find also a considerable improvement of the Sharpe ratio from 0.33 p.m. to 0.36 p.m. for the term spread-based strategy put forth in Ang and Chen (2010). All three test statistics corresponding to the term spread portfolio are significant at the 5% level. Notable improvements are also detected for the strategy based on changes in long-term rates, with a maximum attainable Sharpe ratio of 0.35. However, only the two regression-based tests are significant at the 10% level. The improvement of the mean-variance frontier is lowest for the strategies based on changes in short-term rates and long-term rates (both with Sharpe ratios of 0.34), and is also statistically insignificant. As reported in Panel B, both additional momentum strategies (one-month and twelve-month) hardly provide any improvements. Not surprisingly, all three test statistics are insignificant for the two additional momentum strategies.

– Insert TABLE 6 about here –

In a nutshell, Ang and Chen's (2010) term spread strategy is the only additional FX investment style delivering further portfolio improvements. All other strategies, including one-month and twelve-month FX momentum and a FX volatility strategy, cannot compete with the baseline FX investment styles presented in the previous sections.

VIII. Out-of-Sample Results

The previous results indicate that it has historically been possible for an investor to improve the portfolio's Sharpe ratio using FX investment styles. However, the optimal portfolio weights are revealed ex post. Therefore, we reassess our results for the three baseline FX investment styles, namely the carry trade, FX momentum (three-month), and FX value, when only prior information is used for portfolio formation.

In a rolling sample approach, we take the first 120 observations of our sample to compute optimal portfolio weights and calculate the implied portfolio return for the following period. Next, we move the rolling window one period forward and repeat the previous steps. This results in a time-series of out-of-sample portfolio returns.[31] We first follow this procedure for the benchmark assets containing U.S. bonds/stocks and international stocks and then applying it to the augmented set of assets including the baseline FX investment styles. In the spirit of DeMiguel, Garlappi, and Uppal (2009), we use optimized as well es naive portfolio formation rules.[32] We do not intend to compare different portfolio rules with each other or even to recommend one of them, as each has its specific drawbacks and difficulties. Rather, we focus on the comparison (i.e. the change in the Sharpe ratio) between the portfolio containing the benchmark assets and the portfolio containing the augmented asset menu given a particular portfolio formation rule.

As naive portfolio formation rules we use equal weights to all assets ("1/N"), conservative weights (60% U.S. bonds), balanced weights (30% U.S. bonds), and aggressive weights (0% U.S. bonds).[33] For the optimized portfolios, we use the unconstrained mean-variance (tangency) portfolio, the mean-variance Bayes-Stein shrinkage portfolio, the mean-variance portfolio with short selling constraints, and the minimum variance

[31]Thus, our out-of-sample setting is comparable to the related literature, e.g., Glen and Jorion (1993), de Roon, Nijman, and Werker (2003), DeMiguel, Garlappi, and Uppal (2009).

[32]DeMiguel, Garlappi, and Uppal (2009) evaluate the out-of-sample performance of the mean-variance model and the naive 1/N (equal weights) rule across several datasets. Overall, they do not find consistently better results from optimal portfolio formation rules compared to a simple 1/N rule.

[33]In the benchmark portfolio "conservative" we allocate 60% to U.S. bonds, and 40% to the stock markets. The weights of the stock markets are according to the country's relative World (PPP) GDP share from the IMF, and imply an allocation of 50% to U.S. stocks and 50% to international stocks. For the augmented portfolio, we assign the same allocation to the FX investment styles as to international stocks and rescale the portfolio weights to 100%. In the balanced and aggressive portfolio, we change the weight of U.S. bonds and recalculate the allocation to all other assets such that their relative weights to each other remain unchanged.

portfolio as described in DeMiguel, Garlappi, and Uppal (2009). Furthermore, we consider the unconstrained mean-variance portfolio, but calculated with an expanding window instead of a rolling window.[34]

A serious problem with the optimized portfolio formation rules is that they typically exhibit noisy weights, which may imply quite large (and in some cases from a practical point of view simply impossible) portfolio turnovers (see DeMiguel, Garlappi, and Uppal, 2009). As the naive portfolio rules only imply a small amount of portfolio turnover, they are intended to give an idea of the portfolio improvement through the FX investment styles without this issue. Furthermore, real life investors do follow naive portfolio rules (Benartzi and Thaler, 2001), and given that this paper is about portfolio improvement with FX investment styles and not portfolio optimization techniques it seems useful to include some simple portfolio formation rules as well.

Table 7 reports the out-of-sample Sharpe ratio of the benchmark portfolio containing U.S. bonds, U.S. stocks and international stocks (labeled "Bench") and next to it the out-of-sample Sharpe ratio of the portfolio augmented with the Carry trade ("Carry"), the FX momentum strategy ("Mom"), the FX value strategy ("Value"), and all three FX investment styles together ("ALL"). We consider the FX investment styles based on all countries and adjusted for transaction costs, in order to conserve space.[35] Below the out-of-sample Sharpe ratios of the augmented portfolios, we report HAC-robust t-statistics for the difference of the Sharpe ratio to the benchmark portfolio in brackets, computed by the delta method as proposed by Ledoit and Wolf (2008) (see Appendix B for computational details).

– Insert TABLE 7 about here –

Turning to the results, most importantly, the FX investment styles increase the Sharpe ratio in each scenario (naive and optimized portfolios, for unhedged as well as fully hedged international stocks in the benchmark). The investor is on average better off with the portfolio augmented with FX investment styles than without. The performance increase is

[34]We present the sample average portfolio weights for each strategy in Table A.2 in Appendix C.

[35]Out-of-sample results for the FX investment styles based on the developed countries (G10 currencies) are available in the Web Appendix.

also quite substantial in terms of Sharpe ratios, e.g. even a small allocation to all three FX investment styles, as large as 17% in case of the conservative portfolio, elevates the out-of-sample Sharpe ratio by more than 30%. As the t-statistics indicate, the increase of the out-of-sample Sharpe ratio is also highly significant for the carry trade and for all three FX investment styles together, no matter which portfolio formation rule is considered. Similar results are obtained for the momentum and the value FX investment styles regarding the naive portfolios. However, the associated t-statistics are lower and insignificant for some of the optimized portfolios, despite increased out-of-sample Sharpe ratios.

Summarizing the out-of-sample evidence, we find the results of the previous sections confirmed. Also, the out-of-sample Sharpe ratio is distinguishably increased when FX styles are added to the investment universe. The largest benefits are obtained from the carry trade, followed by the FX momentum and the FX value strategy.

IX. Conclusion

Investment styles such as value and momentum are popular and widely practiced trading strategies among asset management practitioners. Style investing has not only played a big role in stock markets for several decades, but it has become more and more widespread among professional currency fund managers as well and nowadays constitutes a quantitatively substantial fraction in foreign exchange market turnover. Thus, a more profound knowledge about the risk-return characteristics of style-based investment strategies as well as implications for portfolio choice are of high importance, not only from an academic but also from a practical perspective.

In this paper, we study the implications of foreign exchange investment styles – such as carry trades as well as strategies known as FX momentum, and FX value – for optimal portfolio choice. We investigate if diversification benefits can be achieved by augmenting a benchmark allocation consisting of U.S. stocks and U.S. bonds and international stocks by FX style portfolios. To this end, we rely on classical tests for mean-variance efficiency and newly developed tests based on the appealing stochastic dominance criterion.

Overall, our results suggest that there are significant improvements in international portfolio diversification from style-based investing in FX markets. This holds in both the statistical, and most importantly, in the economic sense. These diversification gains prevail for the most important investment styles after accounting for transaction costs which occur due to re-balancing of currency positions. The largest benefits derive from carry trades, (three-month) FX momentum, FX value and Ang and Chen's (2010) term spread strategy. Our results are further confirmed in an out-of-sample analysis with various portfolio formation rules. Moreover, these diversification gains do not only apply to a mean-variance investor, but we show that international portfolios augmented by FX investment styles are also superior in terms of stochastic dominance. These findings imply that even an investor who dislikes negatively skewed return distributions (as is common in carry trades, for instance, which are prone to large occasional losses) would prefer a portfolio augmented by FX investment styles compared to the benchmark allocation.

References

Akram, F. Q., D. Rime, and L. Sarno, 2008, "Arbitrage in the Foreign Exchange Market: Turning on the Microscope," *Journal of International Economics*, 76, 237–253.

Anderson, R. W., and J.-P. Danthine, 1981, "Cross Hedging," *Journal of Political Economy*, 89, 1182–1192.

Ang, A., and J. S. Chen, 2010, "Yield Curve Predictors of Foreign Exchange Returns," Working Paper.

Asness, C. S., T. J. Moskowitz, and L. H. Pedersen, 2009, "Value and Momentum Everywhere," Working Paper, NYU.

Avramov, D., T. Chordia, G. Jostova, and A. Philipov, 2010, "Anomalies and Financial Distress," Working Paper, University of Maryland.

Bacchetta, P., and E. van Wincoop, 2010, "Infrequent Portfolio Decisions: A Solution to the Forward Discount Puzzle," *American Economic Review*, 100, 870–904.

Bawa, V. S., 1975, "Optimal Rules for Ordering Uncertain Prospects," *Journal of Financial Economics*, 2, 95–121.

Bekaert, G., R. J. Hodrick, and X. Zhang, 2009, "International Stock Return Comovements," *Journal of Finance*, 64, 2591–2626.

Bekaert, G., and M. S. Urias, 1996, "Diversification, Integration and Emerging Market Closed-End Funds," *Journal of Finance*, 51, 835–869.

Benartzi, S., and R. H. Thaler, 2001, "Naive Diversification Strategies in Retirement Saving Plans," *American Economic Review*, 91, 79–98.

BIS, 2010, "Triennial Central Bank Survey," *Foreign Exchange and Derivative Market Activitiy in April 2010*, Revised September 2010.

Britten-Jones, M., 1999, "The Sampling Error in Estimates of Mean-Variance Efficient Portfolio Weights," *Journal of Finance*, 54, 655–671.

Brunnermeier, M. K., S. Nagel, and L. H. Pedersen, 2009, “Carry Trades and Currency Crashes,” *NBER Macroeconomics Annual 2008*, 23, 313–347.

Burnside, C. A., M. Eichenbaum, I. Kleshchelski, and S. Rebelo, 2011, “Do Peso Problems Explain the Returns to the Carry Trade?,” *Review of Financial Studies*, forthcoming.

Burnside, C. A., B. Han, D. Hirshleifer, and T. Y. Wang, 2011, “Investor Overconfidence and the Forward Premium Puzzle,” *Review of Economic Studies*, forthcoming.

Campbell, J. Y., K. S. de Medeiros, and L. M. Viceira, 2010, “Global Currency Hedging,” *Journal of Finance*, 65, 87–121.

Chen, L., R. Novy-Marx, and L. Zhang, 2010, “An Alternative Three-Factor Model,” Working Paper.

Christiansen, C., A. Ranaldo, and P. Söderlind, 2010, “The Time-Varying Systematic Risk of Carry Trade Strategies,” *Journal of Financial and Quantitative Analysis*, forthcoming.

de Roon, F. A., T. E. Nijman, and B. J. Werker, 2001, “Testing for Mean-Variance Spanning with Short Sales Constraints and Transaction Costs: The Case of Emerging Markets,” *Journal of Finance*, 56, 721–742.

de Roon, F. A., T. E. Nijman, and B. J. Werker, 2003, “Currency Hedging for International Stock Portfolios: The Usefulness of Mean-Variance Analysis,” *Journal of Banking & Finance*, 27, 327–349.

de Santis, G., and B. Gerard, 1997, “International Asset Pricing and Portfolio Diversification with Time-Varying Risk,” *Journal of Finance*, 52, 1881–1912.

DeMiguel, V., L. Garlappi, and R. Uppal, 2009, “Optimal Versus Naive Diversification: How Inefficient is the 1/N Portfolio Strategy?,” *Review of Financial Studies*, 22, 1915–1953.

Eiling, E., B. Gerard, P. Hillion, and F. A. de Roon, 2009, “International Portfolio Diversification: Currency, Industry and Country Effects Revisited,” Working Paper.

Errunza, V., K. Hogan, and M.-W. Hung, 1999, “Can the Gains from International Diversification Be Achieved without Trading Abroad?,” *Journal of Finance*, 54, 2075–2107.

Eun, C. S., W. Huang, and S. Lai, 2008, "International Diversification with Large- and Small-Cap Stocks," *Journal of Financial and Quantitative Analysis*, 43, 489–523.

Eun, C. S., S. Lai, F. A. de Roon, and Z. Zhang, 2010, "International Diversification with Factor Funds," *Management Science*, 56, 1500–1518.

Eun, C. S., and J. Lee, 2010, "Mean-Variance Convergence Around the World," *Journal of Banking & Finance*, 34, 856–870.

Eun, C. S., and B. G. Resnick, 1988, "Exchange Rate Uncertainty, Forward Contracts, and International Portfolio Selection," *Journal of Finance*, 43, 197–215.

Fama, E. F., 1984, "Forward and Spot Exchange Rates," *Journal of Monetary Economics*, 14, 319–338.

Fama, E. F., and K. R. French, 1993, "Common Risk Factors in the Returns on Stocks and Bonds," *Journal of Financial Economics*, 33, 3–56.

Fama, E. F., and K. R. French, 1996, "Multifactor Explanations of Asset Pricing Anomalies," *Journal of Finance*, 51, 55–84.

Fama, E. F., and K. R. French, 1998, "Value versus Growth: The International Evidence," *Journal of Finance*, 53, 1975–1999.

Farhi, E., S. P. Fraiberger, X. Gabaix, R. Rancière, and A. Verdelhan, 2009, "Crash Risk in Currency Markets," CEPR Discussion Paper June 2009.

Fishburn, P. C., 1977, "Mean-Risk Analysis with Risk Associated with Below-Target Returns," *American Economic Review*, 67, 116–126.

Fong, W. M., 2010, "A Stochastic Dominance Analysis of Yen Carry Trades," *Journal of Banking & Finance*, 34, 1237–1246.

Galati, G., A. Heath, and P. McGuire, 2007, "Evidence of Carry Trade Activity," *BIS Quarterly Review*, (Sept.), 27–41.

Glen, J., and P. Jorion, 1993, "Currency Hedging for International Portfolios," *Journal of Finance*, 48, 1865–1886.

Goyal, A., and A. Saretto, 2009, "Cross-Section of Option Returns and Volatility," *Journal of Financial Economics*, 94, 310–326.

Grubel, H. G., 1968, "Internationally Diversified Portfolios: Welfare Gains and Capital Flows," *American Economic Review*, 58, 1299–1314.

Hansen, L. P., and R. Jagannathan, 1991, "Implications of Security Market Data for Models of Dynamic Economies," *Journal of Political Economy*, 99, 225–262.

Heston, A., R. Summers, and B. Aten, 2009, "Penn World Table, Income and Prices at the University of Pennsylvania," Center for International Comparisons of Production, Version 6.3, August.

Huberman, G., and S. Kandel, 1987, "Mean-Variance Spanning," *Journal of Finance*, 42, 873–888.

Jegadeesh, N., and S. Titman, 1993, "Returns to Buying Winners and Selling Losers: Implications for Stock Market Efficiency," *Journal of Finance*, 48, 65–91.

Jobson, J., and B. Korkie, 1981, "Performance Hypothesis Testing with the Sharpe and Treynor Measures," *Journal of Finance*, 36, 889–908.

Jobson, J., and B. Korkie, 1989, "A Performance Interpretation of Multivariate Tests of Asset Set Intersection, Spanning, and Mean-Variance Efficiency," *Journal of Financial and Quantitative Analysis*, 24, 185–204.

Jorion, P., 1994, "Mean/Variance Analysis of Currency Overlays," *Financial Analysts Journal*, May-June, 48–56.

Kan, R., and G. Zhou, 2008, "Tests of Mean-Variance Spanning," Working Paper.

Lakonishok, J., A. Shleifer, and R. W. Vishny, 1994, "Contrarian Investment, Extrapolation, and Risk," *Journal of Finance*, 49, 1541–1578.

Ledoit, O., and M. Wolf, 2008, "Robust Performance Hypothesis Testing with the Sharpe Ratio," *Journal of Empirical Finance*, 15, 850–859.

Levy, H., 2006, *Stochastic Dominance*, Springer Science Business Media.

Lo, A. W., 2002, "The Statistics of Sharpe Ratios," *Financial Analysts Journal*, July-August, 36–52.

Lustig, H., N. Roussanov, and A. Verdelhan, 2010, "Common Risk Factors in Currency Markets," Working Paper.

Lustig, H., and A. Verdelhan, 2007, "The Cross Section of Foreign Currency Risk Premia and Consumption Growth Risk," *American Economic Review*, 97, 89–117.

Lyons, R. K., 2001, *The Microstructure Approach to Exchange Rates*, MIT Press, Cambridge.

Mao, J. C. T., 1970, "Models of Capital Budgeting, E-V vs E-S," *Journal of Financial and Quantitative Analysis*, 4, 657–675.

Memmel, C., 2003, "Performance Hypothesis Testing with the Sharpe Ratio," *Finance Letters*, 1, 21–23.

Menkhoff, L., L. Sarno, M. Schmeling, and A. Schrimpf, 2010, "Currency Momentum Strategies," Working Paper.

Menkhoff, L., L. Sarno, M. Schmeling, and A. Schrimpf, 2011, "Carry Trades and Global Foreign Exchange Volatility," *Journal of Finance*, forthcoming.

Menkhoff, L., and M. P. Taylor, 2007, "The Obstinate Passion of Foreign Exchange Professionals: Technical Analysis," *Journal of Economic Literature*, 45, 936–972.

Okunev, J., and D. White, 2003, "Do Momentum-Based Strategies Still Work in Foreign Currency Markets?," *Journal of Financial and Quantitative Analysis*, 38, 425–447.

Palazzo, G., and S. Nobili, 2010, "Explaining and Forecasting Bond Risk Premiums," *Financial Analysts Journal*, July-August, 1–16.

Pojarliev, M., and R. M. Levich, 2008, "Do Professional Currency Managers Beat the Benchmark?," *Financial Analysts Journal*, September-October, 18–32.

Post, T., and P. Versijp, 2007, "Multivariate Tests for Stochastic Dominance Efficiency of a Given Portfolio," *Journal of Financial and Quantitative Analysis*, 42, 489–515.

Samuelson, P. A., 1970, "The Fundamental Approximation Theorem of Portfolio Analysis in Terms of Means, Variances and Higher Moments," *Review of Economic Studies*, 37, 537–542.

Sarno, L., and M. P. Taylor, 2009, *The Economics of Exchange Rates*, Cambridge.

Solnik, B. H., 1974, "Why Not Diversify Internationally Rather Than Domestically?," *Financial Analysts Journal*, July-August, 48–54.

Verdelhan, A., 2010, "A Habit-Based Explanation of the Exchange Rate Risk Premium," *Journal of Finance*, 65, 123–146.

Appendix

A Multivariate Stochastic Dominance Efficiency Tests

This section of the appendix reviews the multivariate stochastic dominance efficiency tests we use in our empirical analysis. Following Post and Versijp (2007), we denote the pricing errors of the N test assets as $\alpha(m) = E\left[R_\theta^N m_\theta\right]$, where m_θ is a candidate SDF, and R_θ^N are the test asset excess returns. We use subscripts $\theta = 1, ..., \Theta$ here to emphasize that the T time-series elements of $R^N = \left[R_1^N, ..., R_T^N\right]$ are ranked according to the benchmark portfolio returns which, in turn, are sorted in an increasing order, that is $R_1^K w < R_2^K w < ... < R_\Theta^K w$, where w are evaluated portfolio weights that generate a stochastic dominance efficient benchmark portfolio from the K benchmark assets. In our empirical implementation, we minimize the benchmark portfolio's second-order lower partial moment with a target rate of zero

$$LPM_2(0) = \frac{1}{T}\sum_{t=1}^{T}\left[max\left(0, \left(0 - R_t\right)\right)\right]^2, \tag{A.1}$$

to find the weights w. Bawa (1975) and Fishburn (1977) for instance show that minimizing the $LPM_2(0)$ produces SSD and TSD efficient portfolios. Similar to the well-known J-test in the GMM framework, the test statistic for SSD efficiency of the benchmark portfolio can be calculated by

$$J_{SSD} = \min_{m \,\epsilon\, M_{SSD}} \Theta\hat{\alpha}(m)'\,\hat{\Omega}(m)^{-1}\,\hat{\alpha}(m), \tag{A.2}$$

where M_{SSD} represents the subset of marginal utility functions that are in line with the SSD criterion, for which the mean of the SDFs (or marginal utility) equals unity, and $\hat{\Omega}(m)$ is the sample covariance matrix of $\hat{\alpha}(m) = \frac{1}{\Theta}\sum_{\theta=1}^{\Theta} R_\theta^N m_\theta$. Given the ordering of the data, M_{SSD} can be represented as the following restrictions on the SDFs

$$M_{SSD} = \left\{ m \,\epsilon\, \mathbb{R}_+^\Theta : \frac{1}{\Theta}\sum_{\theta=1}^{\Theta} m_\theta = 1;\ m_{\theta-1} \geq m_\theta,\ \theta = 2, ..., \Theta \right\}, \tag{A.3}$$

for the minimization problem in (A.2), and corresponds to decreasing or at least constant change in marginal utility from low to high returns ($U' \geq 0$ and $U'' \leq 0$). The test statistic for TSD efficiency can be calculated in a similar fashion as

$$J_{TSD} = \min_{m \, \epsilon \, M_{TSD}} \Theta \hat{\alpha}(m)' \, \hat{\Omega}(m)^{-1} \, \hat{\alpha}(m), \tag{A.4}$$

where M_{TSD} represents the subset of marginal utility functions that are in line with the TSD criterion, and for which the mean of the SDFs equals unity. Given the ordering of the data, M_{TSD} can be represented as a set of restrictions on the SDFs for the minimization problem in (A.4), given by

$$M_{TSD} = \left\{ m \, \epsilon \, M_{SSD} : \frac{m_{\theta-1} - m_{\theta-2}}{R^K_{\theta-1} w - R^K_{\theta-2} w} \leq \frac{m_\theta - m_{\theta-1}}{R^K_\theta w - R^K_{\theta-1} w}, \ \theta = 3, ..., \Theta \right\}, \tag{A.5}$$

and corresponds to decreasing marginal utility at a diminishing rate from low returns to high returns ($U' \geq 0$, $U'' \leq 0$, and $U''' \geqslant 0$).

Computing J_{SSD} and J_{TSD} is a quadratic minimization problem with linear constraints and can be solved iteratively. We use the initial weighting matrix $\hat{\Omega}(m = 1)$ as proposed by Post and Versijp (2007), and use a two-step estimator as described therein. Post and Versijp (2007) show that the SSD and the TSD test statistics asymptotically follow a central chi-square distribution with N degrees of freedom. Their simulation study of the SSD and TSD test statistics suggests that the asymptotic distribution is appropriate for the sample length used in our analysis.

B Robust Out-of-Sample Inference for Sharpe Ratios

This section outlines how we estimate t-statistics for out-of-sample difference Sharpe ratios that we use in our empirical analysis. Ledoit and Wolf (2008) propose an application of the delta method/GMM for a test of the difference Sharpe ratio that is HAC robust.[36] In contrast, the frequently used test statistic proposed by Jobson and Korkie (1981) relies

[36]See Lo (2002) for a similar test of an individual Sharpe ratio.

on i.i.d. returns.[37]

Denote the moments of a benchmark portfolio, with excess return R_t^B, and a contender portfolio augmented with test assets, R_t^T, as $\mu^i = E\left(R_t^i\right)$, and $v^i = E[(R_t^i)^2]$ for $i = T, B$. The moments can be stacked in a vector $f = \left(\mu^T, \mu^B, v^T, v^B\right)'$, which is assumed to satisfy $\sqrt{T}(\hat{f} - f) \xrightarrow{d} N\left(0, \Sigma\right)$, where expressions with hats denote sample counterparts of population moments. The difference Sharpe ratio between the benchmark and the test portfolio is

$$\triangle SR = g\left(f\right) = \frac{\mu^T}{\sqrt{v^T - \left(\mu^T\right)^2}} - \frac{\mu^B}{\sqrt{v^B - \left(\mu^B\right)^2}}. \tag{B.1}$$

Then, the delta method implies

$$\sqrt{T}\left(\triangle \hat{SR} - \triangle SR\right) \xrightarrow{d} N\left(0; \frac{\partial g}{\partial f}\Sigma\frac{\partial g}{\partial f'}\right), \tag{B.2}$$

with

$$\frac{\partial g}{\partial f} = \left(\frac{v^T}{\left[v^T - (\mu^T)^2\right]^{1.5}}, -\frac{v^B}{\left[v^B - (\mu^B)^2\right]^{1.5}}, -\frac{1}{2}\frac{\mu^T}{\left[v^T - (\mu^T)^2\right]^{1.5}}, \frac{1}{2}\frac{\mu^B}{\left[v^B - (\mu^B)^2\right]^{1.5}}\right). \tag{B.3}$$

A HAC robust kernel estimate of Σ can be used to construct a t-test for the difference Sharpe ratio based on B.2,

$$t = \frac{\triangle \hat{SR}}{\sqrt{T^{-1}\frac{\partial g}{\partial f}\hat{\Sigma}\frac{\partial g}{\partial f'}}}. \tag{B.4}$$

Ledoit and Wolf (2008) provide some evidence on the size of this test statistic and find that asymptotic inference is already reliable for 120 observations.

[37] Memmel (2003) gives a corrected version of the test, which is applied in DeMiguel, Garlappi, and Uppal (2009), for instance.

C Additional Tables

– Insert TABLE A.1 about here –

– Insert TABLE A.2 about here –

Table 1: Descriptive Statistics of Benchmark and Test Assets

The Table reports the monthly mean (in percentage points), standard deviation (StD), skewness (Skew), first order autocorrelation (Ac1), and the Sharpe ratio (SR) of U.S. bonds, U.S. stocks, international stocks, international FX returns and FX investment styles conditional on time t-1 forward discounts (carry trade), last 3-month cumulative returns (momentum), and the 5-year deviation from purchasing power parity (value). The FX investment styles are based on a broad set of currencies (without subscript), and below based on the developed countries in Panel B with the subscript G10 ("G10 currencies"). The returns are monthly simple returns and measured in USD. Stock and bond returns are in excess of the one-month U.S. Treasury bill from Ibbotson, FX excess returns are computed as long forward returns. The sample period is 01/1985 - 12/2009.

	Mean	StD	Skew	Ac1	SR	Mean	StD	Skew	Ac1	SR	Mean	StD	Skew	Ac1	SR
Panel A: National assets															
U.S. bonds	0.34	1.93	0.16	0.06	0.18										
U.S. stocks	0.58	4.50	-0.85	0.08	0.13										
Panel B: International assets															
	Unhedged stocks					Fully hedged stocks					FX excess returns				
Australia	0.92	6.70	-1.29	0.04	0.14	0.57	4.81	-2.07	0.01	0.12	0.34	3.37	-0.70	0.12	0.10
Canada	0.67	5.68	-0.74	0.12	0.12	0.51	4.58	-0.78	0.12	0.11	0.16	2.01	-0.49	0.02	0.08
Germany	0.84	6.84	-0.42	0.04	0.12	0.55	6.50	-0.55	0.08	0.09	0.28	3.19	-0.12	0.07	0.09
Japan	0.29	6.64	0.27	0.12	0.04	0.15	5.88	-0.12	0.10	0.02	0.14	3.44	0.49	0.04	0.04
New Zealand	0.59	7.47	-0.34	0.07	0.08	0.01	6.26	-0.22	0.05	0.00	0.58	3.55	-0.05	0.06	0.16
Norway	0.94	7.74	-0.83	0.12	0.12	0.54	7.13	-0.84	0.14	0.08	0.39	3.07	-0.44	0.10	0.13
Sweden	1.15	7.54	-0.29	0.11	0.15	0.88	7.14	-0.13	0.12	0.12	0.26	3.23	-0.42	0.17	0.08
Switzerland	0.90	5.24	-0.25	0.09	0.17	0.69	5.16	-0.77	0.15	0.13	0.21	3.46	0.25	0.03	0.06
U.K.	0.68	5.27	-0.26	0.08	0.13	0.33	4.71	-0.98	0.05	0.07	0.35	3.03	-0.06	0.11	0.11
Panel C: FX investment styles															
	without bid-ask adj.					with bid-ask adj.					Correlation (with b-a)				
Carry trade	0.76	2.92	-0.84	0.11	0.26	0.71	2.93	-0.84	0.11	0.24	1.00				
Momentum	0.49	2.95	0.44	-0.06	0.17	0.37	2.96	0.41	-0.05	0.13	0.08	1.00			
Value	0.39	2.45	-0.09	0.16	0.16	0.36	2.45	-0.10	0.16	0.15	0.13	-0.12	1.00		
Carry trade $_{G10}$	0.57	3.23	-0.90	0.07	0.18	0.55	3.23	-0.90	0.07	0.17	1.00				
Momentum $_{G10}$	0.40	3.04	0.17	-0.11	0.13	0.32	3.05	0.15	-0.11	0.10	0.07	1.00			
Value $_{G10}$	0.40	3.12	0.15	0.04	0.13	0.37	3.12	0.15	0.04	0.12	-0.01	-0.09	1.00		

Table 2: Mean-Variance Efficiency Tests for International Stocks and FX Returns

The Table reports mean-variance efficiency tests for a portfolio of K benchmark assets when N test assets are added to the investment universe. F and W_{hac} are regression-based tests for mean-variance efficiency, SDF_{hac} is a stochastic discount factor based test. The reported test statistics with subscript HAC are robust against heteroscedasticity and autocorrelation (Newey-West with Bartlett kernel and four lags), p-values are in parentheses. SR is the Sharpe ratio on a monthly basis. The sample period is 01/1985 - 12/2009.

Panel A: Benchmark: U.S. bonds and U.S. stocks (K=2), SR=0.21				
Test assets	F	W_{hac}	SDF_{hac}	SR
Unhedged intern. stocks (N=9)	1.23 (0.276)	14.78 (0.097)	11.52 (0.242)	0.29
Fully hedged intern. stocks (N=9)	2.01 (0.038)	25.15 (0.003)	19.14 (0.024)	0.33

Panel B: Benchmark: U.S. bonds, U.S. stocks and international stocks (K=11)								
	Unhedged stocks (SR=0.29)				Fully hedged stocks (SR=0.33)			
Test assets	F	W_{hac}	SDF_{hac}	SR	F	W_{hac}	SDF_{hac}	SR
FX returns (N=9)	2.08 (0.032)	17.18 (0.046)	16.74 (0.053)	0.40	1.32 (0.225)	10.39 (0.320)	9.64 (0.381)	0.40

Table 3: Mean-Variance Efficiency Tests for FX Investment Styles

The Table reports mean-variance efficiency tests for a portfolio of K benchmark assets when N test assets are added to the investment universe. F and W_{hac} are regression-based tests for mean-variance efficiency, SDF_{hac} is a stochastic discount factor based test. The reported test statistics with subscript HAC are robust against heteroscedasticity and autocorrelation (Newey-West with Bartlett kernel and four lags), p-values are in parentheses. SR is the Sharpe ratio on a monthly basis. The FX investment styles are adjusted for transaction costs, they are based on all countries in Panel A, and are based on the developed countries (G10 currencies) in Panel B. The sample period is 01/1985 - 12/2009.

	Benchmark: U.S. bonds, U.S stocks and international stocks (K=11)							
	Unhedged stocks (SR=0.29)				Fully hedged stocks (SR=0.33)			
Test assets	F	W_{hac}	SDF_{hac}	SR	F	W_{hac}	SDF_{hac}	SR
Panel A: FX investment styles, **all countries** adjusted for transaction-costs								
Carry trade (N=1)	17.47	14.07	8.62	0.39	15.32	11.73	7.48	0.41
	(0.000)	(0.000)	(0.003)		(0.000)	(0.001)	(0.006)	
Momentum (N=1)	3.19	4.04	3.89	0.31	2.95	3.67	3.65	0.35
	(0.075)	(0.045)	(0.049)		(0.087)	(0.056)	(0.056)	
Value (N=1)	4.76	3.62	3.28	0.32	5.60	4.06	3.41	0.36
	(0.030)	(0.057)	(0.070)		(0.019)	(0.044)	(0.065)	
ALL (N=3)	7.98	18.58	13.79	0.42	7.30	15.76	12.07	0.44
	(0.000)	(0.000)	(0.003)		(0.000)	(0.001)	(0.007)	
Panel B: FX investment styles, **developed countries** (G10 currencies) adjusted for transaction costs								
Carry trade (N=1)	5.58	4.81	3.64	0.32	5.28	4.70	3.37	0.36
	(0.019)	(0.028)	(0.056)		(0.022)	(0.030)	(0.067)	
Momentum (N=1)	2.93	3.27	3.29	0.31	2.46	2.82	2.88	0.35
	(0.088)	(0.071)	(0.070)		(0.118)	(0.093)	(0.090)	
Value (N=1)	3.15	2.08	2.22	0.31	3.12	2.36	2.32	0.35
	(0.077)	(0.149)	(0.137)		(0.078)	(0.124)	(0.128)	
ALL (N=3)	4.24	11.12	9.44	0.36	3.64	9.34	7.27	0.39
	(0.006)	(0.011)	(0.024)		(0.013)	(0.025)	(0.064)	

Table 4: Stochastic Dominance Efficiency Tests for FX Investment Styles

The Table shows pricing errors (with standard errors in parentheses) and p-values for the multivariate second-order stochastic dominance (SSD) test and the multivariate third-order stochastic dominance (TSD) test for efficiency of the mean-$LPM_2(0)$ tangency portfolio of U.S. bonds, U.S. stocks and currency risk unhedged/fully hedged international stocks relative to FX investment styles. The SSD and TSD test are restricted to price the benchmark portfolio correctly, the pricing kernels and pricing errors are based on one iteration, while the p-values are computed based on the resulting weighting matrix. The FX investment styles are adjusted for transaction costs and are based on all countries in Panel A, and they are based on the G10 currencies in Panel B. The sample period is 01/1985 - 12/2009.

	Benchmark: U.S. bonds, U.S. stocks and international stocks							
	Pricing Errors (SE), unhedged benchmark				Pricing Errors (SE), hedged benchmark			
Test assets	SSD		TSD		SSD		TSD	
Panel A: FX investment styles, **all countries** adjusted for transaction costs								
Carry trade	0.589	(0.188)	0.631	(0.185)	0.596	(0.198)	0.656	(0.188)
Momentum	0.245	(0.183)	0.270	(0.174)	0.307	(0.189)	0.291	(0.174)
Value	0.296	(0.157)	0.409	(0.157)	0.272	(0.171)	0.377	(0.161)
p-value	(0.004)		(0.000)		(0.003)		(0.001)	
Panel B: FX investment styles, **developed countries** (G10 currencies) adjusted for transaction costs								
Carry trade	0.419	(0.214)	0.500	(0.246)	0.401	(0.222)	0.454	(0.216)
Momentum	0.180	(0.205)	0.313	(0.208)	0.282	(0.207)	0.272	(0.200)
Value	0.312	(0.217)	0.285	(0.239)	0.257	(0.219)	0.357	(0.217)
p-value	(0.076)		(0.004)		(0.100)		(0.019)	

Table 5: Descriptive Statistics of Additional FX Investment Styles

The Table reports the monthly mean (in percentage points), standard deviation (StD), skewness (Skew), first order autocorrelation (Ac1), and the Sharpe ratio (SR) of FX investment styles. Panel A shows strategies based on time t-1 yield curve variables. Panel B shows strategies based on time t-1 momentum (measured by cumulative returns of the past one, three, and twelve month window), value (measured by the 5-year deviation from PPP), and volatility (measured by the change of the volatility computed from the past 66 trading days). The FX investment styles are based on the G10 currencies. The returns are monthly computed simple returns and measured against the USD. The sample period is 01/1985 - 12/2009.

	Mean	StD	Skew	Ac1	SR	Mean	StD	Skew	Ac1	SR
	without bid-ask adj.					with bid-ask adj.				
Panel A.1: FX investment styles based on yield curve variables										
Carry trade	0.57	3.23	-0.90	0.07	0.18	0.55	3.23	-0.90	0.07	0.17
Δ short-term rate	0.28	2.35	-0.53	0.09	0.12	0.14	2.34	-0.55	0.08	0.06
Long-term rate	0.35	3.35	-0.71	0.08	0.10	0.34	3.35	-0.71	0.08	0.10
Δ long-term rate	0.25	2.31	-0.11	0.04	0.11	0.10	2.31	-0.16	0.04	0.04
Term	0.50	2.77	-0.17	0.09	0.18	0.46	2.76	-0.20	0.08	0.17
Panel A.2: FX investment styles based on momentum, value, and volatility										
Momentum1	0.20	2.97	0.31	0.00	0.07	0.06	2.99	0.29	0.01	0.02
Momentum3	0.40	3.04	0.17	-0.11	0.13	0.32	3.05	0.15	-0.11	0.10
Momentum12	0.18	3.29	-0.23	-0.01	0.06	0.13	3.30	-0.24	-0.01	0.04
Value	0.40	3.12	0.15	0.04	0.13	0.37	3.12	0.15	0.04	0.12
Volatility	0.26	2.76	-0.33	0.09	0.09	0.17	2.77	-0.34	0.09	0.06
				Correlation, with bid-ask adj.						
Panel B.1: FX investment styles based on yield curve variables										
Carry trade	1.00									
Δ short-term rate	0.03	1.00								
Long-term rate	0.87	0.07	1.00							
Δ long-term rate	-0.10	0.06	-0.10	1.00						
Term spread	0.64	0.08	0.45	-0.22	1.00					
Panel B.2: FX investment styles based on momentum, value, and volatility										
Momentum1	0.04	-0.09	0.03	0.04	0.02	1.00				
Momentum3	0.07	0.00	0.07	0.03	0.03	0.60	1.00			
Momentum12	0.06	0.01	0.06	0.10	0.09	0.28	0.41	1.00		
Value	-0.01	-0.07	0.02	0.01	-0.17	0.00	-0.09	-0.29	1.00	
Volatility	0.05	-0.12	0.00	-0.03	-0.07	0.01	0.06	-0.17	0.12	1.00

Table 6: Mean-Variance Efficiency Tests for Additional FX Investment Styles

The Table reports p-values of mean-variance intersection tests for the tangency portfolio of K benchmark assets when N test assets are added to the investment universe. F and W_{hac} are regression-based tests for mean-variance efficiency, SDF_{hac} is a stochastic discount factor based test. The reported test statistics with subscript HAC are robust against heteroscedasticity and autocorrelation (Newey-West with Bartlett kernel and four lags). SR is the Sharpe ratio on a monthly basis. The FX investment styles are based on the G10 currencies, they are adjusted for transaction-costs. Panel A shows strategies based on time t-1 yield curve variables. Panel B shows strategies based on time t-1 momentum, value, and volatility. The sample period is 01/1985 - 12/2009.

Benchmark: U.S. bonds, U.S. stocks and int. fully hedged stocks (K=11), SR=0.33				
Test assets	F	W_{hac}	SDF_{hac}	SR
Panel A: FX investment styles based on yield curve variables				
Carry trade (N=1)	0.022	0.030	0.067	0.36
Δ short-term rate (N=1)	0.206	0.208	0.234	0.34
Long-term rate (N=1)	0.265	0.325	0.348	0.34
Δ long-term rate (N=1)	0.091	0.099	0.111	0.35
Term spread (N=1)	0.018	0.027	0.043	0.36
ALL (N=5)	0.023	0.032	0.168	0.40
Panel B: FX investment styles based on momentum, value, and volatility				
Momentum1 (N=1)	0.768	0.788	0.790	0.33
Momentum3 (N=1)	0.118	0.093	0.090	0.35
Momentum12 (N=1)	0.357	0.343	0.344	0.34
Value (N=1)	0.268	0.307	0.319	0.34
Volatility (N=1)	0.268	0.307	0.319	0.34
ALL (N=5)	0.067	0.148	0.123	0.39

Table 7: Out-of-Sample Results - All Countries

The Table reports out-of-sample Sharpe ratios for 120-month rolling windows. The benchmark assets are U.S. bonds, U.S. stocks, and international stocks. The test assets are FX styles based on all countries and are adjusted for transaction costs. We use the first 120 observations to compute the portfolio weights for the return in period 121. Next, we move the rolling window one period forward and repeat the previous step, which results in a time-series of out-of-sample returns of one benchmark and one test portfolio. The naive portfolio formation rules are equal weights ("1/N"), conservative, balanced, and aggressive weights. The conservative weights of the benchmark portfolio allocates 60% to U.S. bonds, 20% to U.S. stocks and 20% to international stocks (the weights of the stock markets correspond to the countries' relative World (PPP) GDP share from the IMF). For the augmented portfolios, we assign the same weights to the FX investment styles as to international stocks and rescale the portfolio weights to 100%. In the balanced and aggressive portfolio, we change the weight of U.S. bonds and recalculate the allocation to all other assets such that their relative weights to each other remain unchanged. The optimization portfolio formation rules are in the following order: the traditional mean-variance tangency portfolio, the mean-variance Bayes-Stein shrinkage tangency portfolio (we shrink the sample mean to the mean of the minimum-variance portfolio), the mean-variance tangency portfolio with short-selling constraints, the minimum-variance portfolio, and the mean-variance tangency portfolio using an expanding window instead of the rolling window. We report HAC-robust t-statistics for the difference Sharpe ratio between the benchmark portfolio and the test portfolio in brackets (Newey-West with Bartlett kernel and four lags). The sample period is 01/1985 - 12/2009.

	Bench	Carry	Mom	Value	ALL	Bench	Carry	Mom	Value	ALL
	Unhedged					Fully hedged				
	Out-of-sample Sharpe ratios of naive portfolios									
Equal Weights	0.12	0.14	0.13	0.13	0.15	0.12	0.14	0.13	0.13	0.16
(1/(N+K))		[3.43]	[2.19]	[1.88]	[3.92]		[3.42]	[2.21]	[1.73]	[3.94]
Conservative	0.17	0.25	0.21	0.20	0.23	0.19	0.27	0.23	0.22	0.24
(60% bonds)		[2.98]	[1.94]	[1.60]	[3.83]		[2.83]	[1.87]	[1.48]	[3.77]
Balanced	0.12	0.20	0.16	0.15	0.18	0.13	0.21	0.17	0.16	0.19
(30% bonds)		[3.25]	[2.02]	[1.68]	[4.00]		[3.12]	[1.98]	[1.58]	[3.98]
Aggressive	0.09	0.17	0.13	0.12	0.15	0.09	0.18	0.14	0.13	0.15
(0% bonds)		[3.49]	[2.13]	[1.70]	[4.14]		[3.40]	[2.11]	[1.63]	[4.16]
	Out-of-sample Sharpe ratios of optimized portfolios									
Mean-Variance	0.16	0.27	0.17	0.20	0.32	0.23	0.31	0.23	0.26	0.36
		[2.20]	[0.42]	[1.10]	[2.54]		[2.41]	[0.05]	[0.81]	[2.35]
MV Bayes-Stein	0.16	0.32	0.20	0.20	0.37	0.24	0.35	0.25	0.27	0.41
		[2.93]	[0.94]	[0.99]	[2.85]		[2.44]	[0.65]	[0.69]	[2.47]
MV short constr.	0.16	0.29	0.18	0.20	0.34	0.19	0.31	0.21	0.21	0.34
		[2.37]	[0.79]	[1.08]	[2.59]		[2.26]	[0.66]	[0.54]	[2.23]
Minimum-Var.	0.14	0.29	0.20	0.18	0.33	0.18	0.30	0.23	0.22	0.36
		[2.51]	[1.64]	[0.64]	[2.58]		[2.20]	[1.67]	[0.96]	[2.71]
MV exp. window	0.17	0.31	0.19	0.19	0.33	0.23	0.35	0.25	0.26	0.36
		([3.34]	[1.30]	[0.70]	[2.98]		[3.44]	[1.27]	[0.67]	[2.43]

Figure 1: Cumulative Returns of FX Investment Styles

The Figure shows cumulative simple returns adjusted for transaction costs for the carry trade, the momentum, and the value FX investment style. The sample period is 01/1985 - 12/2009.

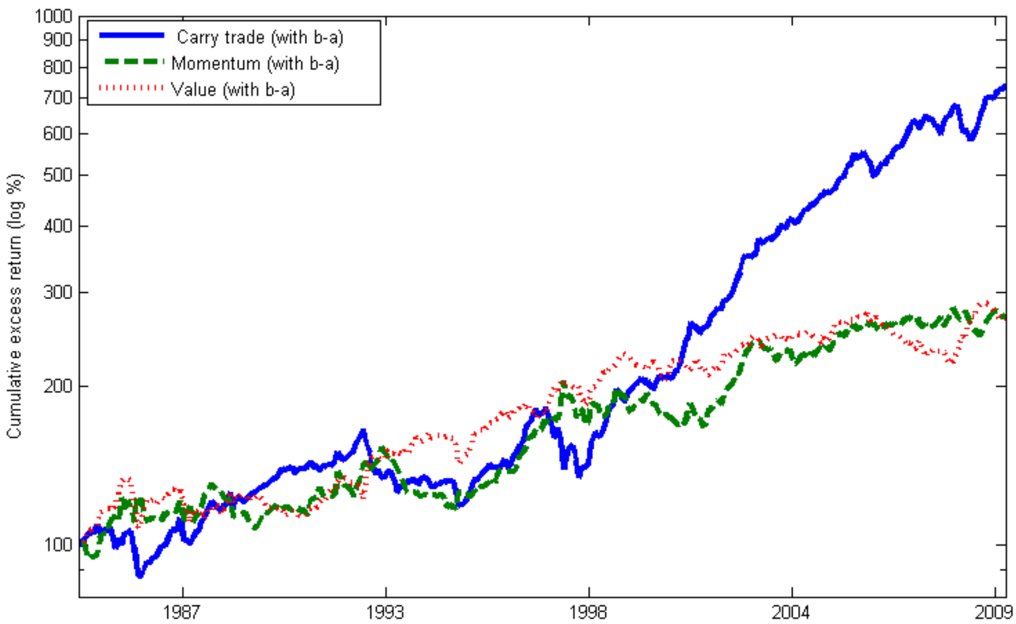

Figure 2: The Role of Transaction Costs

The Figure shows cumulative simple returns adjusted and unadjusted for transaction costs for the carry trade, and the momentum FX investment style.The sample period is 01/1985 - 12/2009.

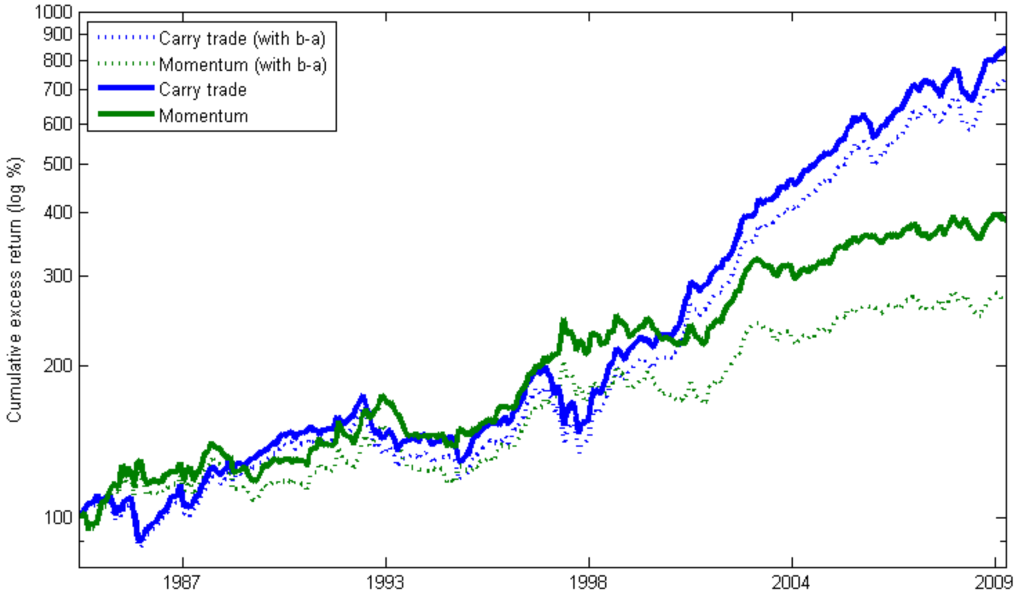

Figure 3: Mean-Variance Frontiers of Alternative Investment Strategies

The Figure shows mean-variance frontiers, starting with lower right frontier constructed from U.S. bonds and U.S. stocks (crossed circles), adding international unhedged stocks (crosses), proceeding with international fully hedged stocks (circles) replacing the unhedged stocks, and finally the carry trade, momentum, and value based FX investment styles (based on all countries) adjusted for transaction costs (stars) are added to the investment universe with fully hedged stocks. All data are on a monthly basis. The sample period is 01/1985 - 12/2009.

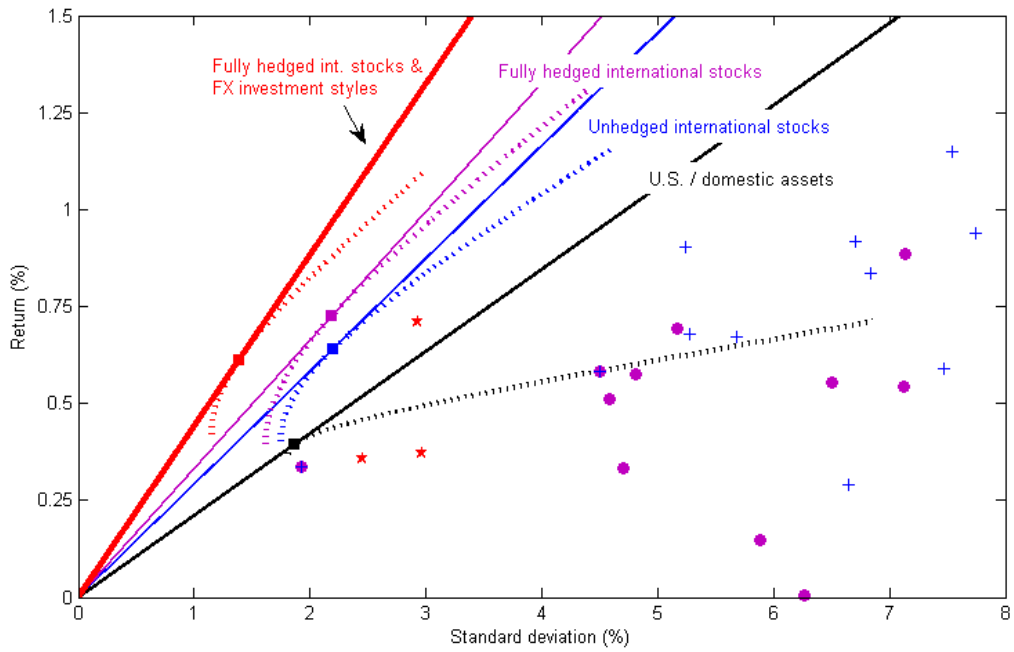

Figure 4: Pricing Kernels

The Figure shows the fitted pricing kernels (marginal utility) for the SSD and TSD tests for the sample in Table 4. We use the $LPM_2(0)$ tangency portfolio of U.S. bonds, U.S. stocks and fully currency hedged international stocks as benchmark and the FX investment styles carry trade, momentum, and value as test assets. The pricing kernels are based on one iteration. Below is also the hypothetical pricing kernel of a mean-variance test, implying a quadratic utility function, with the same benchmark and same test assets as for the SSD and TSD tests.

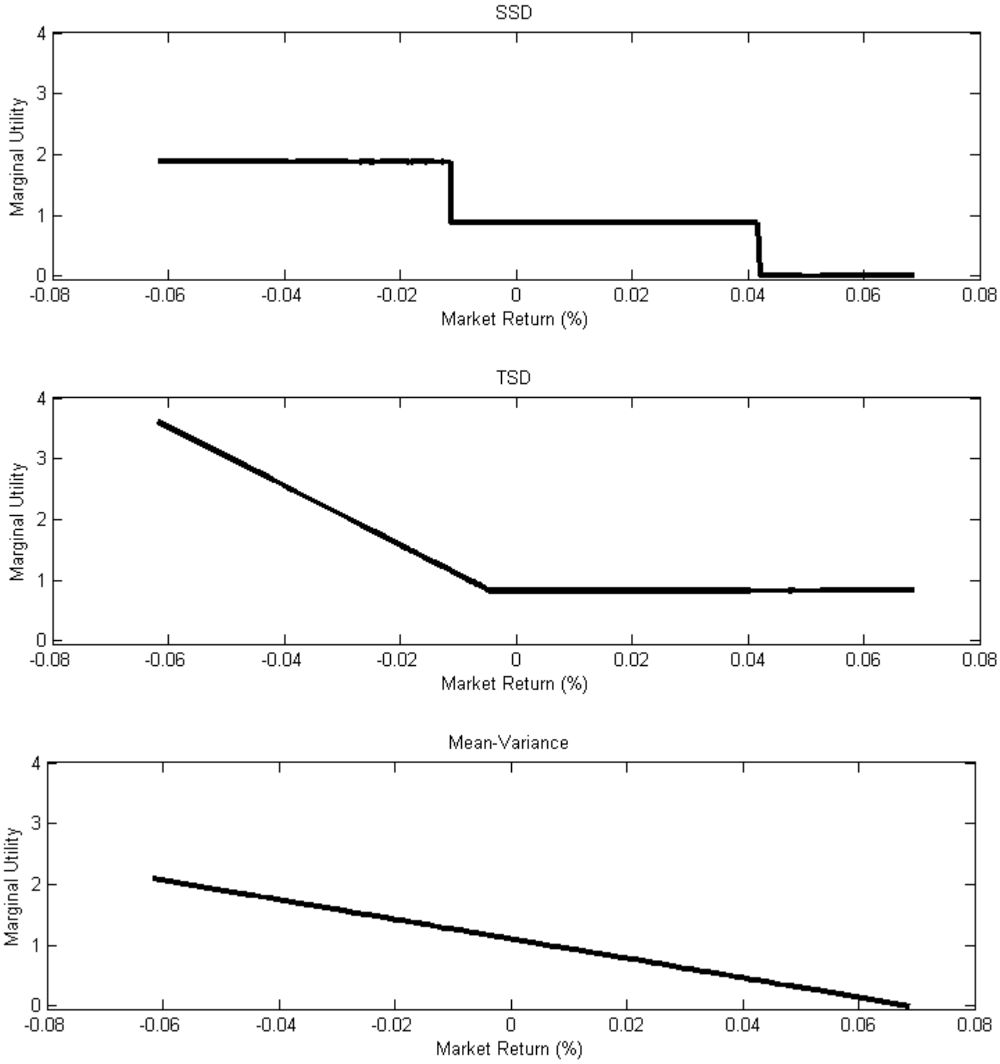

Table A.1: Mean-Variance Efficiency Tests for FX Investment Styles - Optimally Hedged

The Table reports mean-variance efficiency tests for a portfolio of K benchmark assets when N test assets are added to the investment universe. F and W_{hac} are regression-based tests of mean-variance efficiency, SDF_{hac} is a stochastic discount factor based test. The reported test statistics with subscript HAC are robust against heteroscedasticity and autocorrelation (Newey-West with Bartlett kernel and four lags), p-values are in parentheses. SR is the Sharpe ratio on a monthly basis. The FX investment styles are adjusted for transaction costs, they are based on all countries in Panel A, and are based on the developed countries (G10 currencies) in Panel B. The sample period is 01/1985 -12/2009.

Benchmark: U.S. bonds/stocks, international stocks, and FX excess returns (K=20)				
	Optimally hedged stocks (SR=0.40)			
Test assets	F	W_{hac}	SDF_{hac}	SR
Panel A: FX investment styles, **all countries** adjusted for transaction costs				
Carry trade (N=1)	14.84	12.69	7.91	0.47
	(0.000)	(0.000)	(0.005)	
Momentum (N=1)	2.11	2.82	2.81	0.41
	(0.148)	(0.093)	(0.094)	
Value (N=1)	9.36	7.19	6.07	0.44
	(0.002)	(0.007)	(0.014)	
ALL (N=3)	8.23	20.08	13.69	0.51
	(0.000)	(0.000)	(0.003)	
Panel B: FX investment styles, **developed countries** adjusted for transaction costs				
Carry trade (N=1)	7.12	7.86	7.43	0.43
	(0.008)	(0.005)	(0.006)	
Momentum (N=1)	2.87	3.26	3.26	0.41
	(0.091)	(0.071)	(0.071)	
Value (N=1)	6.18	5.06	5.09	0.43
	(0.014)	(0.024)	(0.024)	
ALL (N=3)	5.90	13.65	12.87	0.48
	(0.001)	(0.003)	(0.005)	

Table A.2: Portfolio Weights: Out-of-Sample Results - All Countries

The Table reports the average weight of the out-of-sample portfolios in Table 7. The benchmark ("Bench") portfolio contains U.S. bonds/stocks and international stocks. The augmented portfolios contain FX investment styles, namely the carry trade ("Carry"), FX momentum ("Mom"), FX value ("Value"), and all three FX styles together ("All"). The FX styles are based on all countries and are adjusted for transaction costs. US-B corresponds to the weight of U.S. bonds, US-S to U.S. stocks, Int-S to the sum over unhedged or fully hedged international stocks, and FX to the FX investment styles.

		Bench	Carry	Mom	Value	ALL	Bench	Carry	Mom	Value	ALL
		Unhedged					Fully hedged				
EW	US-B	0.09	0.08	0.08	0.08	0.07	0.09	0.08	0.08	0.08	0.07
	US-S	0.09	0.08	0.08	0.08	0.07	0.09	0.08	0.08	0.08	0.07
	Int-S	0.82	0.75	0.75	0.75	0.64	0.82	0.75	0.75	0.75	0.64
	FX		0.08	0.08	0.08	0.21		0.08	0.08	0.08	0.21
Conserv.	US-B	0.60	0.50	0.50	0.50	0.50	0.60	0.50	0.50	0.50	0.50
	US-S	0.20	0.17	0.17	0.17	0.17	0.20	0.17	0.17	0.17	0.17
	Int-S	0.20	0.17	0.17	0.17	0.17	0.20	0.17	0.17	0.17	0.17
	FX		0.17	0.17	0.17	0.17		0.17	0.17	0.17	0.17
Balanced	US-B	0.30	0.22	0.22	0.22	0.22	0.30	0.22	0.22	0.22	0.22
	US-S	0.35	0.26	0.26	0.26	0.26	0.35	0.26	0.26	0.26	0.26
	Int-S	0.35	0.26	0.26	0.26	0.26	0.35	0.26	0.26	0.26	0.26
	FX		0.26	0.26	0.26	0.26		0.26	0.26	0.26	0.26
Aggressive	US-B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	US-S	0.50	0.34	0.34	0.34	0.34	0.50	0.34	0.34	0.34	0.34
	Int-S	0.49	0.33	0.33	0.33	0.33	0.49	0.33	0.33	0.33	0.33
	FX		0.33	0.33	0.33	0.33		0.33	0.33	0.33	0.33
MV	US-B	0.79	0.50	0.59	0.47	0.34	0.75	0.56	0.63	0.48	0.38
	US-S	0.20	0.17	0.18	0.12	0.05	0.33	0.19	0.27	0.19	0.12
	Int-S	0.01	-0.01	-0.01	0.02	0.01	-0.09	-0.10	-0.09	-0.08	-0.10
	FX		0.35	0.24	0.39	0.59		0.35	0.19	0.40	0.60
MV BS	US-B	0.84	0.59	0.66	0.53	0.40	0.80	0.63	0.67	0.55	0.44
	US-S	0.11	0.05	0.08	0.06	-0.01	0.14	0.04	0.10	0.08	0.02
	Int-S	0.05	0.04	0.03	0.05	0.04	0.06	0.03	0.05	0.02	0.00
	FX		0.31	0.23	0.36	0.57		0.30	0.19	0.35	0.54
MV SC	US-B	0.65	0.47	0.52	0.45	0.34	0.66	0.51	0.54	0.48	0.37
	US-S	0.13	0.08	0.09	0.07	0.03	0.12	0.07	0.09	0.08	0.04
	Int-S	0.22	0.14	0.17	0.15	0.10	0.23	0.12	0.18	0.15	0.08
	FX		0.31	0.21	0.33	0.53		0.30	0.19	0.30	0.51
Min.V	US-B	0.89	0.70	0.72	0.60	0.46	0.86	0.72	0.72	0.63	0.51
	US-S	0.02	-0.04	-0.01	0.00	-0.05	-0.10	-0.13	-0.10	-0.04	-0.08
	Int-S	0.09	0.08	0.07	0.07	0.06	0.23	0.19	0.19	0.13	0.10
	FX		0.26	0.22	0.33	0.53		0.22	0.19	0.29	0.47
MV exp.w	US-B	0.71	0.54	0.61	0.49	0.39	0.80	0.66	0.69	0.56	0.47
	US-S	0.22	0.11	0.18	0.14	0.06	0.37	0.24	0.30	0.29	0.19
	Int-S	0.08	0.05	0.05	0.06	0.03	-0.16	-0.15	-0.15	-0.18	-0.16
	FX		0.30	0.16	0.31	0.52		0.25	0.16	0.34	0.50

Supplementary Internet-Appendix to the Paper

International Diversification Benefits with Foreign Exchange Investment Styles

by

Tim A. Kroencke   Felix Schindler   Andreas Schrimpf

Further Mean-Variance Tests

Table IA.1 reports mean-variance efficiency tests for the FX investment styles without taking transaction costs into account. Hence, the Table gives an upper bound of the diversification benefits with FX investment styles. As can be seen, including all three FX investment styles increases the Sharpe ratios from 0.33 p.m. to 0.47 p.m. for the baseline case of fully hedged benchmark assets, i.e. additional 0.03 points compared to the transaction cost-adjusted case. Not surprisingly, we find considerable lower p-values, allowing for rejection of mean-variance efficiency of the benchmark assets for each of the three individual FX investment styles.

Table IA.1: Mean-Variance Efficiency Tests for FX Investment Styles - Without Adjustment for Transaction Costs

The Table reports mean-variance efficiency tests for a portfolio of K benchmark assets when N test assets are added to the investment universe. F and W_{hac} are regression-based tests of mean-variance efficiency, SDF_{hac} is a stochastic discount factor-based test. The reported test statistics with subscript HAC are robust against heteroscedasticity and autocorrelation (Newey-West with Bartlett kernel and four lags), p-values are in parentheses. SR is the Sharpe ratio on a monthly basis. They are based on all countries in Panel A and they are based on the developed countries (G10 currencies) in Panel B. The sample period is 01/1985 - 12/2009.

	Benchmark: U.S. bonds, U.S. stocks and international stocks (K=11)							
	Unhedged stocks (SR=0.29)				Fully hedged stocks (SR=0.33)			
Test assets	F	W_{hac}	SDF_{hac}	SR	F	W_{hac}	SDF_{hac}	SR
Panel A: FX investment styles, **all countries** unadjusted for transaction costs								
Carry trade (N=1)	20.00	16.03	9.49	0.40	17.49	13.34	8.20	0.42
	(0.000)	(0.000)	(0.002)		(0.000)	(0.000)	(0.004)	
Momentum (N=1)	6.05	7.81	7.29	0.33	5.65	7.13	6.98	0.36
	(0.015)	(0.005)	(0.007)		(0.018)	(0.008)	(0.008)	
Value (N=1)	5.81	4.39	3.92	0.33	6.69	4.83	3.97	0.37
	(0.017)	(0.036)	(0.048)		(0.010)	(0.028)	(0.046)	
ALL (N=3)	10.08	23.31	17.34	0.45	9.24	20.04	15.55	0.47
	(0.000)	(0.000)	(0.001)		(0.000)	(0.000)	(0.001)	
Panel B: FX investment styles, **developed countries** (G10 currencies) unadjusted for transaction costs								
Carry trade (N=1)	6.24	5.36	4.00	0.33	5.85	5.23	3.67	0.36
	(0.013)	(0.021)	(0.046)		(0.016)	(0.022)	(0.055)	
Momentum (N=1)	4.68	5.30	5.29	0.32	4.08	4.72	4.81	0.35
	(0.031)	(0.021)	(0.022)		(0.044)	(0.030)	(0.028)	
Value (N=1)	3.74	2.46	2.62	0.31	3.71	2.79	2.72	0.35
	(0.054)	(0.117)	(0.105)		(0.055)	(0.095)	(0.099)	
ALL (N=3)	5.31	13.75	11.83	0.38	4.58	11.86	9.35	0.40
	(0.001)	(0.003)	(0.008)		(0.004)	(0.008)	(0.025)	

Further Stochastic Dominance Tests

Table IA.2 reports stochastic dominance efficiency tests based on the second order (SSD) and third order (TSD) stochastic dominance criterion when international stocks are the test assets and the mean-$LPM_2(0)$ tangency portfolio constructed from U.S. bonds, U.S. stocks is taken as benchmark. As shown in the table, the SSD and the TSD test statistics do not lead us to conclude that there are diversification benefits for the unhedged as well as fully hedged international stock returns. However, the drop of the p-values between the unhedged and the fully hedged setting is noteworthy, and does indicate at least some improvements of the investment opportunity set from unwinding unintended FX exposure in the stock market positions.

Table IA.3 reports stochastic dominance efficiency tests for additional FX investment styles based on yield curve variables (long-term rates, term spread, change in short and long-term rates), FX momentum (defined over the one-month and twelve-month horizon) and the FX volatility (change in three month volatility) strategy. The mean-$LPM_2(0)$ tangency portfolio constructed from U.S. bonds, U.S. stocks and international stocks is taken as benchmark. The mean-variance results are broadly confirmed. Interestingly, we find lower p-values for the SSD and TSD test in case of the yield curve-based portfolios than for the strategies based on past returns. In summary, after accounting for transaction costs we find better diversification opportunities from FX investment strategies based on yield curve variables than for the strategies trying to exploit information of past FX returns.

Table IA.2: Stochastic Dominance Efficiency Tests for Portfolios of International Stocks

The Table shows pricing errors (with standard errors in parentheses) and p-values for the multivariate second-order stochastic dominance test (SSD) and the third-order stochastic dominance test (TSD) for efficiency of the $LPM_2(0)$ tangency portfolio of U.S. bonds, U.S. stocks relative to international stocks. The SSD and TSD test are restricted to price the benchmark portfolio correctly, the pricing kernels and pricing errors are based on one iteration, while the p-values are computed based on the resulting weighting matrix. The sample period is 01/1985 - 12/2009.

	Benchmark: U.S. bonds and U.S. stocks							
	Pricing Errors (SE) of unhedged stocks				Pricing Errors (SE) of fully hedged stocks			
	SSD		TSD		SSD		TSD	
Australia	0.149	(0.644)	0.081	(0.690)	0.301	(0.316)	0.290	(0.322)
Canada	0.020	(0.555)	-0.040	(0.579)	0.175	(0.299)	0.147	(0.309)
Germany	-0.036	(0.659)	-0.133	(0.717)	0.083	(0.486)	0.040	(0.497)
Japan	-0.207	(0.473)	-0.234	(0.489)	-0.224	(0.453)	-0.287	(0.468)
New Zealand	0.000	(0.597)	-0.088	(0.624)	-0.102	(0.388)	-0.081	(0.394)
Norway	0.326	(0.710)	0.352	(0.734)	0.397	(0.433)	0.340	(0.446)
Sweden	0.340	(0.665)	0.294	(0.701)	0.487	(0.477)	0.459	(0.487)
Switzerland	0.222	(0.446)	0.191	(0.491)	0.370	(0.343)	0.351	(0.346)
UK	0.048	(0.452)	0.034	(0.476)	0.028	(0.350)	-0.023	(0.358)
p-value	(0.785)		(0.647)		(0.154)		(0.123)	

Table IA.3: Stochastic Dominance Efficiency Tests for Additional FX Investment Styles
The Table shows pricing errors (with standard errors in parentheses) and p-values for the second-order stochastic dominance (SSD) test and the third-order stochastic dominance (TSD) test for efficiency of the $LPM_2(0)$ tangency portfolio of U.S. bonds, U.S. stocks and fully currency hedged international stocks relative to FX investment styles. The SSD and TSD test are restricted to price the benchmark portfolio correctly, the pricing kernels and pricing errors are based on one iteration, while the p-values are computed based on the resulting weighting matrix. The FX investment styles are adjusted for transaction costs. Panel A shows strategies based on time t-1 yield curve variables. Panel B shows strategies based on time t-1 momentum, value, and volatility. The sample period is 01/1985 - 12/2009.

Benchmark: U.S. Bonds, U.S. stocks and international fully hedged stocks				
	SSD		TSD	
	Pricing Errors (SE)		Pricing Errors (SE)	
Panel A: FX investment styles based on yield curve variables				
Carry trade	0.411	(0.208)	0.472	(0.201)
Δ short-term rate	0.101	(0.139)	0.139	(0.136)
Long-term rate	0.257	(0.217)	0.258	(0.216)
Δ long-term rate	0.178	(0.147)	0.221	(0.146)
Term spread	0.360	(0.176)	0.413	(0.170)
p-value	(0.157)		(0.021)	
Panel B: FX investment styles based on momentum, value, and volatility				
Momentum1	0.089	(0.239)	0.123	(0.253)
Momentum3	0.296	(0.203)	0.337	(0.209)
Momentum12	0.235	(0.260)	0.270	(0.276)
Value	0.198	(0.244)	0.194	(0.259)
Volatility	0.180	(0.168)	0.169	(0.167)
p-value	(0.218)		(0.138)	

Further Out-of-Sample Tests

Table IA.4 presents out-of-sample Sharpe ratios for the FX investment styles based on the smaller G10 set, and Table IA.5 reports the underlying portfolio weights on average. The Sharpe ratios are substantially increased in most settings. Considering the naive portfolio formation rules, the increase due to the carry trade and momentum style is significant at least at the 10% level. Including all three FX investment styles leads to significant portfolio gains at the 1% level. Also in case of the optimized portfolios, the Sharpe ratio is increased under every portfolio formation rule when all three FX styles are added to the investment menu, but we find less significant t-statistics than above.

Table IA.4: Out-of-Sample Results - Developed Countries

The Table reports out-of-sample Sharpe ratios for 120-month rolling windows. The benchmark assets are U.S. bonds, U.S. stocks, and international stocks. The test assets are FX styles based on developed countries, and are adjusted for transaction costs. We use the first 120 observations to compute the portfolio weights for the return in period 121. Next, we move the rolling window one period forward and repeat the previous step, which results in a time-series of out-of-sample returns of one benchmark and one test portfolio. The naive portfolio formation rules are equal weights ("1/N"), conservative, balanced, and aggressive weights. The conservative weights of the benchmark portfolio allocates 60% to U.S. bonds, 20% to U.S. stocks and 20% to international stocks (the weights of the stock markets correspond to the countries' relative World (PPP) GDP share from the IMF). For the augmented portfolios, we assign the same weights to the FX investment styles as to international stocks and rescale the portfolio weights to 100%. In the balanced and aggressive portfolio, we change the weight of U.S. bonds and recalculate the allocation to all other assets such that their relative weights to each other remain unchanged. The optimization portfolio formation rules are in the following order: the traditional mean-variance tangency portfolio, the mean-variance Bayes-Stein shrinkage tangency portfolio (we shrink the sample mean to the mean of the minimum-variance portfolio), the mean-variance tangency portfolio with short-selling constraints, the minimum-variance portfolio, and the mean-variance tangency portfolio using an expanding window instead of the rolling window. We report HAC-robust t-statistics for the difference Sharpe ratio between the benchmark portfolio and the test portfolio in brackets (Newey-West with Bartlett kernel and four lags). The sample period is 01/1985 - 12/2009.

	Bench	Carry	Mom	Value	ALL	Bench	Carry	Mom	Value	ALL
	Unhedged					Fully hedged				
	Out-of-sample Sharpe ratios of naive portfolios									
Equal Weights	0.12	0.13	0.13	0.13	0.14	0.12	0.13	0.13	0.13	0.15
(1/(N+K))		[1.68]	[2.04]	[1.35]	[3.03]		[1.65]	[2.00]	[1.28]	[2.97]
Conservative	0.17	0.21	0.21	0.20	0.21	0.19	0.22	0.22	0.22	0.23
(60% bonds)		[1.33]	[1.60]	[0.93]	[3.01]		[1.19]	[1.55]	[0.89]	[2.93]
Balanced	0.12	0.16	0.16	0.15	0.16	0.13	0.16	0.17	0.16	0.17
(30% bonds)		[1.56]	[1.72]	[1.02]	[3.07]		[1.47]	[1.68]	[1.00]	[3.02]
Aggressive	0.09	0.13	0.13	0.12	0.13	0.09	0.13	0.13	0.12	0.14
(0% bonds)		[1.75]	[1.81]	[1.06]	[3.11]		[1.71]	[1.79]	[1.05]	[3.09]
	Out-of-sample Sharpe ratios of optimized portfolios									
Mean-Variance	0.16	0.15	0.17	0.17	0.20	0.23	0.25	0.23	0.22	0.27
		[-0.29]	[0.49]	[0.28]	[0.74]		[0.65]	[0.59]	[-0.16]	[1.00]
MV Bayes-Stein	0.16	0.17	0.19	0.17	0.23	0.24	0.27	0.26	0.23	0.31
		[0.16]	[1.03]	[0.24]	[1.01]		[0.68]	[0.99]	[-0.08]	[1.31]
MV short constr.	0.16	0.19	0.17	0.16	0.24	0.19	0.21	0.21	0.17	0.25
		[0.79]	[0.60]	[-0.08]	[1.55]		[0.52]	[0.59]	[-0.74]	[1.07]
Minimum-Var.	0.14	0.18	0.19	0.14	0.22	0.18	0.22	0.22	0.19	0.29
		[0.78]	[1.36]	[-0.04]	[1.07]		[1.12]	[1.27]	[0.36]	[1.72]
MV exp. window	0.17	0.20	0.19	0.16	0.22	0.23	0.27	0.25	0.23	0.28
		[0.81]	[1.47]	[-0.22]	[1.20]		[1.03]	[1.37]	[-0.20]	[1.01]

Table IA.5: Portfolio Weights: Out-of-Sample Results - Developed Countries

The Table reports the average weight of the out-of-sample portfolios in Table IA.4. The benchmark ("Bench") portfolio contains U.S. bonds/stocks and international stocks. The augmented portfolios contain FX investment styles, namely the carry trade ("Carry"), FX momentum ("Mom"), FX value ("Value"), and all three FX styles together ("All"). The FX styles are based on the G10 currencies and are adjusted for transaction costs. US-B corresponds to the weight of U.S. bonds, US-S to U.S. stocks, Int-S to the sum over unhedged or fully hedged international stocks, and FX to the FX investment styles.

		Bench	Carry	Mom	Value	ALL	Bench	Carry	Mom	Value	ALL
		Unhedged					Fully hedged				
EW	US-B	0.09	0.08	0.08	0.08	0.07	0.09	0.08	0.08	0.08	0.07
	US-S	0.09	0.08	0.08	0.08	0.07	0.09	0.08	0.08	0.08	0.07
	Int-S	0.82	0.75	0.75	0.75	0.64	0.82	0.75	0.75	0.75	0.64
	FX		0.08	0.08	0.08	0.21		0.08	0.08	0.08	0.21
Conserv.	US-B	0.60	0.50	0.50	0.50	0.50	0.60	0.50	0.50	0.50	0.50
	US-S	0.20	0.17	0.17	0.17	0.17	0.20	0.17	0.17	0.17	0.17
	Int-S	0.20	0.17	0.17	0.17	0.17	0.20	0.17	0.17	0.17	0.17
	FX		0.17	0.17	0.17	0.17		0.17	0.17	0.17	0.17
Balanced	US-B	0.30	0.22	0.22	0.22	0.22	0.30	0.22	0.22	0.22	0.22
	US-S	0.35	0.26	0.26	0.26	0.26	0.35	0.26	0.26	0.26	0.26
	Int-S	0.35	0.26	0.26	0.26	0.26	0.35	0.26	0.26	0.26	0.26
	FX		0.26	0.26	0.26	0.26		0.26	0.26	0.26	0.26
Aggressive	US-B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	US-S	0.50	0.34	0.34	0.34	0.34	0.50	0.34	0.34	0.34	0.34
	Int-S	0.49	0.33	0.33	0.33	0.33	0.49	0.33	0.33	0.33	0.33
	FX		0.33	0.33	0.33	0.33		0.33	0.33	0.33	0.33
MV	US-B	0.79	0.54	0.59	0.61	0.35	0.75	0.53	0.62	0.57	0.38
	US-S	0.20	0.18	0.18	0.12	0.10	0.33	0.14	0.25	0.21	0.12
	Int-S	0.01	-0.02	0.01	0.03	-0.01	-0.09	-0.01	-0.05	-0.07	-0.05
	FX		0.31	0.23	0.24	0.56		0.34	0.19	0.29	0.55
MV BS	US-B	0.84	0.61	0.63	0.64	0.39	0.80	0.61	0.64	0.63	0.42
	US-S	0.11	0.08	0.08	0.06	0.03	0.14	0.02	0.08	0.08	0.02
	Int-S	0.05	0.02	0.04	0.05	0.02	0.06	0.09	0.07	0.03	0.03
	FX		0.29	0.24	0.25	0.56		0.28	0.21	0.26	0.52
MV SC	US-B	0.65	0.47	0.52	0.54	0.33	0.66	0.51	0.54	0.56	0.38
	US-S	0.13	0.08	0.09	0.08	0.03	0.12	0.05	0.08	0.09	0.04
	Int-S	0.22	0.15	0.19	0.18	0.12	0.23	0.16	0.20	0.18	0.11
	FX		0.30	0.21	0.20	0.52		0.28	0.18	0.18	0.47
Min.V	US-B	0.89	0.66	0.68	0.68	0.43	0.86	0.69	0.67	0.70	0.47
	US-S	0.02	0.00	-0.01	0.00	-0.03	-0.10	-0.11	-0.10	-0.06	-0.08
	Int-S	0.09	0.06	0.08	0.07	0.04	0.23	0.20	0.20	0.15	0.12
	FX		0.28	0.25	0.24	0.55		0.23	0.23	0.22	0.49
MV exp	US-B	0.71	0.53	0.61	0.55	0.41	0.80	0.66	0.70	0.63	0.52
	US-S	0.22	0.11	0.16	0.15	0.07	0.37	0.23	0.30	0.31	0.21
	Int-S	0.08	0.07	0.07	0.06	0.05	-0.16	-0.13	-0.14	-0.20	-0.16
	FX		0.29	0.16	0.24	0.47		0.23	0.14	0.26	0.42