ESSAYS ON EMPIRICAL INTERNATIONAL ASSET PRICING

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Abstract

This dissertation consists of two essays in empirical international asset pricing. In the first essay, I document carry trade returns based on the moments extracted from options on the underlying currencies.[1] I establish three important results. First, a currency pair is predicted to have greater excess returns if option-implied returns are more volatile, are more left-skewed, and have fatter tails than the returns of other currency pairs. Second, strategies based on option-implied information improve on benchmark strategies based on realized market returns and macroeconomic data. Third, if the option-implied returns of a currency pair are more left-skewed than in the past, anti-carry trades rather than carry trades perform better.

In the second essay, I examine the relation between ex ante skewness and the cross-section of country-specific index returns. I show that the ex ante skewness measured using country-specific index options is negatively related to country-specific returns in the cross-section. The results are robust to controlling for volatility risk, macroeconomic variables, sensitivities to the international factor risks, and realized return moments. Trading strategies based on ex ante skewness which outperform benchmark strategies based on the aforementioned control variables. I also provide evidence of time-series return predictability using ex ante skewness for Asian and non-euro area European countries. These results suggest that investors in international indices are compensated for the exposure to skewness risk.

[1]This essay is published in the *Journal of International Money and Finance* 78, November 2017, Pages 1–20.

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Contents

List of Figures

List of Tables

Chapter 1

Introduction

An extensive literature discusses the advantages of international investments. Errunza, Hogan, and Hung (1999) and Eiteman, Stonehill, and Moffett (2012) document that such investments benefit the investors from participating in the growth of foreign countries, diversifying their portfolios, and reducing the volatility at the same return. An internationally diversified portfolio enlarges the opportunity set and extends the efficient frontier by the introduction of foreign assets which are of less than perfect correlation with the portfolios within the domestic opportunity set.[1]

Institutional investors allocate their assets under management globally to seek these advantages. For example, PricewaterhouseCoopers (2015) reports that in 2014 domestic equity funds accounted for 45% while world equity funds accounted for 13%, or $1.04 trillion, within investment funds.[2] PricewaterhouseCoopers (2016) discloses that the largest three pension funds in the U.S. allocate 19.1% of their total assets in the foreign investments in 2015.[3]

[1]See Solnik (1995), DeSantis and Gerard (1997), Coeurdacier and Guibaud (2011), and Bergin and Pyun (2016) for a detailed discussion of advantages of the international diversification. Recent papers, such as Longin and Solnik (2001), Christoffersen, Errunza, Jacobs, and Langlois (2012), Hodrick and Zhang (2014), document that the correlations have increased obviously within developed countries and Ghysels, Plazzi, and Valkanov (2016) show that realized return asymmetry in the emerging markets leads to gain in the international portfolio. However, the literature agrees that the benefits from international diversification still significantly exist in general.

[2]It is also worthwhile to note that U.S. pension funds outsource 33% of their total assets to the external portfolio management through investment funds, based on the reports in PricewaterhouseCoopers (2015).

[3]The largest three pension plans in the U.S. based on the assets under management are Federal Retirement Thrift, California Public Employees, and California State Teachers. See PricewaterhouseCoopers (2015).

Moreover, Investment Company Institute (2017) reports that 14% of total U.S. mutual fund and Exchange-Traded Fund (ETF) assets, or $2.65 trillion, invest in the world equity as of year-end 2016.[4] Other institutional investors, such as hedge funds, private equities, and insurance companies, also allocate and invest their assets globally.[5]

In our empirical analysis, we find *ex ante* international characteristics and provide profitable trading strategies for such institutional investors who allocate their assets in the international markets.[6] Most of the empirical literature examines the relation between returns and option-implied information in an extensive financial assets and instruments. For example, Chang, Christoffersen, and Jacobs (2013), Conrad, Dittmar, and Ghysels (2013), DeMiguel, Plyakha, Uppal, and Vilkov (2013), Kozhan, Neuberger, and Schneider (2013), and Bali, Hu, and Murray (2017) document this relation in the U.S. stock markets, while Navatte and Villa (2000) and Muzzioli (2013) document that in the French and Italian stock index markets, respectively. All of the above researches involve the stock index in only one country.[7]

Option-implied information is "*ex ante*," or forward-looking, and thus insightful for investors to forecast future returns of the underlying assets. Hence, in our research we investigate the relation between international asset returns and the model-free option-implied information and find whether option-implied moments are able to predict future international returns. We investigate the predictability of option-implied higher moments on the international asset returns both from carry trades in the currency markets and from international stock indices.

[4] A large literature on international investments discusses "home bias" or "international diversification puzzle," which means investors prefer investing in the domestic securities or those close to home. The literature includes Cooper and Kaplanis (1994), Brennan and Cao (1997), Kang and Stulz (1997), Coval and Moskowitz (1999), and Heathcote and Perri (2013). We do not emphasize this puzzle in the essays and focus solely on the profitability of the international investments.

[5] See Stowell (2017).

[6] For a detailed discussion for constructing trading strategies based on a characteristic, see Fama and French (1993), Carhart (1997), and Fung and Hsieh (1997).

[7] There is also a large literature that documents this relation in the commodity and fixed income markets, such as Askari and Krichene (2008), Trolle and Schwartz (2009), and Datta, Londono, and Ross (2017).

In the first essay documented in Chapter 2, we use the option-implied information from not only USD-based but also Japanese yen (JPY)-based and Swiss franc (CHF)-based currency options to investigate their respective excess returns on carry trades funded by a cross-section of low-yield currencies.

In the cross-section, we find that the carry trade excess returns are related to market downside risk. We discover that the model-free option-implied moments can significantly predict excess returns, irrespective of the funding currency. If the option-implied returns of a currency pair are more volatile, are more left-skewed, and have fatter tails than those of other currency pairs in the same period, the pair is predicted to have greater excess returns. Namely, a carry trader who is exposed to greater volatility, crash, and disaster risks generally acquires more compensation from future excess returns. Each option-implied moment contains specific information about the future excess returns, and this information is not explained by other option-implied moments. The return predictability of the option-implied moments is distinct and not explained by the risk factors in the foreign exchange market or the equity market. Furthermore, this return predictability exists even after we control for the sensitivity to the time-series variations of each currency pair.

We propose strategies using the option-implied moments as characteristics: implied skewness, implied kurtosis, and implied volatility. Compared to the benchmark strategies, which are the interest rate differential strategy, momentum of spot exchange rate movements strategy, current account-to-GDP strategy, and purchasing power strategy, the option-implied information strategies perform better. The main reason is that the option-implied moments contain a forward-looking feature.

In the time series, if the option-implied return skewness reaches a historically low threshold, implying a relatively higher crash risk than was previously the case, the carry trade excess returns are forecasted to be smaller, particularly trades funded by the Japanese yen. Therefore, a trader may unwind his or her carry trade position or, more aggressively, execute an "anti-carry trade" when the option-implied skewness approaches a very negative level relative to its historical values. The portfolios that allow for anti-carry trades usually outperform those that execute only carry trades.

In the second essay documented in Chapter 3, we investigate the relation between ex ante option-implied moments and index returns from an international perspective. We examine the relation between ex ante higher moments with a focus on skewness and the cross-section of country-specific index returns. Our cross-sectional findings reveal a strong negative relation between ex ante skewness and the cross-section of subsequent index returns. The significant negative relation is robust to controlling for ex ante volatility, loadings of risk factors, realized return moments, and macroeconomic variables.

We form portfolios based on ex ante skewness. Specifically, we sort countries into quartile portfolios based on skewness and compute the subsequent returns. A long-short strategy which buys the low (more negative) skewness portfolio and sells the high skewness portfolio generates a significant annualized return of 4.9%. This strategy performs substantially better than other strategies based on inflation, GDP growth, the change in real effective exchange rates (REER), moments of the realized return distribution, and the sensitivity of the country returns to international risk factors.

Besides skewness, we also examine the role of volatility in explaining the cross-section of country-specific returns. Our finding with regards to international index markets reveals that there is no significant cross-sectional relationship between ex ante volatilities and future international returns. This result is different from the findings in the literature discussing domestic U.S. markets, including Ang, Hodrick, Xing, and Zhang (2006) and Conrad, Dittmar, and Ghysels (2013). Our results also indicate that neither market demands for hedging nor volatility feedback effect is able to explain the activities in international index markets.

Finally, we examine whether there is a skewness and volatility premium in the time series of the international stock index returns. The presence of a skewness premium indicates that if an individual country's index options imply a greater negative skewness risk than was previously the case, the index returns tend to be higher than the historical returns. We find that the skewness premium exists in the time series for Asian and non-euro area European stock indices. Our time-series results are explained by the fact that option-implied skewness is associated with the forward-looking one-sided skewness risk but volatility relates to a two-sided risk. A skewness decrease in the time series clearly infers a high probability to crash in return but an increase in volatility represents an ambiguous signal because the investors do not understand whether their position implies a potential upside or downside movement. Thus, option-implied skewness provides a more desirable risk-bearing signal for investors than volatility in the time series.

This dissertation proceeds as follows. Chapter 2 discusses that the performance of various carry trade strategies in the currency markets. We show and compare the profitability of strategies based on option-implied information and on the conventional characteristics documented in the literature. Chapter 3 investigates the intertemporal relationship between option-implied ex ante skewness and expected international stock index returns. Chapter 4 concludes.

Chapter 2

Carry Trade Strategies Based on Option-Implied Information: Evidence from a Cross-Section of Funding Currencies[1]

2.1 Introduction

A carry trade is a trading strategy in which an investor sells or borrows currencies with relatively low interest rates and simultaneously purchases or invests in currencies with higher interest rates. Under interest rate parity (IRP), a carry trade strategy does not pay off because the interest rate differential between currencies will be offset by the returns from spot foreign exchange rate movements. However, the empirical literature shows that high-yield currencies tend to appreciate and low-yield currencies tend to depreciate.[2] (See Lustig, Roussanov, and

[1] This chapter is published as an independent article in the *Journal of International Money and Finance*, Volume 78, November 2017, Pages 1–20.

[2] Since the mid-1990s, the Japanese economy has experienced a long recession; see Krugman (2013). In response, the Bank of Japan has adopted an extremely loose monetary policy. Because of the resulting extremely low interest rates, the Japanese yen has become a funding currency for the carry trade strategy in the currency market. Carry trade strategists tend to borrow the Japanese yen and invest in high-yield currencies, such as the Australian dollar or the New Zealand dollar. When carry trades prevailed between 2003 and the financial crisis in 2008, on average, the Japanese yen depreciated 8.4% per year against the Australian dollar and 7.1% per year against the New Zealand dollar in spot foreign exchange markets.

Verdelhan, 2011.) This empirical failure of interest rate parity and the resulting forward rate bias, which is called the "forward premium puzzle," has been documented by an extensive literature, which includes Bansal (1997), Baillie and Bollerslev (2000), Bansal and Dahlquist (2000), Backus, Foresi, and Telmer (2001), Burnside, Eichenbaum, and Rebelo (2007), and Burnside, Eichenbaum, and Rebelo (2009), among many other works.

Carry trade investors take risks to enjoy abnormally high returns when the strategy prevails in the market. Thus, the carry trade strategy is definitely not an arbitrage strategy. For instance, the Japanese yen appreciated substantially and rapidly while high-yield currencies depreciated during the global financial crisis due to the wave of carry trade unwinding.[3] There is a large literature that discusses the volatility risks of carry trades, which includes Cai, Cheung, Lee, and Melvin (2001), Bhansali (2007), Clarida, Davis, and Pedersen (2009), and Menkhoff, Sarno, Schmeling, and Schrimpf (2012a). More important, the substantial and rapid changes in exchange rates relate to the crash or disaster risks. Many recent papers document these risks of carry trades, such as Brunnermeier, Nagel, and Pedersen (2008), Jurek (2014), Dupuy (2015), Farhi, Fraiberger, Gabaix, Ranciere, and Verdelhan (2015), Daniel, Hodrick, and Lu (2016), and Chernov, Graveline, and Zviadadze (2018).

Most of the existing carry trade literature examines the relationship between returns and option-implied information solely on the basis of US dollar (USD)-based trades.[4] We use the option-implied information from not only USD-based but also Japanese yen (JPY)-based and Swiss franc (CHF)-based currency options to investigate their respective excess returns on carry trades funded by a cross-section of low-yield currencies. The information content implied by

[3] During the 2008 crisis, many carry traders lowered their risk exposure and unwound their positions.

[4] Comparatively, an extensive literature documents the relationship between the option-implied moments and returns in the stock market, such as Corrado and Su (1997), Bakshi, Kapadia, and Madan (2003), Chang, Christoffersen, and Jacobs (2013), Conrad, Dittmar, and Ghysels (2013), DeMiguel, Plyakha, Uppal, and Vilkov (2013), and Bali, Hu, and Murray (2017). Option-implied moments are forward-looking, and revealing such a relationship is insightful for market participants.

currency options differs from that extracted from currency spot, forwards, or futures contracts: the payoffs of currency spot, forwards, and futures contracts are linear,[5] but the payoffs from currency options are non-linear.[6] Using the JPY-based and the CHF-based options, we can directly investigate the option-implied return distributions of a typical carry trade that is funded by the Japanese yen or the Swiss franc.

In the cross-section, the carry trade excess returns are related to market downside risk. We discover that the model-free option-implied moments can significantly predict excess returns, irrespective of the funding currency. If the option-implied returns of a currency pair are more volatile, are more left-skewed, and have fatter tails than those of other currency pairs in the same period, the pair is predicted to have greater excess returns. Namely, a carry trader who is exposed to greater volatility, crash, and disaster risks generally acquires more compensation from future excess returns. This phenomenon holds irrespective of whether the trade is funded by the US dollar, the Japanese yen, or the Swiss franc.

Moreover, we find that each option-implied moment contains specific information about the future excess returns, and this information is not explained by other option-implied moments. The return predictability of the option-implied moments is distinct and not explained by the risk factors in the foreign exchange market or the equity market. Furthermore, this return predictability exists even after we control for the sensitivity to the time-series variations of each currency pair.

We propose strategies using the option-implied moments as characteristics: implied skewness, implied kurtosis, and implied volatility. In every period, a carry trader can construct a

[5] Chang and Wong (2003) and Du (2013) document the triangular parity condition. The condition specifies that one of the three triangular linear payoff relationships among any three currencies is redundant and easily replicated by the other two relationships.

[6] Among three pairwise currency options from three currencies, none is easily replicated by the other two options with simple multiplication or division using a cross-section of currency options with specific strike foreign exchange rates and tenors.

strategy by investing in the one-month forward contracts of the currency pairs in the most beneficial quartile. This strategy is predicted to be rewarding to traders. Compared to the benchmark strategies, which are the interest rate differential strategy, momentum of spot exchange rate movements strategy, current account-to-GDP strategy, and purchasing power strategy, the option-implied information strategies perform better when measured by the cumulative returns, Sharpe ratio, and certainty equivalent excess returns. The reason is that the option-implied moments contain a forward-looking feature, which is more informative than lagged macroeconomic data or realized returns.

According to the target and constraints, a trader can form a portfolio based on the strategies. We consider three utility-free portfolios: the equal-weighted portfolio, the minimum-variance portfolio, and the mean-variance portfolio. The portfolios based on all strategies, including the three option-implied information strategies and the four benchmark strategies, outperform those based solely on the benchmark strategies. Therefore, the existence of option-implied information strategies benefits carry traders and enlarges the set of investment opportunities.

In contrast to the cross-sectional results that carry traders are expected to be compensated for bearing risks, the time-series results provide carry traders with a signal to unwind their position. In the time series, if the option-implied return skewness reaches a historically low threshold, implying a relatively higher crash risk than was previously the case, the carry trade excess returns are forecasted to be smaller, particularly trades funded by the Japanese yen. Therefore, a trader may unwind his or her carry trade position or, more aggressively, execute an "anti-carry trade"[7] when the option-implied skewness approaches a very negative level relative to its historical values. The portfolios that allow for anti-carry trades usually outperform those that execute only carry trades.

[7]"Anti-carry trade" is a practical term meaning the opposite of carry trade exposure: borrowing high-yield currencies and investing in low-yield currencies.

The paper proceeds as follows. Section 2.2 reviews the methodology to measure carry trade returns and option-implied moments. Section 3.2 discusses the data and descriptive statistics. Section 3.3 reports the cross-sectional empirical results. Section 2.5 discusses the construction of carry trade strategies and portfolios. Section 3.4 presents the time-series results and the profitability of the portfolios that allow for anti-carry trades. Section 3.5 concludes.

2.2 Option-Implied Moments and Currency Returns

We first discuss the computation of currency returns and option-implied moments. We decompose the total excess returns into interest rate differentials and spot exchange returns and relate the returns to the carry trade in Subsection 2.2.1. In Subsection 2.2.2, we extract model-free implied moments from options using the methodology proposed by Bakshi, Kapadia, and Madan (2003).

2.2.1 Currency Returns

Spot and one-period forward exchange rates at time t are defined as S_t and F_t, respectively. We treat the countries with low-yield funding currencies – the United States, Japan, and Switzerland – as home countries. Exchange rates are defined as units of the domestic currencies per unit of the foreign currency. An increase in S_t therefore represents appreciation of the foreign currency, and a decrease in the former represents depreciation of the latter. For example, the exchange rate that exchanges a number of units of the Japanese yen (JPY) for one unit of the Australian dollar (AUD) is written as "AUDJPY."

The excess return (XR) on buying one unit of foreign currency in the forward market at time t with maturity $(t+1)$ and then selling it in the spot market at time $(t+1)$ is $XR_{t+1} =$

$(S_{t+1} - F_t)/S_t$. This excess return can also be written as the spot exchange rate return (SR) minus the forward premium (FP). $XR_{t+1} = SR_{t+1} - FP_t$, where $SR_{t+1} = (S_{t+1} - S_t)/S_t$ and $FP_t = (F_t - S_t)/S_t$. Here, we define one period as one month. Thus, the time to maturity of the forward contract is $\tau = 1/12$.

The forward premium (FP_t) is related to the negative interest rate differential between the investment currency and the funding currency and is realized at time t. To show this relationship, one has to refer to covered IRP, which holds empirically with low-frequency data or in long-term equilibrium:

$$F_t = S_t \cdot \exp\{(r_t - r_t^f) \times \tau\}, \tag{2.1}$$

where r_t and r_t^f represent the annualized domestic and foreign default-free interest rates, respectively, with the corresponding maturity of the forward contract (τ). After rearranging equation (2.1) and approximating to the first order by Taylor expansion, one can trivially show that the forward premium approximately equals the interest rate differential between two countries: $FP_t \approx (r_t - r_t^f) \times \tau$.[8] As a result, the currency excess return is approximately equal to spot exchange rate movements minus an interest rate differential, which is $XR_{t+1} \approx SR_{t+1} - (r_t - r_t^f) \times \tau$.

The forward premiums of carry trade pairs, such as AUDJPY, are negative and very large in absolute value. The reason is that the interest rate differentials between the investment currency (such as the Australian dollar) and the funding currency (such as the Japanese yen) are positive and usually large.

2.2.2 Implied Moments from Currency Options

Bakshi, Kapadia, and Madan (2003) propose a method to extract model-free implied skew-

[8]See Akram, Rime, and Sarno (2008) for a detailed derivation.

ness and kurtosis from options. They assume that there exist hypothetical swaps, the payoffs of which equal the non-central moments of the log returns. Moreover, we accurately calculate the option-implied moments from observed options based on the methodology proposed by Jiang and Tian (2005) and Bu and Hadri (2007).[9]

2.3 Data and Descriptive Statistics

In this section, we discuss the data. We introduce the data sources and the sample in Subsection 3.2.1. Subsection 2.3.2 presents the descriptive statistics.

2.3.1 Data Sources

We obtain the short-term risk-free interest rates,[10] the spot exchange rates, and the one-month forward exchange rates from Datastream, and the option-implied volatility market quotes from J.P. Morgan. The tenor of the options is one month. The sample period is from April 1, 2002, to August 22, 2014. The macroeconomic data include the current account balance, the gross domestic product (GDP), and the consumer price index (CPI). We collect them from Datastream. The Fama-French three factors in the equity market: returns on the market portfolio, size, and book-to-market are from Kenneth French's website at Dartmouth College.

J.P. Morgan's currency options dataset provides daily over-the-counter quotes in the form of Garman and Kohlhagen (1983) implied volatilities for the European options at constant maturities and five fixed levels of Garman-Kohlhagen deltas: 10Δ puts, 25Δ puts, 50Δ (at-

[9] See Appendix A for a detailed discussion.

[10] We collect the short-term risk-free interest rates in Datastream by referring to the Thomson Reuters Datastream guides. We use the following interest rates as the risk-free rates. USD: Treasury-bills 3-month. CAD: Treasury-bills 3-month. GBP: Treasury-bills 3-month. EUR: Germany Treasury-bills 3-month. NZD: Treasury-bills 3-month. AUD: Dealer bills 90-day. CHF: 3-month deposit rates. SEK: 3-month deposit rates. NOK: 3-month interbank offer rates. JPY: Gensaki repo rates 1-month, the collateral of which are Japanese government bonds.

the-money) options, 25Δ calls, and 10Δ calls. Except for the at-the-money options, the other four types of options are all out-of-the-money with Δ, the absolute value of delta, equal to the number stated ahead divided by 100. The currencies in this research are the "G10 currencies," which are ten of the most heavily traded and the most liquid currencies in the world. We decompose the G10 currencies into two groups. One group includes the high-yield currencies or investment currencies: the Australian dollar (AUD), the New Zealand dollar (NZD), the Euro (EUR),[11] the British pound (GBP), the Canadian dollar (CAD), the Swedish krona (SEK), and the Norwegian krone (NOK). The other group includes the low-yield currencies or funding currencies: the Japanese yen (JPY), the Swiss franc (CHF), and the US dollar (USD).[12] Typically, most carry trades in the currency market are funded by one of these three currencies.[13] In all of the analysis, we treat these three funding currencies as three separate funding sources. Namely, a carry trader borrows one of them and invests in seven high-yield currencies as a portfolio. Thus, we separately show the JPY-, CHF-, and USD- based results and investigate the performance of each funding currency.

2.3.2 Descriptive Statistics

Table 2.1 indicates that the Japanese interest rates are lowest among the currencies in our sample. The Swiss franc and US dollar rank as the second- and the third-lowest interest rates,

[11] The European Central Bank has lowered the risk-free interest rates of the Euro to a very low level since the second half of 2011 and even applied a negative deposit facility interest rate since mid-2014. We classify the Euro as a high-yield currency based on the average rate over the sample period.

[12] Our analysis does not take into account the effects of interventions by governments or central banks in the foreign exchange market. In most of our sample, the governments of G10 countries did not intervene in currency markets. However, there are some exceptions. For instance, Japan has intervened to weaken the yen due to Prime Minister Abe's "Three Arrow" policy since 2013, and the Swiss National Bank (SNB, the central bank of Switzerland) maintained a 1.20 floor on EURCHF between September 2011 and January 2015. For a more detailed discussion of the intervention by the SNB, see Hossfeld and MacDonald (2015).

[13] The US risk-free interest rate was higher than the Japanese one before the global financial crisis in 2008. In 2008, the Federal Reserve began cutting rates aggressively, but the Japanese yen remains the most "effective" funding currency if the forward premium puzzle exists.

respectively, throughout most of the sample period.[14]

[Insert Table 2.1 around here.]

Table 2.2 illustrates that the average carry trade excess returns are all positive. If the trades are funded by the Japanese yen or the US dollar, the positive excess returns come from earning not only positive interest but also positive spot exchange rate returns.

Table 2.3 shows that, in general, the carry trade risk-neutral returns are negatively skewed. This indicates that, on average, carry traders are exposed to downside risk or crash risk, which confirms the findings in Jurek (2014).[15]

[Insert Table 2.2 around here.]

[Insert Table 2.3 around here.]

2.4 Empirical Results: the Cross-Section of Currency Returns

In this section, we document the cross-sectional connection between option-implied moments and carry trade returns. We examine whether option-implied moments have significant predictive power for future returns based on individual funding currencies in Subsection 2.4.1. We investigate the relationship between the cross-sectional carry trade excess returns and the downside market risk in Subsection 2.4.2. We discuss the cross-sectional return predictability of the option-implied moments in subsection 2.4.3.

[14] See Figure B.1 in Appendix B for the time variation of the interest rates.

[15] Table B.1 in Appendix B illustrates the time-series statistics of the option-implied dispersion.

2.4.1 Option-Implied Moments and Carry Trade Returns Based on Individual Funding Currencies

In this subsection, we use Fama-MacBeth regressions to document the cross-sectional relationship between implied moments extracted from options at the beginning of the period and the carry trade returns realized over the month. If this relationship is significant, traders are expected to make profits by investing in the currency pairs with high or low option-implied moments, depending on which direction is beneficial to them.

Carry traders earn high interest rate differentials, or invest in the currency pairs with negative forward premiums with large absolute values. Hence, we examine the relationship between carry trades and crash risks by investigating how the contemporaneous forward premiums (FP) or the interest rate differentials (RD) associate with the option-implied skewness across currency pair i. For example, Jurek (2014) and Farhi, Fraiberger, Gabaix, Ranciere, and Verdelhan (2015) propose that USD-based carry traders typically bear crash risks associated with high-yield currency depreciation. Based on these regressions, we can confirm the USD-based results documented in the literature. More important, we can investigate whether the JPY- and CHF-based carry trades have similar results using the cross-JPY and cross-CHF option data.

Regression 1.a. $FP_{it} = \alpha_t + \beta_{1.\mathrm{a},t} \cdot \mathrm{iskew}_{it} + \varepsilon_{it}$; given a specific time t,

Regression 1.b. $RD_{it} = \alpha_t + \beta_{1.\mathrm{b},t} \cdot \mathrm{iskew}_{it} + \varepsilon_{it}$; given a specific time t,

For these cross-sectional regressions, the Fama-MacBeth coefficients are the mean of all regressions estimated at different times t, which are $\hat{\beta}_1 = \left(\sum_{t=1}^{T} \hat{\beta}_{1,t}\right)/T$, while we report the robust standard errors adjusted for time dependence based on Petersen (2009). Forward premiums or interest rate differentials that are gained from time t to $(t+1)$ are realized at time t, the beginning of each time period. As a result, these cross-sectional regressions are contemporaneous regressions. We expect that carry trade investors bear high crash risk from high-yield currency depreciation and low-yield currency appreciation. Thus, the loading coefficient $\hat{\beta}_{1.a}$ in Regression 1.a is expected to be positive, and the loading coefficient $\hat{\beta}_{1.b}$ in Regression 1.b is expected to be negative.

There is an extensive literature on conditionally autocorrelated currency returns, including Bekaert (1995) and Neely and Weller (2000). Thus, each of the regressions in Regression 1.a adds the lagged forward premium as an additional independent variable for robustness.

Panel A of Table 2.4 shows the results of Regression 1.a: the forward premiums are significantly and positively related to the option-implied skewness, irrespective of whether a low-yield currency funds the carry trade. Similarly, Panel B of Table 2.4 shows the results of Regression 1.b: the interest rate differential is negatively correlated with the risk-neutral return skewness. That is, if the carry trade interest rate differential is higher, then there is a higher crash risk from depreciation of the high-yield currencies and appreciation of the low-yield currencies. These results are consistent with the recent findings of Jurek (2014) and Farhi, Fraiberger, Gabaix, Ranciere, and Verdelhan (2015) that crash risk is related to carry trades and is priced in the currency market through the option-implied volatility smirk.

The JPY-based regressions have the highest average R^2. Namely, the JPY-based option-implied skewness better explains the interest bearings than do the CHF-based and the USD-based option-implied skewness.

[Insert Table 2.4 around here.]

A carry trade investor bears volatility, crash, and disaster risks, meaning that (s)he may earn significantly positive excess returns as compensation.[16] To discover whether the carry

[16]In general, the compensation for risk exposure is priced in the cross-section of returns on assets. An exten-

trader obtains this compensation from the cross-sectional risk exposure, we can investigate the following Fama-MacBeth regressions, which indicate the relationships between the carry trade excess returns and the option-implied moments:

Regression 2.a. $XR_{i,t+1} = \alpha_t + \beta_{2.\mathrm{a},t} \cdot \mathrm{iskew}_{it} + \varepsilon_{i,t+1}$; given a specific time $(t+1)$,

Regression 2.b. $XR_{i,t+1} = \alpha_t + \beta_{2.\mathrm{b},t} \cdot \mathrm{ikurt}_{it} + \varepsilon_{i,t+1}$; given a specific time $(t+1)$,

Regression 2.c. $XR_{i,t+1} = \alpha_t + \beta_{2.\mathrm{c},t} \cdot \mathrm{ivol}_{it} + \varepsilon_{i,t+1}$; given a specific time $(t+1)$,

For the options quoted at time t and expiring at time $(t+1)$, the implied moments can be extracted at time t. However, the excess returns, which are gained from time t to $(t+1)$, are realized at time $(t+1)$, the end of the period. As a result, the cross-sectional regressions in Regression 2 are intertemporal regressions. We expect that a carry trader bears crash risk, disaster risk, and volatility risk, meaning that (s)he earns positive out-of-sample excess returns as compensation. Thus, the loading coefficient $\hat{\beta}_{2.\mathrm{a}}$ in Regression 2.a is expected to be negative and the loading coefficients $\hat{\beta}_{2.\mathrm{b}}$ and $\hat{\beta}_{2.\mathrm{c}}$ in Regressions 2.b and 2.c are both expected to be positive.

There is an extensive literature on conditionally autocorrelated currency returns, including Bekaert (1995) and Neely and Weller (2000). Hence, each of the regressions in Regression 2 adds the lagged excess return as an additional independent variable for robustness.

Table 2.5 shows the predictive relationships between the option-implied moments and the future excess returns. Panel A shows that the option-implied skewness significantly predicts the

sive literature studies the compensation for risk exposure in the cross-section. For example, Koijen, Lustig, and Van Nieuwerburgh (2017) document that cross-sections of returns are explained by the compensation for exposure to risk factors. Chang, Christoffersen, and Jacobs (2013), adopting a cross-sectional perspective on the stock market, report that investors are compensated with higher expected wealth when their portfolios exhibit returns with high volatility, low skewness, or high kurtosis. However, from the time-series perspective, Moskowitz, Ooi, and Pedersen (2012) document that excess returns do not appear to be compensation for risk exposure. Goyal and Jegadeesh (2018) explain that the cross-sectional and the time-series risk factors are based on different net active positions, and thus, the difference between the returns on these two factors partially comes from the compensation for bearing risks.

future excess returns. In the cross-section, if the option-implied skewness of a currency pair is more negative than other cross-sectional counterparts, the excess returns of this currency pair are forecasted to be higher. This empirical result indicates that a carry trader who bears greater crash risks, on average, acquires more compensation from the future excess returns. Hence, this predictive relationship supports the forward premium puzzle and indicates that a carry trade with a high interest rate differential has profitable prospects. The results are also consistent with what is suggested in Lustig, Roussanov, and Verdelhan (2014); that the USD-based carry trade excess returns compensate carry traders for taking aggregate risks in bad times. We extend their results from USD-based carry trades alone to JPY-based and CHF-based carry trades. Moreover, based on the average R^2, the crash risks better explain the compensation in the future returns in the JPY- and the CHF-based trades than in the USD-based trades.

Panel B of Table 2.5 shows that the option-implied kurtosis significantly predicts future excess returns. If the option-implied returns of a currency pair have fatter tails, this pair is predicted to have greater future excess returns. Thus, a carry trader who is exposed to greater disaster risk, on average, obtains greater compensation from the future excess returns. This confirms the finding in Dupuy (2015) that the excess returns in carry trades are related to the currency tail risks.

Panel C of Table 2.5 illustrates that the option-implied volatility significantly predicts future excess returns. If the option-implied returns of a currency pair are more volatile than other cross-sectional counterparts, the future excess returns of this currency pair are predicted to be higher. This empirical result suggests that a carry trader bearing greater volatility risk, on average, receives greater compensation from the future excess returns.

[Insert Table 2.5 around here.]

2.4.2 Cross-Sectional Carry Trade Returns and Downside Market Risk

The cross-sectional carry trade excess returns are related to downside risk. We investigate whether the contemporaneous cross-sectional carry trade excess returns can be explained by the downside risk measure. Lettau, Maggiori, and Weber (2014) document sensitivity to downside market return and test the contemporaneous relationship between the excess returns and the sensitivity to the downside market return using a downside risk capital asset pricing model. We follow their methodology and investigate the downside market returns using an equity market factor (RX_E) and a foreign exchange market factor (RX_{FX}). The latter factor, which is documented in Lustig, Roussanov, and Verdelhan (2011), is the average excess return on all USD-denominated foreign currency portfolios in our sample. To increase statistical power, we combine all of the carry trades across funding currencies in one sample with a larger number of observations.

Regression 3.

The first stage: (Time-series regressions)

$$XR_{i,t} = \alpha_i + \beta_i \cdot r_{m,t} + \varepsilon_{i,t}; \text{ given } i, \forall t, \text{ and} \tag{2.2}$$

$$XR_{i,t} = \alpha_i^- + \beta_i^- \cdot r_{m,t} + \varepsilon_{i,t}^-; \text{ given } i, \forall t, \text{ whenever } r_{m,t} \leq \overline{r}_m - \sigma_{r_m} \tag{2.3}$$

The second stage: (Fama-MacBeth regression)

$$\left(XR_{i,t} - \hat{\beta}_i \cdot r_{m,t}\right) = \alpha_t + \lambda_{\text{downside},t} \cdot \left(\hat{\beta}_i^- - \hat{\beta}_i\right) + \varepsilon_{i,t}; \tag{2.4}$$

Equation (2.3) captures the downside risk, where r_m is the market excess return or the market factor, and $\bar{r}_m$ and σ_{r_m} are the sample average and standard deviation of the market excess return, respectively. The point estimates $\hat{\beta}$ and $\hat{\beta}^-$ in the first stage are unconditional and downside betas respectively, and they are the explanatory variables in the second stage.

Table 2.6 presents the result that the cross-sectional carry trade excess returns are significantly related to the downside risk. The carry trade's downside price of risk ($\lambda_{\text{downside}}$) is significantly positive using either the equity market factor or the foreign exchange market factor. Moreover, the average of the pricing errors (α) is not significantly different from zero.

[Insert Table 2.6 around here.]

2.4.3 The Return Predictability of the Option-Implied Moments

To investigate whether all of the crash risk, disaster risk, and volatility risk can predict future excess returns, we simultaneously include all of these three option-implied moments in one Fama-MacBeth regression. Given the similar results across funding currencies, we pool all of the carry trades in one sample such that the test uses a larger number of observations and has greater statistical power. Due to the similarity across currency pairs, we add cross-sectional dummy variables to control for the effects of both the investment currency and the funding currency.

Regression 4.

$$XR_{i,t+1} = \alpha_t + \beta_{4s,t} \cdot \text{iskew}_{it} + \beta_{4k,t} \cdot \text{ikurt}_{it} + \beta_{4v,t} \cdot \text{ivol}_{it} +$$
$$\gamma_{X,t} \cdot X_{it} + \gamma_{I,t} \cdot DI_{it} + \gamma_{F,t} \cdot DF_{it} + \varepsilon_{i,t+1};$$

In the first stage, we estimate the cross-sectional regression at each time $(t+1)$. Then, we compute the averages and the robust standard errors of the coefficients in the second stage. DI is the vector of the dummy variables for the investment currency, and DF is the vector of the dummy variables for the funding currency. X is the vector of other control variables that we describe below. We can investigate the significance of the predictability of the moments after considering other explanatory variables.

Column (A) of Table 2.7 presents the results of the cross-sectional return predictability of the option-implied moments. Similar to the results analyzed using individual funding currencies in Subsection 2.4.1, the option-implied skewness, which represents the crash risk, is negatively related to the future excess returns. However, option-implied volatility and kurtosis which represent the volatility and disaster risks, respectively, are positively related to the future excess returns. This is evidence that each moment contains specific information about the future excess returns and that this information is not explained by other option-implied moments.[17]

Time-series variations in the moments of individual carry trades might have commonalities. Thus, the cross-sectional variations of the individual carry trades may be related to their sensitivities to time-series variations in the option-implied moments. We control for the time-series sensitivity of each currency pair and investigate whether the option-implied moments can still significantly predict carry trade excess returns. We compute this sensitivity of each currency pair by estimating the coefficients of the option-implied moments in the time-series regressions, following the methodology proposed in Elton (1999). The methodology is similar to Equation (2.2) in the first stage of Regression 3.

The results are tabulated in Column (B) of Table 2.7. After considering the sensitivities to the time-series variations in the option-implied moments, the moments remain able to predict

[17] To investigate the robustness of the predictability, we split our sample and analyze a subsample corresponding to the global financial crisis. During the crisis period, we do not find return predictability for option-implied kurtosis. However, option-implied skewness and volatility generate greater and more statistically significant return predictability compared to the full-sample analysis presented in Table 2.7. We can think of the recent global financial crisis as a disaster. During a disaster, tail events occur more frequently and the information contained in the kurtosis is noisier than in normal times. However, option-implied skewness contains information to more clearly predict future returns. Furthermore, from a cross-sectional perspective, bearing volatility or crash risk is more rewarding for the carry traders than it is during normal times.

the future carry trade excess returns. The return predictability of the moments exists even after we control for the sensitivity to the time-series variations of each currency pair.

Moreover, we expect that the return predictability of the option-implied moments is distinct and not explained by other known factors. Thus, we examine the relationship between the future excess returns and explanatory variables, which include the option-implied moments and the loadings to other known factors documented in the literature. Lustig, Roussanov, and Verdelhan (2011) cite two important factors in the foreign exchange market. The first is the dollar risk factor (RX_{FX}), which is essentially the average excess return on all USD-denominated foreign currency portfolios in our sample. The second is the carry trade risk factor (HML_{FX}), which is the excess return of buying the highest and selling the lowest interest rate currencies in our sample in each period.

Because the carry trade returns are related to the equity market, we also examine factors in the equity market. We focus on the equity market factor (RX_E) and the Fama and French (1992) three factors: market, size (SMB_E), and book-to-market (HML_E).

Then, we estimate the loadings to these factors given a currency pair, following the methodology proposed in Elton (1999). We examine whether the option-implied moments can still significantly predict future excess returns after considering the loadings to the factors of each currency pair.

The results are tabulated in Columns (C) to (F) of Table 2.7. Controlling for the factor loadings from either the foreign exchange market or the equity market, the return predictability of the option-implied moments is still robust.[18] The return predictability of the moments does not come from these factors.

[Insert Table 2.7 around here.]

[18]The coefficient of the implied skewness in Column (D) is significant at the 10% level, where the p-value is 7.3%.

2.5 Trading Strategies and Portfolios Based on the Cross-Sectional Results

Based on the cross-sectional empirical results discussed in the previous section, we propose profitable trading strategies based on cross-sectional sorting of the option-implied moments in Subsection 2.5.1. To compare the profitability of these strategies, we discuss the "benchmark" strategies based on the realized returns or macroeconomic variables in Subsection 2.5.2 and compare the performance of the strategies in Subsection 2.5.3. A carry trader can form a portfolio based on these available strategies. We discuss the importance of including option-implied information strategies in Subsection 2.5.4.

2.5.1 Option-Implied Information Strategies

A carry trader forms a strategy by borrowing one of the three funding currencies – JPY, USD, or CHF – and investing in some of the high-yield currencies in the G10 currencies – AUD, CAD, EUR, GBP, NOK, NZD, and/or SEK. Based on a specific characteristic j, the carry trader invests in the most beneficial quartile (two currency pairs) of the one-month forward contracts at time t. The excess returns of the strategy are realized at time $(t + 1)$. The empirical results are generally robust if the "quartile" or "two" currency pair is replaced by the quintile or median. Note that the carry trader does not simultaneously buy the top quartile and sell the bottom quartile as Fama and French (1992) model in the equity market. The reason is that investing in a currency pair is already simultaneously buying one currency and selling another currency. Applying the Fama-French framework directly here results in funding-currency-neutral (such as JPY-neutral), which is not the spirit of the carry trade.

Based on the cross-sectional regressions in Subsection 2.4.1, we propose the following option-implied information strategies:

Implied Skewness (Iskew)

According to Regression 2.a and the Fama-MacBeth regression results presented in Panel A of Table 2.5, the option-implied skewness is negatively related to the excess returns realized in the future. Investing in the two currency pairs that have the most left-skewed option-implied returns (the bottom quartile) is predicted to be profitable to carry traders.

Implied Kurtosis (Ikurt)

Based on the results of Regression 2.b and the Fama-MacBeth regressions presented in Panel B of Table 2.5, the option-implied kurtosis is positively related to the future excess returns. Investing in the two currency pairs with the fattest-tailed option-implied returns (the top quartile) is forecasted to be rewarding to carry traders.

Implied Volatility (Ivol)

Based on the results of Regression 2.c and the Fama-MacBeth regressions shown in Panel C of Table 2.5, the option-implied volatility positively relates to the excess returns realized one month ahead. Investing in the two currency pairs with the highest option-implied volatilities (the top quartile) is predicted to be beneficial to carry traders.

2.5.2 Benchmark Strategies

To compare the investment performance of the option-implied information strategies proposed in this paper, we present four benchmark strategies by referring to the existing literature. We apply these benchmarks to the carry trade framework.

Interest Rate Differential (Rate)

Although the carry trade framework is applied, a trader still can invest in the two highest-yield currencies by borrowing one of the low-yield currencies. This strategy is named the "interest rate differential" or "Rate" strategy, which can be viewed as a "pure" carry trade strategy. Lustig, Roussanov, and Verdelhan (2011) document this carry trade strategy and form a "carry" factor in the currency market, akin to the approach of Fama and French (1992) for the equity market. This "carry" factor is widely used and implemented in subsequent studies, such as Asness, Moskowitz, and Pedersen (2013) and Koijen, Moskowitz, Pedersen, and Vrugt (2015).

Momentum of Spot Exchange Rate Movements (SR)

Akin to Carhart (1997), who constructs a momentum factor in the equity market, Menkhoff, Sarno, Schmeling, and Schrimpf (2012b) derive a momentum factor by sorting historical spot exchange rate returns in the currency market. They document that the spot rate returns have momentum. That is, a currency pair tends to continue to have high returns if its historical spot rate returns are large. The momentum strategy is also widely utilized in practice and discussed in currency market studies, such as Burnside, Eichenbaum, and Rebelo (2011), Asness, Moskowitz, and Pedersen (2013), and Olszweski and Zhou (2013).

Current Account, Standardized by GDP (CATOGDP)

From open macroeconomic theory, the exchange rate is determined along with the general equilibrium in the goods, monetary, and asset markets. Based on Dornbusch and Fischer (1980), a current account deficit indicates that the country spends more on international trade than it earns and that it may borrow capital from foreign sources to make up the deficit. In other words, the country requires more foreign currencies through imports than it receives, and it supplies more domestic currency than demanded from foreign countries through its exported products. The excess demand for the foreign currencies lowers this country's currency value until the domestic goods and services are sufficiently inexpensive for foreigners and foreign assets are too expensive to generate sales for domestic interests to achieve general equilibrium. In the twenty-first century, Obstfeld and Rogoff (2005) still observe this empirical relationship between current account imbalances and exchange rate adjustments. Although capital account liberalization has increased the importance of the capital and financial accounts in the balance of payments, Obstfeld (2012) discovers that current account imbalances can still signal elevated macroeconomic and financial stresses in the recent financial crisis. Therefore, we treat the current account normalized by the country's GDP ("CATOGDP") as a benchmark strategy in the carry trade framework. Based on the "CATOGDP" characteristic, carry traders invest in the high-yield currencies ranked in the top quartile of the normalized current account surplus.

Purchasing Power (CPIMOM)

According to purchasing power parity (PPP), purchasing power should be identical across two countries after the foreign exchange rate is taken into account. We cannot easily derive the long-term equilibrium of the price index or the citizens' purchasing power in a specific country. However, we know that inflation in a single country represents the increase in the prices of goods and services and the decrease in the value of the currency.[19] A large literature, including Goldberg and Campa (2010) and Engel, Mark, and West (2015), investigates the

[19]Central banks usually set inflation targets and tend to raise interest rates or tighten monetary policy when inflation exceeds the target. Market expectations of future interest rate hikes for one currency usually make this currency appreciate against other currencies, other things being equal. This phenomenon is complicated, and the market reactions are not direct or easy to predict. See Edwards (2006) for a more detailed discussion. We rule out this phenomenon in this paper and focus solely on the negative relationship between inflation and the currency value, without loss of generality.

relationship among the consumer price index (CPI), PPP, and exchange rates. This strategy focuses on the negative relationship between inflation and the currency value. For simplicity, we focus on the month-over-month percentage change in CPI, which we term "CPIMOM." Thus, a carry trader invests in the high-yield currencies, and these currencies are circulated in the countries (regions) with the two lowest values of month-over-month percentage change in CPI. Additionally, the results are robust and similar if we substitute year-over-year change for the month-over-month change.

2.5.3 The Performance of Individual Carry Trade Strategies

As presented in the previous subsections, we have seven carry trade strategies. The three discussed in Subsection 2.5.1 are the option-implied information strategies proposed in this paper. The other four discussed in Subsection 2.5.2 are treated as the benchmark strategies, which are presented in the literature. Each strategy begins investing in April 2002, the beginning of the sample period, and rolls over based on the characteristic observed in the market or extracted from currency options at each month-end. Because the macroeconomic data are announced later than the exact periods, we assume that market participants obtain the macroeconomic information after two months because of the time lag involved in the collection, arrangement, and announcement of the data by the official institutions. Thus, this two-month lag influences the "CATOGDP" and "CPIMOM" strategies.

We use the cumulative returns from the beginning of sample period, the Sharpe ratio, and the certainty equivalent excess returns as performance measures.[20]

Table 2.8 shows that, irrespective of which low-yield currency funds the trades, the option-

[20]For the certainty equivalent excess returns, we present the value using a constant absolute risk aversion (CARA) utility function, or exponential utility function, with risk aversion coefficient 5. Applying other risk aversion coefficients leads to similar results.

implied information strategies generally outperform the benchmark strategies related to the realized market returns or the macroeconomic data. The reason is that option-implied moments are forward-looking, and hence, one can distinguish the market's attitude toward the future currency returns by observing the option-implied information. Therefore, the option-implied moments are more informative than the lagged economic data or the realized returns.

The only exception regarding outperformance is that the option-implied skewness strategy is beaten by the interest rate differential strategy when using JPY as the funding currency. There are two explanations for this exception. First, due to Japan's very low interest rates, the carry traders borrowing JPY and applying the "Rate" strategy earn substantial returns from interest rate differentials, which are greater than those of traders borrowing CHF or USD. Second, the Japanese government intervened significantly in the foreign exchange market to weaken the yen after 2013. This intervention ruins the predictive profitability of the "Iskew" strategy.

Figure 2.1 illustrates the time-series cumulative return of each individual carry trade strategy funded by one of the low-yield currencies. The figures apparently show that the option-implied information strategies usually have greater cumulative returns than the benchmark strategies. However, although the "Rate" strategy sometimes performs as well as, or even better than, the option-implied information strategies, the latter achieve greater returns after the financial crisis. This phenomenon can be interpreted as the "Rate" strategy having larger downside pressure when carry trades are unfavorable to market participants. As mentioned above, the framework presented here is a carry trade framework, and the "Rate" strategy is a typical "pure" carry trade strategy, and hence, it tends to operate well when carry trades have good performance and poorly when they do not. We further discuss this time-series result regarding whether a trader executes a carry trade or an anti-carry trade in Section 3.4.

Although there is high correlation between any two of the option-implied information strategies,[21] none of them is redundant. Figure 2.1 and Table 2.8 show that no strategy consistently dominates the other strategies. If a carry trader places an appropriate weight on each of the strategies, the trader may achieve his or her "targeted" performance by optimizing the objective function. We further discuss this issue, the portfolios of the carry trade strategies, in the next subsection.

[Insert Figure 2.1 around here.]

[Insert Table 2.8 around here.]

2.5.4 The Performance of Portfolio Strategies

Given the strategies, a trader can form a portfolio by placing the optimal weights on the strategies according to his or her objectives and constraints to achieve the targeted returns. We focus on the comparison of the portfolios based on the four benchmark strategies alone and those based on all of the strategies, including the three option-implied information strategies. A trader forms a portfolio based on a total of N strategies, given the available strategy $j = 1, 2, \cdots, N$. Following the standard concept of DeMiguel, Plyakha, Uppal, and Vilkov (2013), we propose three utility-free portfolios for simplicity. This concept can be applied to the utility-based models or more complicated objective functions.

Equal-Weighted Portfolios

Each strategy in the equal-weighted portfolio has the same weight $1/N$.

[21] On average, the correlation between any two of the option-implied information strategies is approximately 91.7%.

Minimum-Variance Portfolios

A trader wishes to minimize the return volatility of the portfolio. (S)He solves this objective function to find the optimal weight of each strategy.

$$
\begin{aligned}
\min_w \quad & \boldsymbol{w}^\top \hat{\boldsymbol{\Sigma}} \boldsymbol{w} \\
\text{s.t.} \quad & \boldsymbol{w}^\top \boldsymbol{e} = 1 \quad \text{and} \quad w_j \geq 0, \forall j,
\end{aligned}
$$

where $\boldsymbol{w}$ is an $(N \times 1)$ column vector of weights on each strategy, $\boldsymbol{e}$ is an $(N \times 1)$ column vector with all elements one, and $\hat{\boldsymbol{\Sigma}}$ is the predictive variance-covariance matrix of the returns of strategies. $\hat{\boldsymbol{\Sigma}} = \text{diag}(\hat{\boldsymbol{\sigma}})\hat{\boldsymbol{\Omega}}\,\text{diag}(\hat{\boldsymbol{\sigma}})$, where $\hat{\boldsymbol{\sigma}}$ is an $(N \times 1)$ column vector of the predictive return standard deviation of each strategy, and $\hat{\boldsymbol{\Omega}}$ is an $(N \times N)$ matrix of the predictive correlation coefficients between any two strategies in column and row.

Campbell, Serfaty-De Medeiros, and Viceira (2010) and Christensen and Varneskov (2016) also propose the similar concept of variance-minimization for currency hedging.

Mean-Variance Portfolios

A trader wishes to balance the impact of return volatilities and the returns themselves. The optimal weights of the strategies are obtained by

$$
\begin{aligned}
\min_w \quad & \boldsymbol{w}^\top \hat{\boldsymbol{\Sigma}} \boldsymbol{w} - \boldsymbol{w}^\top \hat{\boldsymbol{\mu}} \\
\text{s.t.} \quad & \boldsymbol{w}^\top \boldsymbol{e} = 1 \quad \text{and} \quad w_j \geq 0, \forall j,
\end{aligned}
$$

where $\hat{\boldsymbol{\mu}}$ is an $(N \times 1)$ column vector of the predictive average future returns of each strategy.

It is difficult to perfectly predict a strategy's return and its standard deviation. Predicting the future correlations between strategies is even more challenging. Therefore, we use the historical measures as proxies for the predictive measures. Admittedly, this is a substantial disadvantage,[22] but no one can perfectly predict future strategy return volatilities and correlations. DeMiguel, Plyakha, Uppal, and Vilkov (2013) suggest that using the option-implied measures, rather than the historical measures, improves portfolio selection. However, we cannot use the strategy's implied volatility or correlation as proxies because there are no tradable derivatives related to these strategies. Moreover, the predictive measures in the objective function are calculated under the physical probability while the option-implied measures are calculated under the risk-neutral probability. Recent studies, such as Londono and Zhou (2017) and Daniel and Moskowitz (2016), nevertheless use the historical measures as proxies for the expected measures in a similar situation.[23]

We impose short-selling constraints in the minimum-variance and in the mean-variance portfolios for two reasons. First, we want to keep the "carry trade" concepts in each strategy. Second, the portfolios should avoid short-selling a specific strategy in a very large volume, such as thirty times, and investing in one or some strategy/(ies) in large volume(s). This constraint prevents having a very high return volatility and short-selling an *ex post* highly profitable strategy. The reason for this flaw is that market participants do not have perfect foresight regarding future strategy returns, as mentioned above.

We determine the weights at each month-end and hold the optimized portfolio for a month to gain monthly excess returns. This monthly frequency matches the information horizon im-

[22]Elton (1999) argues that the realized return is an unbiased proxy for the expected return only if information surprises tend to cancel out.

[23]The predictive methodology is beyond the scope of this paper and left for future study. Monte Carlo simulation is a feasible method if we assume that the strategies' future returns follow a specific multi-dimensional distribution.

plied in the options. The optimized weights of the minimum-variance and the mean-variance portfolios are determined by the information of all the previous periods in our sample. Then, in the following period, we present the out-of-sample returns of the portfolios based on the optimized weights. Table 2.9 reports the average performance of the portfolios, measured by the average returns, the Sharpe ratio, and the certainty equivalent excess returns. The portfolios based on all strategies, including the three option-implied information strategies, outperform the portfolios based on the benchmark strategies alone. Figure 2.2 also illustrates that the portfolios based on all strategies (dark gray lines with square symbols) always outperform the portfolios based solely on the benchmark strategies (light gray lines with cross symbols).[24] Therefore, the option-implied information strategies benefit carry traders and enlarge the set of investment opportunities.

[Insert Figure 2.2 around here.]

[Insert Table 2.9 around here.]

2.6 Empirical Results: the Time Series of Currency Returns

We use time-series regressions to investigate the relationship between carry trade returns and option-implied skewness. We present the regression in Subsection 2.6.1 and the empirical results in Subsection 2.6.2. Based on the time-series comparison of the option-implied skewness, a carry trader could be more profitable by executing an "anti-carry" trade rather than a carry trade. Subsection 2.6.3 discusses the outperformance of portfolios that allow anti-carry trades.

[24]We consider the equal-weighted portfolios as the representative example. See Figure C.1 and Figure C.2 in Appendix C.1 for details on the other two types of portfolios.

2.6.1 Option-Implied Skewness and Carry Trade Returns: Time-Series Regressions

We use time-series regression to investigate the predictive relationship between the option-implied skewness and the future returns over time for a given currency pair. A very negative forward-looking option-implied skewness suggests a high crash risk in the future. If a carry trader weights crash risks greater than a past level, (s)he may encounter a relatively considerable depreciation in the high-yield currencies and suffer an extreme loss. Therefore, traders may avoid losses by unwinding their carry trade positions at this time. More aggressively, they may make profits by executing an anti-carry trade: buying a low-yield currency and selling a high-yield currency.[25]

The time-series relationship between the option-implied skewness and the future carry trade excess returns can be illustrated as

Regression 5. $XR_{i,t+1} = \alpha_i + \beta_{5,i} \cdot \text{iskew}_{it} + \varepsilon_{i,t+1}$; given a currency pair i,

On the one hand, from the options quoted at time t and expiring at time $(t+1)$, the implied skewness is extracted at time t. On the other hand, the carry trade excess returns are gained over the investment period from time t to $(t+1)$ and fully realized at time $(t+1)$. Thus, Regression 5 is an intertemporal predictive regression.

Empirical studies report that currency returns are conditionally autocorrelated; see, for example, Bekaert (1995) and Neely and Weller (2000). Hence, the time-series regression alternatively adds lagged excess return as a further independent variable to check the robustness

[25] Option-implied skewness relates to forward-looking one-sided crash risk, while option-implied volatility and kurtosis relate to two-sided risks. Thus, among the moments we investigate, option-implied skewness provides the most desirable signal for carry traders to unwind their position by comparing it with past records. Comparing the two-sided risks with their historical series results in a vague signal because the carry traders do not understand whether their position implies a potential upside surge or a downside crash. This is the reason that we focus on only option-implied skewness in our time-series analysis.

of our results.

2.6.2 Option-Implied Skewness and Carry Trade Returns: Time-Series Results

Table 2.10 reports the results of Regression 5. In the time series, Table 2.10 shows that if the carry trade option-implied skewness reaches a historically low level, the trade is significantly predicted to suffer considerable losses or earn low returns. This very negative option-implied skewness suggests that a historically high crash risk serves as a warning signal that there will be substantial unwinding of carry trades in the market. The results hold, especially when the carry trade is funded by the Japanese yen. Although the results when CHF or USD are the funding currencies are not entirely supportive of the yen result, some of the currency pairs yield similar and significant results. In addition, the R^2 of the regressions exceeds 2% for some currency pairs. This is an impressively high explanatory power for a time-series predictive regression.

[Insert Table 2.10 around here.]

2.6.3 Carry Trades and Anti-Carry Trades

According to the time-series results, a carry trader can execute an anti-carry trade instead of a carry trade when (s)he observes that the extracted option-implied skewness is ranked in the top nth percentile of the most negative skewness over the last m months. An anti-carry trade consists of borrowing a set of high-yield currencies among the G10 currencies and investing in one of the funding currencies – JPY, USD, or CHF.

We impose constraints on these anti-carry trade portfolios. For the equal-weighted portfolio, the weight of each carry trade strategy is $-1/N$, and the constraints in the minimum-variance and the mean-variance portfolio are

$$\boldsymbol{w}^\top \boldsymbol{e} = -1 \quad \text{and} \quad w_j \leq 0, \forall j. \tag{2.5}$$

Figure 2.3 shows that a trader can frequently make profits by executing anti-carry trades based on the option-implied skewness.[26] In these three-dimensional figures, the vertical axis represents the difference between the Sharpe ratios of (i) the portfolio that allows for anti-carry trades and (ii) the portfolio that executes only carry trades. The horizontal plane is constructed by two axes labeled month (m) and percentile (n): the trader executes an anti-carry trade when the option-implied skewness is ranked in the top nth percentile of the smallest skewness over the last m months. Panels A and B of Figure 2.3 show that the JPY- and CHF-based portfolios that allow for anti-carry trades usually outperform those that execute only carry trades. However, Panel C shows that results for USD-based portfolios differ unless traders choose m and n "correctly," especially for a small n. These results are consistent with the time-series regression results in Subsection 2.6.2: the USD-based option-implied skewness does not perform as well as its JPY-based counterparts in forecasting future excess losses. These findings may be because the US dollar is not always a very-low-yield currency or a typical funding currency of carry trades.

Specifically, we investigate whether a trader who can execute anti-carry trades has positive marginal profits.[27] Consider a representative example in which a trader executes an anti-carry trade when the option-implied skewness is ranked in the top five of the smallest skewness over the last 36 months ($m = 36, n = 5/36$). Table 2.11 demonstrates that a trader who can

[26]We consider the equal-weighted portfolios as the representative example. See Figure C.3 and Figure C.4 in Appendix C.2 for details on the other two types of portfolios.

[27]Only executing anti-carry trades all the time is not a favorable strategy. In most cases, an anti-carry trader loses not only from a negative interest rate differential but also from unfavorable spot exchange rate movements. Taking our framework as an example, the anti-carry trader who simultaneously sells some high-yield currencies and buys one low-yield currency all the time suffers a 2.04% loss per year. The average Sharpe ratio is -5.52%.

execute anti-carry trades performs much better than a trader who executes only carry trades: the former has higher Sharpe ratios and certainty equivalent excess returns. Figure 2.2 shows that the cumulative returns of the portfolios that allow for anti-carry trades (black lines with circle symbols) usually beat those of the portfolios that execute only carry trades (dark gray lines with square symbols), especially during and after the recent financial crisis.

[Insert Figure 2.3 around here.]

[Insert Table 2.11 around here.]

2.7 Conclusion

We document the relationship between information extracted from the currency options and carry trade returns from both the cross-section and time-series perspectives. We use option-implied information to forecast the carry trade excess returns. In these trades, the funding currency is the Japanese yen (JPY), the Swiss franc (CHF), or the US dollar (USD).

In the cross-section, if the option-implied returns of a carry trade currency pair are more volatile, more left-skewed, and have fatter tails than those of other currency pairs in the same period, we find that the currency pair is predicted to have greater future excess returns.

Moreover, each option-implied moment contains specific information about future excess returns, and this information is not explained by either other option-implied moments or the risk factors in the foreign exchange market or the equity market.

Based on these results, a trader can construct a cross-sectional carry trade strategy by sorting on one of the option-implied moments and investing in the most beneficial quartile of currency pairs in each period. Compared with benchmark strategies, the option-implied information strategies perform better when measured by the cumulative returns, the Sharpe ratio, and the certainty equivalent excess returns. The reason is that the option-implied moments contain forward-looking features, which are more informative for traders than are the lagged macroeconomic data or the realized returns.

We consider three utility-free portfolios: the equal-weighted portfolio, the minimum-variance portfolio, and the mean-variance portfolio. The portfolios based on all strategies, including the three option-implied information strategies, outperform those based on only the benchmark strategies. This confirms that the option-implied strategies contain useful additional information.

In the time-series, if the option-implied return skewness reaches a historically low level, future excess returns are forecasted to be smaller, especially trades funded by the Japanese yen. Therefore, the carry trader may unwind his or her carry trade position or, more aggressively, execute an "anti-carry trade" when the option-implied skewness approaches a very negative level compared to its historical records. The portfolios that allow for anti-carry trades usually perform better than those that execute only carry trades.

Chapter 3

Ex Ante Skewness and Expected International Stock Index Returns

3.1 Introduction

A large literature discusses higher moments in returns. Rubinstein (1973) was the first to discuss the asset return with higher moments and incorporate the skewness of asset returns into the capital asset pricing model (CAPM). Kraus and Litzenberger (1976) empirically estimate this extended CAPM using U.S. domestic data. Recent literature investigates the cross-sectional relation between returns, volatilities, and higher moments. For example, Andersen, Bollerslev, Diebold, and Ebens (2001) examine the cross-sectional pricing of volatility risk using realized volatility of U.S. domestic stocks. Harvey and Siddique (2000) and Amaya, Christoffersen, Jacobs, and Vasquez (2015) document that realized skewness helps explain the cross-sectional variation of expected returns in U.S. stocks. Ang, Hodrick, Xing, and Zhang (2009) and Ghysels, Plazzi, and Valkanov (2016) explain international stock market returns using realized volatility and skewness, respectively.

Option-implied information is "*ex ante*," or forward-looking, and thus insightful for investors in forecasting future returns of the underlying assets. Most of the empirical literature examines the cross-sectional relation between returns and option-implied moments. For example, Chang, Christoffersen, and Jacobs (2013), Conrad, Dittmar, and Ghysels (2013), DeMiguel, Plyakha, Uppal, and Vilkov (2013), and Bali, Hu, and Murray (2017) document this relation in the U.S. stock markets or study stocks in a single country. Moreover, Della Corte, Ramadorai, and Sarno (2016) and Chen (2017) discuss option-implied moments from an international perspective but focus on the currency markets.

In our empirical analysis, we extend the existing literature that focuses on only U.S. domestic markets to the USD-based international stock indices in various countries.[1] The objective of this paper is to investigate the relation between ex ante option-implied moments and index returns from an international perspective.

We examine the relation between ex ante higher moments with a focus on skewness and the cross-section of country-specific index returns. We measure ex ante higher moments using the options on the country-specific indices. Our cross-sectional findings reveal a strong negative relation between ex ante skewness and the cross-section of subsequent index returns. The significant negative relation is robust to controlling for ex ante volatility, loadings of risk factors, realized return moments, and macroeconomic variables.

We form portfolios based on ex ante skewness. Specifically, we sort countries into quartile portfolios based on skewness and compute the subsequent returns. A long-short strategy which buys the low (more negative) skewness portfolio and sells the high skewness portfolio generates a significant annualized return of 4.9%. This strategy performs substantially better than other strategies based on inflation, GDP growth, the change in real effective exchange rates (REER), moments of the realized return distribution, and the sensitivity of the country returns to international risk factors.

[1]An extensive literature discusses the advantages of international stock index investments. DeSantis and Gerard (1997) and Errunza, Hogan, and Hung (1999) document that such investments benefit investors through participating in the growth of foreign countries, diversifying their portfolios, and reducing investment volatility.

Besides skewness, we also examine the role of volatility in explaining the cross-section of country-specific returns. Our finding with regards to international index markets reveals that there is no significant cross-sectional relationship between ex ante volatilities and future international returns. This result is different from the findings in the literature discussing domestic U.S. markets, including Ang, Hodrick, Xing, and Zhang (2006) and Conrad, Dittmar, and Ghysels (2013). Our results also indicate that neither market demands for hedging nor volatility feedback effect is able to explain the activities in international index markets.

Finally, we examine whether there is a skewness and volatility premium in the time series of the international stock index returns. The presence of a skewness premium indicates that if an individual country's index options imply a greater negative skewness risk than was previously the case, the index returns tend to be higher than the historical returns. We find that the skewness premium exists in the time series for Asian and non-euro area European stock indices. While ex ante skewness has significant results, the country-specific volatilities have an ambiguous relation with future returns in the time series. Our time-series results are explained by the fact that option-implied skewness is associated with the forward-looking one-sided skewness risk but volatility relates to a two-sided risk. A skewness decrease in the time series clearly infers a high probability to crash in return but an increase in volatility represents an ambiguous signal because the investors do not understand whether their position implies a potential upside or downside movement. Thus, option-implied skewness provides a more desirable risk-bearing signal for investors than volatility in the time series.

Overall, our results on skewness suggest that investors are compensated for skewness risk in the cross-section of country returns. Our results provide support for the findings of Boyer, Mitton, and Vorkink (2010), Conrad, Dittmar, and Ghysels (2013), and Chang, Christoffersen, and Jacobs (2013) who find similar compensation for skewness risk in different contexts.

The paper proceeds as follows. Section 3.2 documents the data and the methodology used to extract the moments. Section 3.3 constructs the international stock index strategies and discusses the cross-sectional empirical results. Section 3.4 presents the time-series results. Section 3.5 concludes.

3.2 Data and Computing Ex Ante Moments

In this section, we document the data and the methodology used to extract ex ante moments from options. Subsection 3.2.1 discusses the data that we use to investigate the international return predictability of ex ante moments. Subsection 3.2.2 reviews the methodology used to extract model-free option-implied moments.

3.2.1 Data

We retrieve data on international stock index options from OptionMetrics. We use daily data on the quoted implied volatilities across moneyness for the index options in 23 countries or regions. The underlying indices of the options are USD-based iShares ETFs which are traded on an exchange in the U.S.[2] Each ETF tracks a country's MSCI stock index as the benchmark. We are able to effectively compare option-implied moments across countries because all of the returns are USD based. Moreover, investing in ETFs traded in the U.S. rather than directly holding or short-selling securities that are traded abroad avoids the additional costs of and potential barriers to international portfolio investments. Detailed sample information is presented in Table 3.1, including the country-specific benchmark indices that the ETFs track and the sample periods. We include both developed and emerging markets in our sample. Recent international studies, such as Kelly, Pastor, and Veronesi (2016), also use this international ETF

[2] See the iShares website (https://www.ishares.com/us/products/etf-product-list) for detailed information on iShares ETFs.

index and option data.

[Insert Table 3.1 around here.]

The iShares ETF options are standardized and traded on the stock exchange.[3] We use one-month options to retrieve the option-implied monthly return distributions.[4] To construct portfolios, we rebalance monthly depending on the information available on the rebalancing day which provides the latest market beliefs.[5]

We obtain the short-term risk-free interest rates, the exchange rates, and the international macroeconomic data including the gross domestic product (GDP), the consumer price index (CPI), and REERs from Datastream. The Fama-French international factors (returns on the market portfolio, size, book-to-market, and momentum) are from Kenneth French's website at Dartmouth College.

[Insert Table 3.2 around here.]

We tabulate the descriptive statistics of option-implied moments in Table 3.2. We observe the evidence as follows. First, overall option-implied volatility in all countries is approximately 7.1%. While the average volatilities do not vary substantially across countries, the eightieth percentiles of the volatilities across countries are different. Second, the average and median levels of option-implied skewness vary a lot across countries, ranging from −0.8 to −1.4. Third, we observe that index returns are, on average, appear to be negatively skewed in all countries in our sample. Even the eightieth percentiles of skewness in all countries are negative.[6] Last,

[3] See the CBOE's website (http://www.cboe.com/products/options-on-single-stocks-and-exchange-traded-products/options-on-exchange-traded-products) for the detailed information of ETF options.

[4] We also check the robustness of our results by using three-month options.

[5] The empirical results are generally robust irrespective of how we choose the rebalancing day in a month. We present results for which the portfolios are rebalanced on every third Wednesday of a month.

[6] The 95th percentiles of skewness in all countries are negative. However, we observe some peaks with positive skewness from the time series in a few countries.

country-specific ex ante volatility and skewness are on average not strongly related to the economic development of each country.

3.2.2 Methodology to Compute Ex Ante Moments

We document the methodology to extract model-free ex ante volatility and skewness from the options proposed by Bakshi, Kapadia, and Madan (2003). The volatility and cubic entropy swap contracts are defined, and their payoffs are related to the squared and cubic returns. The non-central risk-neutral moments of the returns can be extracted from the options with various moneyness. Thus, the kth non-central moments are

$$\mu_{k,t} = E_t^{\mathbb{Q}}\left[\left(\ln \frac{S_{t+\tau}}{S_t}\right)^k\right], \text{where } k = \{1,2,3,4\}. \tag{3.1}$$

The time-t prices of the volatility and cubic entropy swap contracts are computed by portfolios of calls and puts as follows:

$$\text{Contract}_{2,t}(\tau) = \int_{S_t}^{\infty} \frac{2\left(1 - \ln \frac{K}{S_t}\right)}{K^2} C_t(K,\tau)dK + \int_0^{S_t} \frac{2\left(1 + \ln \frac{S_t}{K}\right)}{K^2} P_t(K,\tau)dK, \tag{3.2}$$

$$\text{Contract}_{3,t}(\tau) = \int_{S_t}^{\infty} \frac{6 \ln \frac{K}{S_t} - 3\left(\ln \frac{K}{S_t}\right)^2}{K^2} C_t(K,\tau)dK - \int_0^{S_t} \frac{6 \ln \frac{S_t}{K} + 3\left(\ln \frac{S_t}{K}\right)^2}{K^2} P_t(K,\tau)dK, \tag{3.3}$$

respectively, where $C_t(K,\tau)$ and $P_t(K,\tau)$ are the prices of call and put options with strikes K and τ periods to expiration. The contract prices have to be discounted from expiration to time

t, so the non-central moments are[7]

$$\mu_{k,t}(\tau) = \exp(r_t \cdot \tau) \cdot \text{Contract}_{k,t}(\tau); \text{where } k = \{2,3\}. \tag{3.4}$$

Thus, ex ante volatility and skewness under the risk-neutral $\mathbb{Q}$ probability can be estimated from the options and derived as follows:

$$\text{ivol}_t^{\mathbb{Q}}(\tau) = [\mu_{2,t}(\tau) - \mu_{1,t}(\tau)^2]^{1/2}, \tag{3.5}$$

$$\text{iskew}_t^{\mathbb{Q}}(\tau) = \frac{\mu_{3,t}(\tau) - 3 \cdot \mu_{1,t}(\tau) \cdot \mu_{2,t}(\tau) + 2 \cdot \mu_{1,t}(\tau)^3}{[\mu_{2,t}(\tau) - \mu_{1,t}(\tau)^2]^{3/2}}, \tag{3.6}$$

respectively, where ivol and iskew are (ex ante) option-implied volatility and skewness, respectively. $\mu_{1,t}$ is the expected mean return, defined from the expansion formula as

$$\mu_{1,t}(\tau) = \exp(r_t \cdot \tau) - 1 - \frac{\mu_{2,t}(\tau)}{2!} - \frac{\mu_{3,t}(\tau)}{3!} - \frac{\mu_{4,t}(\tau)}{4!}. \tag{3.7}$$

Theoretically, a continuum of out-of-the-money call and put prices and their moneyness are needed when we compute the contract prices at time t. Thus, empirically, we have to discretize, interpolate, and extrapolate the option data. We discretize the range of integration of the moneyness onto a grid of 1000 points.[8] We extrapolate option-implied volatility below the lowest and above the highest available strikes by appending flat tails. The infinite sum of the appended tails in our computation is truncated at strikes equal to 0.1 and 3.5 times of the index levels.[9] Based on Jiang and Tian (2005), the errors from extrapolation, truncation, and

[7] Without loss of generality, let the risk-free USD interest rate r_t be deterministic.

[8] Jiang and Tian (2005) document that the discretization errors are negligible when the grid contains more than 20 points.

[9] Jiang and Tian (2005) indicate that option-implied higher moments are estimated more precisely by extrapolating flat tails at the level of the last quoted implied volatility at the most extreme available strikes than by simply truncating the range of strikes used in the computation. In the case of stock indices in our sample, the

discretization in our computation are thus negligible.

To interpolate the complete option-implied volatilities across different strikes, we apply a cubic spline interpolation. A cubic spline is superior to a low-order polynomial because it has greater flexibility in the shape of the fitted volatility smile and is also effective at smoothing the fitted function. See Bu and Hadri (2007).

In our sample, we use American options which involve early exercise. Based on Bakshi, Kapadia, and Madan (2003), moment extraction is generalized to using American options. Moreover, we compute option-implied moments using only out-of-the-money options and this reduces the effect of early exercise.[10]

3.3 The Cross-Sectional Return Predictability of Ex Ante Moments

In this section, we document the cross-sectional relation between ex ante volatility and skewness and subsequent international stock index returns. We present the results of the univariate and double-sorted portfolios in Subsection 3.3.1. Based on the results of cross-sectional sorts, we propose international trading strategies on option-implied moments in Subsection 3.3.2. We address the benchmark strategies which are proposed in the literature and compare our option-implied strategies with them in Subsection 3.3.3. Subsection 3.3.4 presents the pure cross-sectional relation between ex ante moments and future returns derived from the Fama-MacBeth regressions. Subsection 3.3.5 examines whether the return predictability

strikes of all available deepest out-of-the-money options do not exceed this range. Thus, the resulting truncation errors are negligible when we consider extrapolation. An extensive literature, including for example DeMiguel, Plyakha, Uppal, and Vilkov (2013), also uses this linear extrapolation to mitigate the truncation error.

[10] DeMiguel, Plyakha, Uppal, and Vilkov (2013) and Conrad, Dittmar, and Ghysels (2013) also extract option-implied moments from American options using the same methodology. The difference caused by the early exercise from out-of-money American options is negligible.

of ex ante moments is significant even after considering benchmark characteristics as control variables in the Fama-MacBeth regressions.

3.3.1 Portfolio Sorts

In this subsection, we sort the cross-section of stock indices across countries into quartiles based on sorting characteristics. We sort portfolios by weighing each country in the portfolio equally and rebalance the portfolios in each month.[11] We report the subsequent returns of the univariate sorted portfolios over the next month in Table 3.3. Quartile 1 contains indices with the lowest sorting characteristics, and Quartile 4 contains indices with the highest ones. We form a "long-short portfolio" in every strategy by buying the most beneficial quartile and short selling the least beneficial quartile based on the sorting characteristics.

[Insert Table 3.3 around here.]

The first column in Table 3.3 shows a negative relation between ex ante volatility and subsequent index returns while this negative relation is not significant. The annualized return differential between the lowest and highest volatility portfolios is 4.16%, although the magnitude of this difference is not statistically different from zero. This result indicates that the option-implied volatility of an index returns are not related to future returns in the cross-section. Empirically, the literature with regards to domestic U.S. stock markets, including Ang, Hodrick, Xing, and Zhang (2006), Ang, Hodrick, Xing, and Zhang (2009), Chang, Christoffersen, and Jacobs (2013), and Conrad, Dittmar, and Ghysels (2013), documents a negative relation between volatility and future returns, which is not consistent with our empirical results

[11]The countries have equal weights rather than weigh by values in the portfolio because we would like to treat each country as important as others when international investors make decision on buying or short-selling countries depending on a specific characteristic. If we use value-weighted portfolio, U.S. or Euro area would dominate the results in the periods that it is chosen in the portfolio.

on international stock index markets. We extend the cross-sectional investigation to international stock indices and find different results that the volatility risk premium does not exist in international stock markets.

There are two explanations of the insignificance. First, volatility contains two-tailed information including downside risk and upside surprise. The two-tailed information is noisier in international markets than in domestic ones. Second, the rankings by volatility across 23 countries do not have obvious cross-sectional variation based on our entire sample period. The difference between the high volatility portfolio and low volatility portfolio is not big enough and the risk premium based on sorting is thus not significant.

The negative relation between volatility and subsequent returns documented in the literature on domestic markets agrees with the findings based on the intertemporal CAPM proposed in Campbell (1996). The literature employing this model indicates that investors are concerned not only with the risks associated with current market returns but also with changes in future market returns. Because volatility positively relates to changes in future market returns and in investment opportunities, risk-averse investors thus attempt to hedge against changes in aggregate volatility. Consider high market volatility for example: investors may expect worse future investment opportunities. If an asset's return is positively associated with market volatility, risk-averse investors wish to buy this asset to hedge against the deterioration of the future investment opportunities.[12] High demand for this asset results in a higher current price or a lower expected future return of this asset. Thus, the price of the volatility risk in the cross-section is negative. Also, French, Schwert, and Stambaugh (1987) propose a volatility feedback effect that a high volatility usually coincides with lower returns. In our findings, neither market demands for hedging nor volatility feedback effect is able to applied in international stock

[12]Although the options are priced under the risk-neutral measure, the expected underlying index returns realized in the future are evaluated under the physical measure. Moreover, international stock market participants are risk averse.

markets.

The second column in Table 3.3 shows a considerably negative relation between ex ante skewness and subsequent index returns. The annualized return differential between the most and least left-skewed portfolios is 4.94%, and the magnitude of this difference is statistically distinguishable from zero. This result provides evidence that if the option-implied skewness of a stock index is more negative than its cross-sectional counterparts in other countries, the subsequent returns in this country are expected to be higher. These higher returns reflect a skewness premium.

The cross-sectional findings related to the skewness in the international index markets are consistent with the domestic stock results documented in Boyer, Mitton, and Vorkink (2010), Chang, Christoffersen, and Jacobs (2013), Conrad, Dittmar, and Ghysels (2013), and DeMiguel, Plyakha, Uppal, and Vilkov (2013) and with the currency market results reported in Lustig, Roussanov, and Verdelhan (2014) and Chen (2017). The literature demonstrates that returns compensate domestic stock investors or currency traders for taking aggregate skewness risks in the cross-section. We extend the results of option-implied ex ante skewness to international stock index portfolios.

Our empirical result of a negative relation between skewness and future returns in the international index portfolios also confirms the findings of the model proposed in Mitton and Vorkink (2007) and Brunnermeier, Gollier, and Parker (2007). These papers report that a positively skewed stock, analogous to a lottery, is widely favored by investors. Investors may increase their demand for holding stocks with more positive (or less negative) skewness and concentrate on investing in these stocks while sacrificing diversification. Therefore, such stocks subsequently have reduced expected returns. In addition, our results are in the line with empirical studies on lottery-like stocks in the U.S., such as Bali, Cakici, and Whitelaw (2011).

[Insert Table 3.4 around here.]

Also, we investigate whether option-implied volatility and skewness are important sources of risk, so we estimate portfolio abnormal returns, or “alphas” after considering Fama and French (2012) international four factors. Table 3.4 shows the result with regards to alpha. Among sorted and long-short portfolios based on all of the international characteristics, only the long-short portfolio based on ex ante skewness have positive and significant alpha. This results indicates that information containing in ex ante skewness is not fully explained by the international four factors proposed in Fama and French (2012) and ex ante skewness is an important source of risk apart from the conventional risk factors.

In addition to the first two columns in Tables 3.3 and 3.4, we sort the cross-section of stock indices based on various “benchmark” characteristics proposed in the literature. Unlike the portfolios based on option-implied moments, none of the long-short portfolios based on the benchmark strategies have significantly positive returns. The benchmark strategies exhibit lower economic and statistical significance than the strategies based on option-implied moments. We discuss the results of the benchmark in detail in Subsection 3.3.3.

Having investigated the univariate sorts, we use double sorts to estimate the relation between ex ante moments and subsequent returns. We independently sort countries into tercile portfolios based on ex ante volatility and skewness.[13] Then, we construct the sorted portfolios based on a combination of the volatility and skewness rankings. The sorted portfolios are equally weighted and rebalanced in each month.

[Insert Table 3.5 around here.]

Table 3.5 presents the double-sorting results. We report subsequent returns for each of the three-by-three portfolios. Across the columns in a given row and keeping volatility in the

[13] We independently sort countries into terciles and report three-by-three portfolios for allocating portfolios reasonably because of our sample size in the cross-section.

same tercile, we observe that indices with low (more negative) skewness typically have higher subsequent returns. If a country's volatility is low, investing in a country's index with low skewness is compensated by significantly higher future returns. International investors holding indices with a comparatively left-skewed ex ante distribution or forming a long-short portfolio by buying indices with a low skewness and short selling indices with high (less negative or more positive) skewness are expected to earn a considerable skewness premium, unless these indices are highly volatile. If investors focus only on the highly volatile indices, buying indices with high skewness is profitable because good outcomes in the right tail ("winning the lottery") may occur. These future potential good outcomes are expected to offset the low returns caused by high current market demand.

When we read across the rows in a given column and keep skewness in the same tercile, we observe that volatility negatively relates to subsequent returns. This result indicates that investors holding a long-short portfolio by buying stable indices and short selling volatile indices are expected to earn significantly higher profits only if these indices have low skewness. This low-skewness scenario is consistent with our univariate results that risk-averse market participants have considerable demand for stock indices that are sensitive to market volatility to hedge possible future bad outcomes.

3.3.2 International Stock Index Trading Strategies

In line with the cross-sectional results of portfolio sorts described in the previous subsection, we propose profitable trading strategies based on cross-sectional sorting of the country-specific characteristics. In this subsection, we propose international trading strategies based on option-implied moments. We also document the benchmark international strategies in the next subsection. We compare the option-implied strategies with the benchmark strategies proposed in the literature. The empirical results show that the strategy based on option-implied skewness outperform the benchmark strategies in terms of cumulative returns, abnormal returns, and Sharpe ratios.

Based on sorting one of the country-specific characteristics, an international investor buys and holds the stock indices in countries in the most beneficial quartile for one month and simultaneously short sells the stock indices in countries in the least beneficial quartile for the same period.[14] The returns of each strategy are realized in the next period.

Based on the cross-sectional portfolio sorts in Subsection 3.3.1, we propose two option-implied strategies. The first strategy is based on option-implied ex ante skewness ("iskew"), which relates to skewness risks and is negatively related to future returns. A portfolio long in the most left-skewed quartile and short in the least left-skewed (or the most right-skewed) quartile is profitable for international investors.[15] The second strategy is based on option-implied ex ante volatility ("ivol"), which is negatively but not significantly associated with the future returns. We investigate that whether investing in the least volatile and selling the most volatile quartile is profitable at some time points.

[Insert Figure 3.1 around here.]

The results are shown in Figure 3.1. In the figure, the performance is measured by the cumulative returns that the investor obtains by initiating the investment strategy in January

[14]Our empirical results are generally robust if the quartile is replaced by the quintile or other percentiles. Moreover, holding long-short portfolios for three months based on the three-month options and the latest available market information leads to similar robust results.

[15]The investor constructs a long-short portfolio which is useful for diversification. Investors can limit their overall market exposure by reducing their long positions or by short selling assets that they expect to underperform. The long-short portfolio benefits investors if the long position outperforms the short position. Hence, the advantage of the long-short portfolio is generally that it minimizes exposure to the market, and investors profit from a change in the difference, or spread, between two groups of assets. In addition to diversification, a long-short portfolio potentially generates additional returns to the investors. We agree that constructing a long-short portfolio is not always possible in reality, such as during the financial crisis. However, in this paper, we focus primarily on the advantages of the long-short portfolio – diversification and market exposure minimization. The results are typically robust if the investor only buys and holds the most beneficial group.

2010.[16] We observe that our option-implied strategies perform well. On average, option-implied skewness and volatility strategies annually earn approximately 4.9% and 4.2% of returns through the internationally diversified long-short portfolios, respectively. The average returns and the Sharpe ratios of the trading strategies are shown in Table 3.3. After adjusting by realized volatility, the long-short portfolios based on the option-implied strategies generally have higher Sharpe ratios than those based on the benchmark strategies, which we discuss in the next subsection. Also, Table 3.4 shows portfolio alphas after considering the international four factors proposed in Fama and French (2012). The long-short portfolios based on option-implied skewness have the highest Sharpe ratio and alpha among all of the international trading strategies.

3.3.3 Benchmark International Trading Strategies

To compare the cross-sectional return predictability of option-implied moments addressed in Subsections 3.3.1 and 3.3.2, we present benchmark strategies that are well-documented in the literature and are useful to explain future index returns. The benchmark characteristics include macroeconomic variables, sensitivities to international factors, and the characteristics of the realized returns.

The first type of the benchmark strategy is related to macroeconomic conditions. An extensive literature investigates the relation between economic variables and stock markets. For example, Ferson and Harvey (1993) document the relation between global economic risks and international stock returns. Liew and Vassalou (2000) relate the equity risk factors to GDP growth in various countries. Schwert (1989) and Paye (2012) also investigate the relation

[16]The reason for this starting point is that we depend on our sample data in the former period to form a portfolio. For example, we have to gather sufficient information to estimate betas in the factor models. Generally, the results are robust to earlier or later initiation.

between macroeconomic risks and characteristic-based risk factors within the U.S. In our research, we use GDP growth, inflation, and the change in the REER to represent a country's macroeconomic situation. We use the growth in the CPI as a proxy for inflation. For GDP, CPI, and REER growth, we use the year-over-year (YoY) change to mitigate seasonal effects.[17]

We discuss these three benchmark macroeconomic variables as follows. First, stock index returns in one country closely relate to the country's GDP growth. Thus, we focus on whether country-specific GDP growth relates to subsequent index returns, as documented in Demirgüç-Kunt and Levine (1996).[18] Second, purchasing power parity (PPP) means that the purchasing power of two countries should be indentical after accounting for the currency values.[19] The inflation in an individual country reflects the change in purchasing power in each period. A large literature, including Nelson (1976) and Fama and Schwert (1977), documents a negative relation between inflation and a country's stock returns. Therefore, we use the inflation as a benchmark and investigate whether inflation relates to future index returns in the cross-section. Third, the REER represents the real currency's relative value. Solnik (1987) empirically examines the relation between real exchange rates and financial prices and economic growth and reports that an undervaluation of the local currency relates to the economic and stock growth in a country, especially for emerging countries. Hence, we add the change in the REER as a benchmark.

[Insert Figure 3.2 around here.]

[17]The results are generally robust to the use of quarter-over-quarter changes. Because official institutions have to collect and arrange the macroeconomic information, the information is announced later than the exact periods. Hence, we report the results based on the macroeconomic information with a two-month time lag when the market participants actually observe the announcements.

[18]Empirically, Harvey (1989) describes stock returns as a leading indicator of economic growth. We agree with this study but do not emphasize the causality or endogeneity of the relation between the stock returns and economic development in this paper.

[19]Although the long-term equilibrium of the price index or purchasing power in a specific country is not easily derived, we focus on the change in purchasing power in each country period by period.

Based on the results we present in Table 3.3, each of the macroeconomic strategies buys the lowest historical GDP growth, the lowest inflation, and the lowest change in the REER quartile, respectively, and sells the opposite quartiles to achieve high returns.[20] Table 3.3 shows that the long-short portfolios based on the macroeconomic strategies cannot earn returns significantly different from zero, although the Sharpe ratio of the portfolios based on the change in REER strategy is 0.23, which is highest among the benchmarks. Panel A of Figure 3.2 shows that our option-implied strategies outperform the macroeconomic strategies. We observe that the macroeconomic strategies have relatively poor performance, especially before 2013. We also observe that the time series of portfolio returns based on inflation is correlated with that based on option-implied volatility, especially after 2014. The unconditional time-series correlation between the returns based on the inflation and those based on option-implied volatility is 10.7%. This phenomenon is supported by Antonakakis, Chatziantoniou, and Filis (2013), who report a positive correlation between option-implied volatility and inflation. Although this positive correlation exists, the cumulative portfolio returns based on option-implied volatility outperform those based on inflation. Therefore, the economic conditions across countries are relevant when when the international investors allocate their assets, but the ex ante information implied by the options is more useful for the investors to obtain future index returns in the cross-section.

The second type of the benchmark strategy is based on the sensitivities to the risk factors. An extensive literature considers factor models in the equity market. In addition to the CAPM, which is used in Ferson and Harvey (1993) to investigate international returns, the most famous factors are the size and book-to-market factors documented in Fama and French (1992) and

[20] We choose to go long in the quartile with the lowest inflation and short in the quartile with the highest inflation based on the economic evidence provided in the literature. Moreover, our empirical findings in Table 3.3 indicate that historical GDP growth and the historical change in the REER have negative relations with future returns in the cross-sectional comparison.

the return momentum factor proposed in Carhart (1997). These papers empirically construct risk factors based on the U.S. domestic equity market. Eun, Lai, Roon, and Zhang (2010) and Hou, Karolyi, and Kho (2011) document that the U.S.-based market, size, book-to-market, and momentum factors are able to describe international stock returns. However, these studies are empirically based on U.S.-based factors only. We extend their results by applying international factor models. Fama and French (2012) review their domestic factors and reconstruct the market, size, book-to-market, and momentum factors based on international stock returns. We use the sensitivities to the international factors constructed in Fama and French (2012) as our benchmark.

We include the sensitivities to the international market factor in the CAPM ("CAPM Market"), the loadings on the size ("FF3 SMB") and book-to-market ("FF3 HML") factors in the Fama and French (2012) international three-factor model, and the loading on the momentum factor ("FF4 Momentum") in the Fama and French (2012) and Carhart (1997) international four-factor model.[21] Based on the empirical results shown in Table 3.3, each of the factor sensitivity strategies buys the quartile with the countries most sensitive to the market and size factors and those least sensitive to the book-to-market and momentum factors and short sells the opposite quartiles.[22] Table 3.3 reports that long-short portfolio returns based on the factor loading strategies are neither economically nor statistically significant. The Sharpe ratios of these portfolios are considerably low. Panel B of Figure 3.2 shows the cumulative returns of these strategies. Although the momentum strategy has good performance before 2014, we observe the poor performance of the factor loading strategies in the full sample period, which on average underperform the option-implied strategies because the option-implied strategies are

[21]The results are generally robust if we adopt all loadings from the four-factor model.

[22]Our book-to-market and momentum strategies have different results from Fama and French (2012) and Carhart (1997). In our findings, the "growth" countries are expected to have better performance than the "value" countries. The sensitivity to the return momentum factor in this paper also yields the opposite results from the literature.

forward-looking and informative of future returns. Moreover, we observe a consistent trend of the time series of cumulative returns across various strategies. For example, the return correlation between the sensitivity to size factor strategy and implied volatility strategy is 55%, while the return correlation between sensitivity to the book-to-market factor strategy and implied volatility strategy is 47.4%. Although the trends among strategies are positively correlated, the option-implied strategies not only have better performance but also dominate the benchmark strategies in explaining future index returns. We examine and discuss which strategy dominates in Subsection 3.3.5.

The third type of the benchmark strategy is associated with realized returns. The literature documents that the characteristics of realized returns are able to predict future returns. For example, Andersen, Bollerslev, Diebold, and Ebens (2001) examine the cross-sectional pricing of volatility risk using the realized volatility of the U.S. domestic stocks. Harvey and Siddique (2000), and Amaya, Christoffersen, Jacobs, and Vasquez (2015) find that realized skewness helps explain the cross-sectional variation in the expected returns of domestic U.S. stocks, and Ghysels, Plazzi, and Valkanov (2016) apply the explanation of realized skewness to emerging markets. Thus, we build benchmark strategies based on the USD-based international index realized return moments that can be compared with the strategies based on their option-implied counterparts. Based on Table 3.3, we go long in the most left-skewed and most volatile quartiles and short in the opposite quartiles in the realized skewness ("rskew") and volatility ("rvol") strategies, respectively. Table 3.3 shows that the average annualized long-short portfolio returns based on realized moments are approximately 3.5% and thus that they outperform most of the benchmark strategies. However, the returns of the realized moment strategies are not significantly greater than zero and are lower than those of the option-implied strategies. The Sharpe ratios of the option-implied strategies are also higher than those of their realized counterparts.

From Panel C of Figure 3.2, we discover that the cumulative returns of the long-short portfolios based on option-implied moments are correlated with those based on their realized counterparts. For example, the return correlation between the option-implied volatility strategy and the realized volatility strategy is 87.2%, and that between the skewness strategies is 21.7%. Despite these high correlations, the option-implied strategies outperform the realized return strategies, and only the option-implied skewness strategy yields statistically significant performance. Moreover, we reveal that option-implied skewness is not dominated by realized skewness in explaining future returns in Subsection 3.3.5. Because option-implied strategies are forward-looking and realized moments depend only on historical information, the former explain future returns better than the latter.

Tables 3.3 and 3.4 show that our option-implied strategies outperform benchmark strategies in terms of the performance measured by not only returns but also by Sharpe ratios and alphas. Moreover, we find that option-implied ex ante skewness has better performance than option-implied ex ante volatility in our international sample. This superior performance is because the skewness is more informative than volatility, and volatility risks are partially diversifiable through international asset allocation, while the skewness risks are not. These diversifiable volatility results are consistent with the findings of DeSantis and Gerard (1997), who report that the cross-country dependence in volatility is not very strong in their sample. Moreover, the cross-sectional variation of ex ante volatility across countries is not large. Ranking and holding long-short portfolios based on sorting ex ante volatilities across countries is not exposed to a high volatility risk, compared to the portfolios constructed by individual stocks in domestic U.S. markets.

3.3.4 Cross-Sectional Return Predictability: Ex Ante Moments

After sorting portfolios based on international characteristics discussed in Subsection 3.3.1, we investigate the cross-sectional return predictability of ex ante moments from another perspective. We use Fama and MacBeth (1973) regressions to document this cross-sectional predictability as follows.

Regression 6. $R_{i,t+1} = \alpha_{6,t} + \beta_{6s,t} \cdot \text{iskew}_{it} + \gamma_{6X,t} \cdot X_{it} + \varepsilon_{6,i,t+1}$; at each time $(t+1)$,

Regression 7. $R_{i,t+1} = \alpha_{7,t} + \beta_{7v,t} \cdot \text{ivol}_{it} + \gamma_{7X,t} \cdot X_{it} + \varepsilon_{7,i,t+1}$; at each time $(t+1)$,

Regression 8. $R_{i,t+1} = \alpha_{8,t} + \beta_{8s,t} \cdot \text{iskew}_{it} + \beta_{8v,t} \cdot \text{ivol}_{it} + \gamma_{8X,t} \cdot X_{it} + \varepsilon_{8,i,t+1}$; at each time $(t+1)$,

where R is the country i's stock index return, X is the vector of control variables, which we discuss in Subsection 3.3.5, and the εs are regression errors, each of which is assumed to have a zero mean. The options quoted at time t and expiring at time $(t+1)$ imply the ex ante return distribution over this period in the initial quotes. On the other hand, the returns from times t to $(t+1)$ are realized at the end of the period, or time $(t+1)$. The cross-sectional regressions in Regressions 6 to 8 are thus intertemporal.

Tables 3.6 to 3.9 report the intertemporal predictions of option-implied volatility and skewness on future returns. In this subsection, we focus on Columns (1) to (3) and (7) to (9) in Table 3.6 to examine the pure relations in these regressions without control variables.

[Insert Table 3.6 around here.]

The results of Regression 6 are shown in Column (1) in Table 3.6, which documents a strong negative relation between ex ante skewness and subsequent international index returns. This result is consistent with the outcomes of the univariate sorts. Because stock returns empirically exhibit autocorrelation, we add the lagged return as a control variable for robustness in Column

(7) in Table 3.6. We observe that the predictability of ex ante skewness is significant after considering the lagged returns.[23]

Further, we present the results of Regression 7 in Column (2) in Table 3.6, which shows that the cross-section of country-specific ex ante volatility negatively relates to subsequent international index returns. As shown in the univariate sorted portfolios, option-implied volatility has a negative (but not significant) relation with subsequent index returns.[24] After adding the lagged return as a control variable, as shown in Column (8) in Table 3.6, the predictability of ex ante volatility is robust and significant.

Regression 8 investigates whether the future returns are simultaneously explained by both ex ante volatility and skewness. We present the results in Columns (3) and (9) in Table 3.6. Column (3) shows that the return predictability is significant when we include both ex ante volatility and skewness together as regressors, and we find the same result when we include the lagged return for robustness in Column (9).

3.3.5 The Return Predictability of Ex Ante Moments: Controlling for the Benchmark Characteristics

In this subsection, we investigate whether the cross-sectional return predictability of ex ante volatility and skewness is significant even after considering the benchmark characteristics documented in Subsection 3.3.3. We include the benchmark characteristics as the control variables Xs in Fama-MacBeth Regressions 6 to 8. We expect that the return predictability of option-implied moments is distinct and not explained by the benchmarks. We describe the

[23] See French, Schwert, and Stambaugh (1987) for a detailed discussion of autocorrelation in stock returns.

[24] The results of univariate sorted portfolios discussed in Subsection 3.3.1 are based on the average portfolio returns over the entire sample period. The cross-sectional results in this and next subsections are based on Fama-MacBeth regressions, which involve the time-average and time-variation of the estimated coefficients. This is an explanation of the potential difference in these two results.

results below.

First, we investigate whether ex ante moments in the Fama-MacBeth regressions explain future cross-sectional returns after controlling for the macroeconomic variables. The results are tabulated in Columns (4) to (6) in Table 3.6. The return predictability of option-implied moments is generally robust to controlling for the macroeconomic situation, meaning that the return predictability does not derive from macroeconomic conditions. Columns (10) to (12) in Table 3.6 show the robust results when we add the lagged return as an additional control variable. In addition to the option-implied moments, the change in the REER is the only macroeconomic variable that exhibits return predictability and negatively relates to future index returns in the cross-section. This results support our findings in Table 3.3 that the "change in REER" strategy has higher average returns and Sharpe ratio than the other macroeconomic strategies. Further, this result confirms the empirical findings documented in Solnik (1987) that an undervaluation of the local currency positively relates to stock growth in a country.

[Insert Table 3.7 around here.]

[Insert Table 3.8 around here.]

Second, we examine the return predictability of ex ante moments after controlling for the sensitivities to the international factors constructed in Fama and French (2012). The results are tabulated in Tables 3.7 and 3.8. We discover that ex ante volatility and skewness have predictive power for subsequent international index returns after considering the return sensitivities to these international-based factors. The benchmark international factors include (i) International CAPM, which controls for the loading on the international market factor and is shown in Table 3.7; (ii) the Fama and French (2012) international three-factor model, which controls for the loadings on the market, size ("SMB") and book-to-market ("HML") factors and is shown in Columns (1) to (3) in Table 3.8; and (iii) the Fama and French (2012) and Carhart (1997) international four-factor model, which controls for the loadings on the market, size, book-to-market, and momentum factors and is shown in Columns (4) to (6) in Table 3.8. We present the robust results after adding the lagged return as an additional control variable in Columns (4) to (6) in Table 3.7 and Columns (7) to (12) in Table 3.8.

In addition, we find that only the sensitivity to the book-to-market (HML) factor significantly explains future international returns in the cross-section among the sensitivities to the international factors. This result is consistent with the evidence we proposed in Table 3.3 that the univariate-sorted long-short portfolios based on the loading on the HML factor have higher average returns and Sharpe ratios than other factor strategies. The negative relation between the loadings on the HML factor and subsequent index returns indicates that the "growth" countries are expected to have better performance than the "value" countries. Moreover, although we observe high return correlation among option-implied volatility, the sensitivity to the size factor, and the sensitivity to the book-to-market factor strategies in Panel B of Figure 3.2, we show that the return predictability of option-implied volatility is not dominated by the characteristics of these correlated strategies in Table 3.8.

[Insert Table 3.9 around here.]

Third, we examine whether ex ante volatility and skewness explain future international index returns in the cross-section after controlling for their realized counterparts. We tabulate these results in Table 3.9. After accounting for realized skewness, ex ante skewness significantly explains future index returns in the cross-section. However, the cross-sectional return predictability of ex ante volatility becomes ambiguous after including realized volatility. When we only investigate the return predictability of the volatilities in Columns (2) and (5), the predictability of option-implied volatility is not statistically significant. However, when we focus simultaneously on volatility and skewness in the regressions whose results are shown in Columns (3) and (6), both option-implied moments have significant return predictability. All of these results are robust after controlling for the lagged returns.

3.4 The Time-Series Return Predictability of Ex Ante Moments

In this section, we use time-series regressions to investigate the predictive relation between option-implied moments and the international stock index returns in each country. We examine whether future index returns are higher when option-implied skewness is relatively lower or when volatility is relatively higher compared with its own time series. The time-series relation between option-implied moments and an individual country's future stock returns can be illustrated as

Regression 9. $R_{i,t+1} = \alpha_{9,i} + \beta_{9,i} \cdot \text{imom}_{it} + \varepsilon_{9,i,t+1}$; given a stock index i,

where "imom" is a vector containing one or both of option-implied moments.

The explanatory variables are option-implied moments, which are extracted from the options quoted at time t and expiring at time $(t+1)$. On the other hand, the response variable is an individual country's USD-based index return, which is gained over the period from times t to $(t+1)$ and fully realized at time $(t+1)$. Hence, Regression 9 is an intertemporal predictive regression.

Tables 3.10 to 3.12 report the results of Regression 9. We present two time-series results with respect to option-implied skewness and volatility.

[Insert Table 3.10 around here.]

First, from the time-series results tabulated in Table 3.10, if an index's option-implied skewness is at a historically low level, the index is predicted to have a higher return than in the past due to the skewness premium. A low option-implied skewness in the time series indicates historically high skewness risk. A stock index investor who bears such risk is expected to earn a higher skewness premium than in the past. Table 3.10 shows that this time-series return predictability of ex ante skewness is significant in the non-euro area European countries and the Asian-Pacific region. This time-series result that higher skewness risks relate to higher skewness risk premia also supports the empirical evidence proposed in the behavioral literature, such as Han (2007) and Bordalo, Gennaioli, and Shleifer (2013).

[Insert Table 3.11 around here.]

[Insert Table 3.12 around here.]

Second, the time-series results of option-implied volatility are not consistent across various countries, as shown in Table 3.11. As the results presented in Table 3.12 indicate, the time-series results of option-implied moments are robust when we simultaneously include both moments as regressors.

Option-implied skewness is associated with forward-looking, one-sided skewness risk because index skewness is mostly negative across countries and time. A decrease in skewness in the time series suggests a high crash probability for the return. However, volatility relates to a two-sided risk that represents an ambiguous signal because investors do not understand whether their position implies a potential upside or downside movement. Thus, in the time series, option-implied skewness provides a more desirable risk-bearing signal for investors than volatility. This may explain why option-implied skewness has significant time-series results but option-implied volatility has relatively ambiguous or incompetent results in the time series.

Although our time-series results regarding option-implied volatility are not conclusive, this ambiguity of the risk premium in the time series is consistent with the literature. Moskowitz, Ooi, and Pedersen (2012) find that returns may not reflect the compensation for risk exposure in the time series. Goyal and Jegadeesh (2018) explain that cross-sectional and time-series risk factors are based on different net active positions, and thus, the difference between the cross-sectional returns and the time-series returns partially results from the compensation for bearing risks. Thus, the time-series return predictability for option-implied volatility is not clear in the most countries because the expected premium for risk exposure is not reflected in the time series. This time-series result is consistent with the empirical findings in Guo (2006), who investigates the ex post realized volatilities of indices in developed countries.

3.5 Conclusion

We investigate the relation between ex ante information extracted from country-specific index options and subsequent returns on the international investments from both cross-sectional and time-series perspectives. We show that option-implied skewness has negative effects on USD-based future international index returns.

In the cross-section, our empirical finding reveal a significantly negative relation between ex ante skewness and subsequent returns. This negative relation between skewness and subsequent returns is consistent with the intuition that an international investor exposed to greater skewness risks is compensated by a higher future skewness premium. Moreover, we document an insignificant relation between ex ante volatility and future international index returns. This result shows that either investor's demand for hedging against changes in market volatility or volatility feedback effect is not able to explain the activities in international index markets. More importantly, our findings are different from the empirical results that there is a negative cross-sectional relation between volatility and future returns with regards to domestic U.S. stock markets.

Based on the cross-sectional results, we form international trading strategies by sorting countries into quartile portfolios based on ex ante skewness and volatility. A long-short strategy which buys the low skewness portfolio and sells the high skewness portfolio outperforms the benchmark strategies in terms of cumulative returns, abnormal returns, and Sharpe ratios. The benchmark characteristics include the macroeconomic variables, sensitivities to international risk factors, and realized return moments. The reason for the outperformance of the strategy based on ex ante skewness is that option-implied skewness contain forward-looking and only downside features, which are more informative than the benchmarks.

In the time series, we document existence of a skewness premium for Asian and non-euro area European stock indice. The presence of a skewness premium indicates that if an individual country's index options imply a greater negative skewness risk than was previously the case, the index returns tend to be higher than the historical returns. Our time-series results are explained by the fact that option-implied skewness is associated with the forward-looking one-sided skewness risk. Namely, a skewness decrease in the time series clearly infers a high probability to crash in return. Thus, international stock index investors are compensated for the exposure to skewness risk.

Chapter 4

Conclusion

This dissertation investigates the predictability of option-implied moments to future returns from the international perspective. The first essay shows the relationship in the currency markets while the second essay investigates the predictability of option-implied skewness on the future international stock index returns.

In the first essay, we document the relationship between information extracted from the currency options and carry trade returns from both the cross-section and time-series perspectives. In the cross-section, if the option-implied returns of a carry trade currency pair are more volatile, more left-skewed, and have fatter tails than those of other currency pairs in the same period, we find that the currency pair is predicted to have greater future excess returns. Based on these results and compared with benchmark strategies, the option-implied information strategies perform better because the option-implied moments contain forward-looking features. In the time-series, if the option-implied return skewness reaches a historically low level, future excess returns are forecasted to be smaller. Therefore, the carry trader may unwind his or her carry trade position or, more aggressively, execute an "anti-carry trade" when the option-implied skewness approaches a very negative level compared to its historical records.

In the second essay, we investigate the relation between ex ante information extracted from country-specific index options and subsequent returns on the international investments from both cross-sectional and time-series perspectives. We show that option-implied skewness have negative effects on USD-based future international index returns. In the cross-section, our empirical finding reveal a significantly negative relation between ex ante skewness and subsequent returns, which is consistent with the intuition that an international investor exposed to greater skewness risks is compensated by a higher future skewness premium. Moreover, we document an insignificant relation between ex ante volatility and future international index returns. This result shows that either investor's demand for hedging against changes in market volatility or volatility feedback effect is not able to explain the activities in international index markets. The findings are different from the empirical results with regards to domestic U.S. stock markets. We form an international trading strategy based on sorting ex ante skewness, which outperforms the benchmark strategies, including the macroeconomic variables, sensitivities to international risk factors, and realized return moments. In the time series, we document existence of a skewness premium for Asian and non-euro area European stock indice.

Appendix A

Implied Moments from Currency Options

Bakshi, Kapadia, and Madan (2003) propose a method to extract model-free implied skewness and kurtosis from options. They assume that there exist hypothetical swaps, the payoffs of which equal the non-central moments of the log returns. The kth non-central moments are defined as

$$\mu_{k,t} = E_t^{\mathbb{Q}}\left[\left(\ln \frac{S_{t+\tau}}{S_t}\right)^k\right], \text{where } k = \{1,2,3,4\}. \tag{A.1}$$

The time-t prices of the non-central second, third, and fourth moment hypothetical swaps, which can be computed by constructing the appropriate portfolios of calls and puts, are as follows:

$$\text{Swap}_{2,t}(\tau) = \int_{S_t}^{\infty} \frac{2\left(1-\ln\frac{K}{S_t}\right)}{K^2} C_t(K,\tau)dK + \int_0^{S_t} \frac{2\left(1+\ln\frac{S_t}{K}\right)}{K^2} P_t(K,\tau)dK, \tag{A.2}$$

$$\text{Swap}_{3,t}(\tau) = \int_{S_t}^{\infty} \frac{6\ln\frac{K}{S_t} - 3\left(\ln\frac{K}{S_t}\right)^2}{K^2} C_t(K,\tau)dK + \int_0^{S_t} \frac{6\ln\frac{S_t}{K} + 3\left(\ln\frac{S_t}{K}\right)^2}{K^2} P_t(K,\tau)dK, \tag{A.3}$$

$$\text{Swap}_{4,t}(\tau) = \int_{S_t}^{\infty} \frac{12\left(\ln\frac{K}{S_t}\right)^2 - 4\left(\ln\frac{K}{S_t}\right)^3}{K^2} C_t(K,\tau)dK + \int_0^{S_t} \frac{12\left(\ln\frac{S_t}{K}\right)^2 + 4\left(\ln\frac{S_t}{K}\right)^3}{K^2} P_t(K,\tau)dK, \tag{A.4}$$

where $C_t(K,\tau)$ and $P_t(K,\tau)$ are the prices of call and put options with strike exchange rates K and τ periods to maturity. Because the above swap prices are discounted from maturity to time t, the non-central moments are adjusted as

$$\mu_{k,t}(\tau) = \exp(r_t \cdot \tau) \cdot \text{Swap}_{k,t}(\tau); \text{where } k = \{2, 3, 4\}. \tag{A.5}$$

Therefore, the model-free option-implied moments under the risk-neutral $\mathbb{Q}$ probability can be derived as

$$\text{ivol}_t^{\mathbb{Q}}(\tau) = (\mu_{2,t}(\tau) - \mu_{1,t}(\tau)^2)^{1/2}, \tag{A.6}$$

$$\text{iskew}_t^{\mathbb{Q}}(\tau) = \frac{\mu_{3,t}(\tau) - 3 \cdot \mu_{1,t}(\tau) \cdot \mu_{2,t}(\tau) + 2 \cdot \mu_{1,t}(\tau)^3}{\left(\mu_{2,t}(\tau) - \mu_{1,t}(\tau)^2\right)^{3/2}}, \tag{A.7}$$

$$\text{ikurt}_t^{\mathbb{Q}}(\tau) = \frac{\mu_{4,t}(\tau) - 4 \cdot \mu_{3,t} \cdot \mu_{1,t}(\tau) + 6 \cdot \mu_{2,t}(\tau) \cdot \mu_{1,t}(\tau)^2 - 3 \cdot \mu_{1,t}(\tau)^4}{\left(\mu_{2,t}(\tau) - \mu_{1,t}(\tau)^2\right)^2}, \tag{A.8}$$

where ivol is the implied standard deviation or the implied volatility, iskew is the implied skewness, and ikurt is the implied kurtosis.

In computing the time-t prices of hypothetical swaps, one needs a continuum of out-of-the-money strike prices and the respective call and put prices. Thus, interpolation, extrapolation, and discretization are needed. We discretize the range of integration of the moneyness onto a grid of 1000 points, or the increment of strikes (ΔK) equal to 0.2% of the standard deviation.[1] We extrapolate the option-implied volatility below the lowest and above the highest available strikes by appending flat tails.[2] Moreover, in our sample, the deepest out-of-the-money options exceed 1.5 standard deviations and often exceed two standard deviations from the underlying exchange rates from both sides. Thus, the extrapolated range is relatively unimportant.[3] The

[1] Jiang and Tian (2005) show that the discretization errors are negligible when ΔK is smaller than 35% of its standard deviation or when the grid contains more than 20 points.

[2] Jiang and Tian (2005) indicate that the implied higher moments are estimated more precisely by extrapolating flat tails at the level of the last quoted implied volatility at the most extreme available strikes than by simply truncating the range of strikes used in the computation.

[3] Jiang and Tian (2005) discuss the truncation error of simply truncating the integration at the most extreme available strikes rather than extrapolating the flat tails. This truncation error accounts for only 0.5% of the true

infinite sum in our computation is truncated at strike exchange rates equal to 0.1 and 3.5 times spot rates.[4] Based on Jiang and Tian (2005), the errors from truncation and discretization in our computation are negligible.

For interpolation of the complete option-implied volatilities across different strikes, we apply a cubic spline interpolation technique. A cubic spline is superior to a low-order polynomial because it has greater flexibility in the shape of the fitted volatility smile and is also effective at smoothing the fitted function. See Bu and Hadri (2007).

realized volatility when the strikes of deepest out-of-the-money options are 1.5 standard deviations from the underlying asset prices. Furthermore, the estimated truncation error is essentially negligible when the strike prices are at two standard deviations from the underlying prices.

[4] In the case of developed countries, the strike exchange rates of all available deepest out-of-the-money options hardly exceed this range given any time to maturity. Hence, the resulting truncation errors after considering extrapolation are negligible.

Appendix B

Supplemental Descriptive Statistics for Chapter 2

Figure B.1 shows the time variation of the risk-free interest rates for the currencies in our sample.

[Insert Figure B.1 around here.]

The forward premium approximately equals the negative interest rate differential, after considering the fraction of a year. Figure B.2 displays additional evidence that the Japanese interest rates are lowest in most of the time periods considered. The forward premiums of the cross-yen pairs are negative except for few days in the exchange rate from the Swiss franc to the Japanese yen.

[Insert Figure B.2 around here.]

Table B.1 shows the time-series statistics of the option-implied volatility and kurtosis.

[Insert Table B.1 around here.]

Appendix C

Supplemental Results for Chapter 2

C.1 The Performance of Portfolio Strategies: Minimum-Variance and Mean-Variance Portfolios

Figures C.1 and C.2 illustrate that the portfolios based on all strategies (dark gray lines with square symbols) always beat the portfolios based on only benchmark strategies (light gray lines with cross symbols). As with the results shown in Subsection 2.5.4, including the option-implied information strategies in the portfolios always benefits carry traders.[1]

Moreover, these figures show that the cumulative returns of the portfolios that allow for anti-carry trades (black lines with circle symbols) usually beat those of the portfolios that execute only carry trades (dark gray lines with square symbols), especially during and after the recent financial crisis.

[Insert Figure C.1 around here.]

[Insert Figure C.2 around here.]

[1] In the mean-variance optimization, the portfolios with only the benchmark strategies and with all the strategies identically place high weights on the macroeconomic strategies. The reason is that the optimization program depends on the historical returns, and the macroeconomic data are sensitive to the historical returns.

C.2 Carry Trades and Anti-Carry Trades: Minimum-Variance and Mean-Variance Portfolios

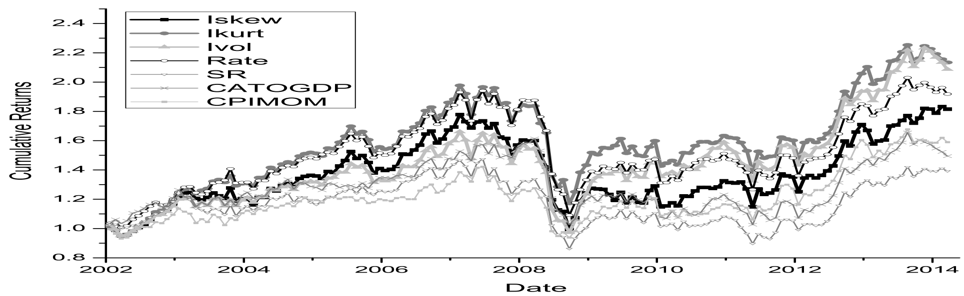
Figure C.3 and Figure C.4 show that a trader can frequently make profits by executing anti-carry trades based on time series of the option-implied skewness. In particular, the JPY- and CHF-based portfolios that allow for anti-carry trades usually outperform those that execute only carry trades. See the discussion in Subsection 2.6.3.

[Insert Figure C.3 around here.]

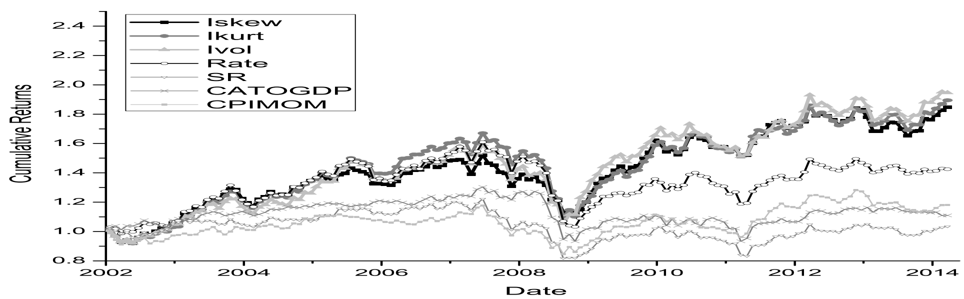
[Insert Figure C.4 around here.]

Figure 2.1: Cumulative Returns of Individual Carry Trade Strategies

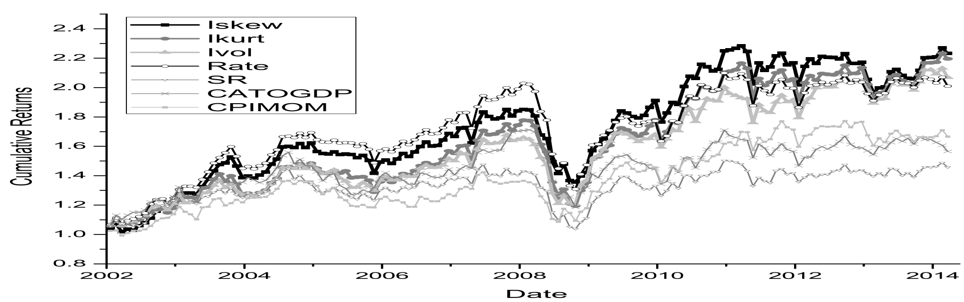
Panel A: Funded by JPY



Panel B: Funded by CHF



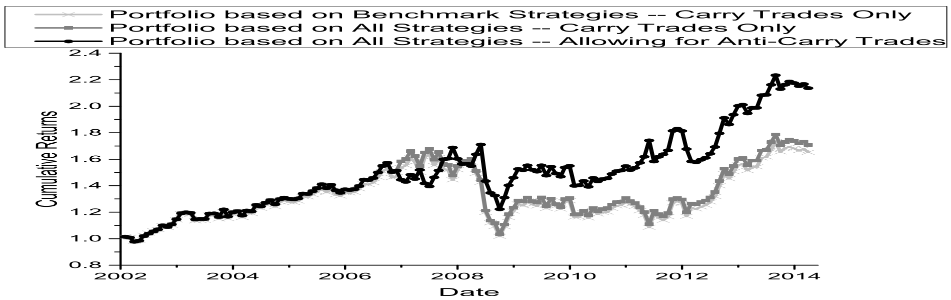
Panel C: Funded by USD



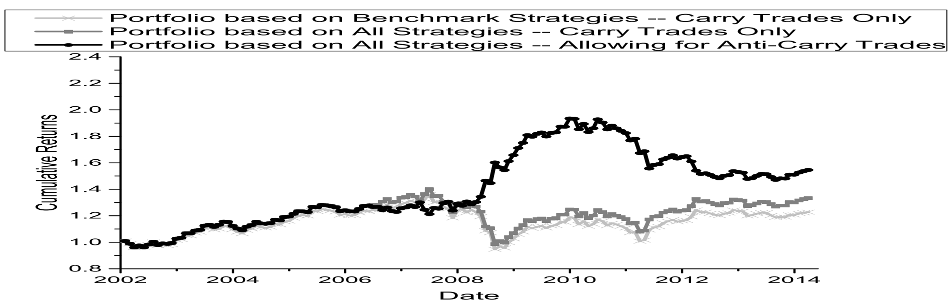
Notes: We plot the cumulative returns of seven individual carry trade strategies. An individual trade strategy is formed by sorting one of the following characteristics, investing in the most beneficial quartile of high-yield currencies and borrowing a low-yield currency. The characteristics include Iskew (implied skewness), Ikurt (implied kurtosis), Ivol (implied volatility), Rate (interest rate differential), SR (momentum of spot exchange rate movements), CATOGDP (current account standardized by GDP), and CPIMOM (purchasing power). See Subsections 2.5.1 and 2.5.2. Cumulative returns are from the beginning of the sample period, April 2002, to the date on the horizontal axis.

Figure 2.2: Cumulative Returns of the Equal-Weighted Portfolio Strategies

Panel A: Funded by JPY



Panel B: Funded by CHF

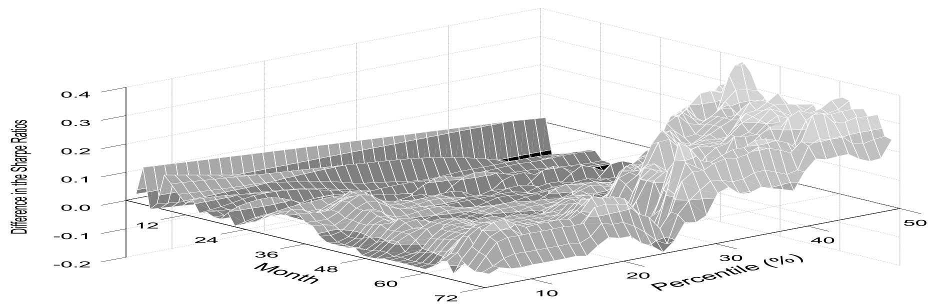


Panel C: Funded by USD

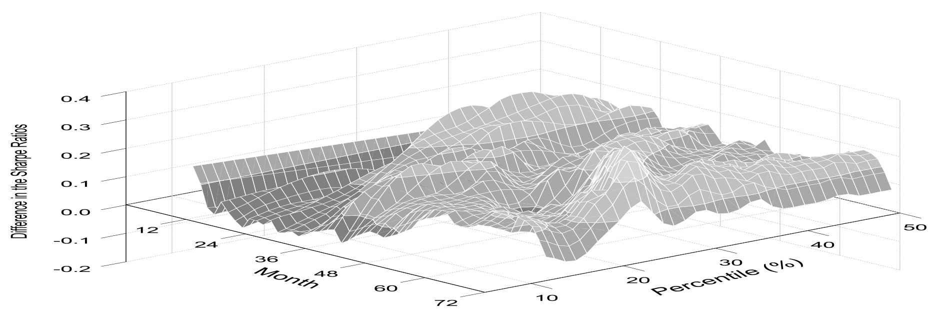
Notes: We plot the cumulative returns of the equal-weighted portfolios. The portfolio is formed by equally weighting the available strategies. See Subsection 2.5.4. "Benchmark strategies" are proposed in the literature and related to realized market and economic variables, including Rate, SR, CATOGDP, and CPIMOM. We propose the option-implied information strategies, including Iskew, Ikurt, and Ivol. "All strategies" include both benchmark and the option-implied information strategies. "Allowing for anti-carry trades" means a trader executes anti-carry trades rather than carry trades when the option-implied skewness is ranked in the bottom five over the last 36 months. See Subsection 2.6.3 for details. Cumulative returns are from the beginning of the sample period, April 2002, to the date on the horizontal axis.

Figure 2.3: Improvements from Allowing for Anti-Carry Trades: Equal-Weighted Portfolio Strategies

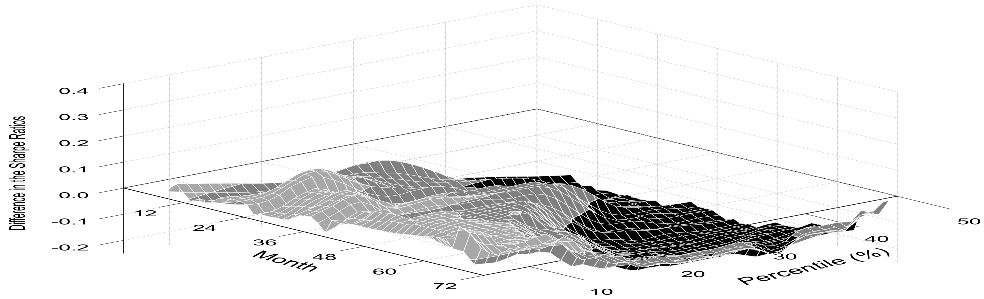
Panel A: Funded by JPY



Panel B: Funded by CHF

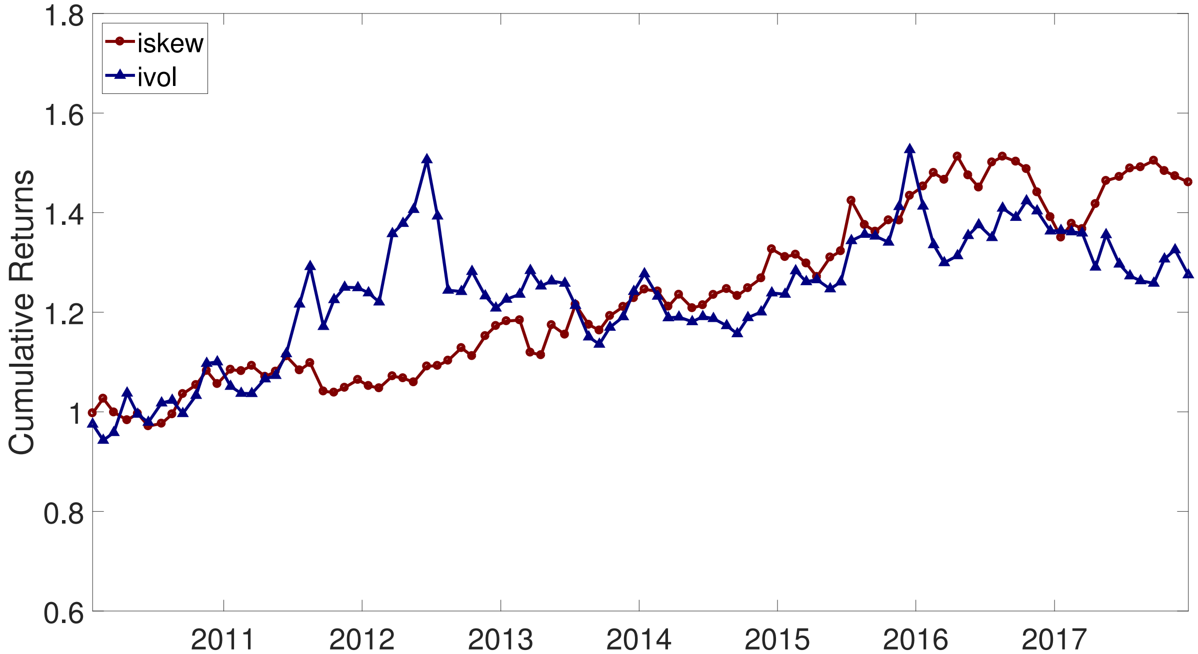


Panel C: Funded by USD



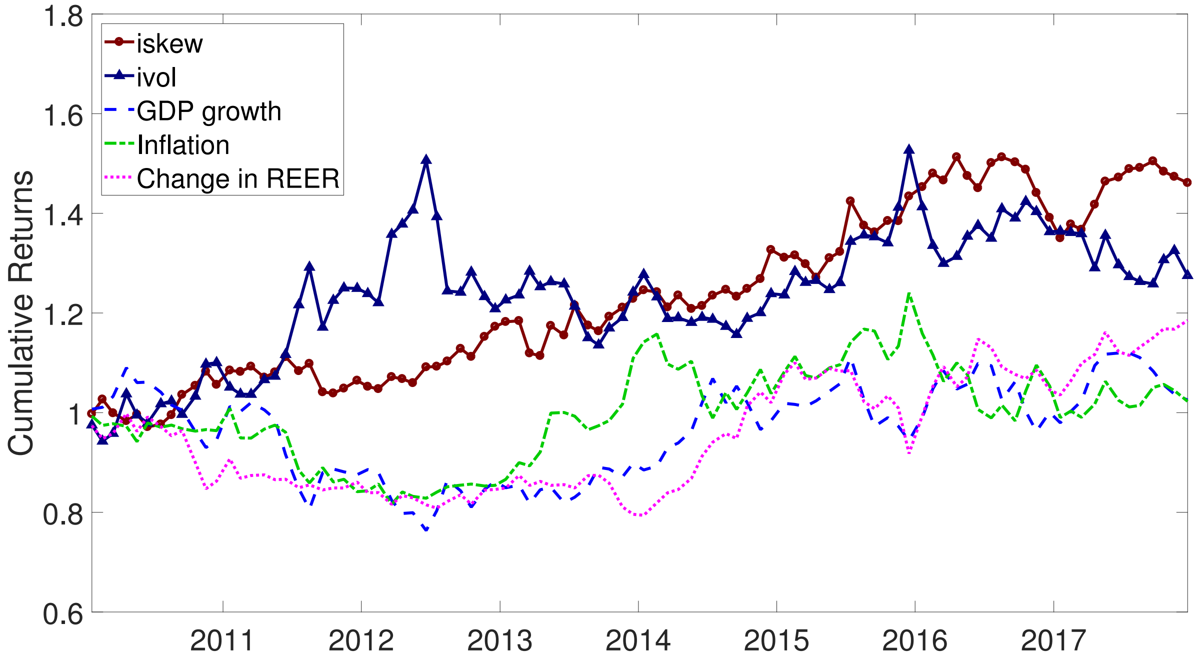
Notes: The figure plots whether a trader benefits from the ability to execute anti-carry trades. The horizontal plane is constructed by two axes, month (m) and percentile (n): A trader executes an anti-carry trade when the option-implied skewness is ranked in the bottom nth percentile over the last m months. The vertical axis represents the difference between the Sharpe ratios of (i) the portfolio that allows for anti-carry trades and (ii) the portfolio that executes only carry trades. Black shading indicates that the difference in the Sharpe ratios is negative. Gray and light gray shading mean that the difference in the Sharpe ratios is positive. The equal-weighted portfolio is formed by equally weighting all strategies. See Subsections 2.5.4 and 2.6.3.

Figure 3.1: Performance of the Option-Implied Trading Strategies

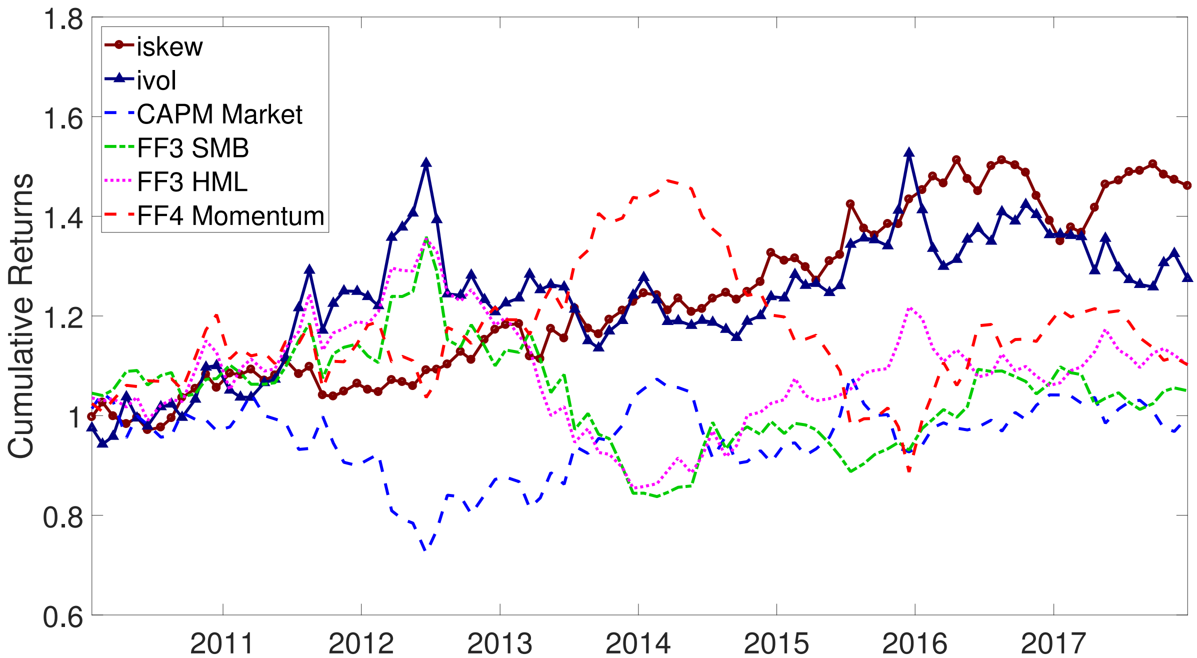


Notes: We plot the cumulative returns of individual trading strategies. An individual trading strategy is constructed by a long-short portfolio with buying and holding the most beneficial quartile and simultaneously short-selling of the least beneficial quartile based on one of the following characteristics of the international stock indices. We propose option-implied strategies: iskew (option-implied skewness) and ivol (option-implied volatility). Cumulative returns are from the beginning of the sample period, January 2010, to the date on the horizontal axis.

Figure 3.2: Performance of the Trading Strategies



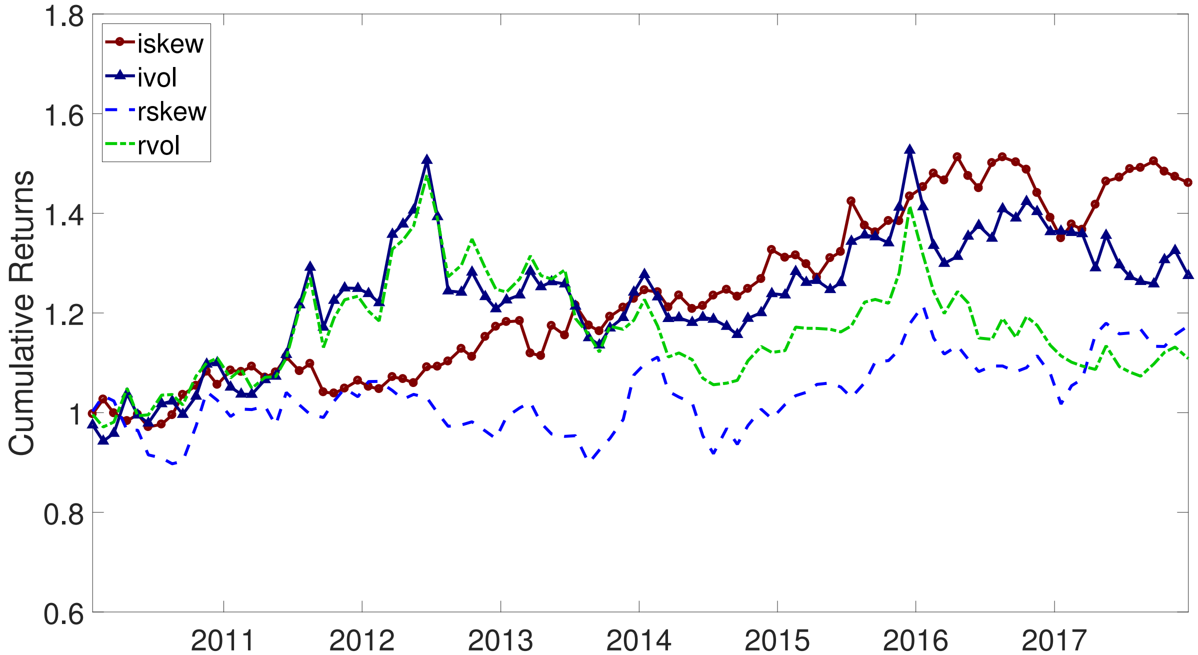
Panel A: Benchmark: Macroeconomic Strategies



Panel B: Benchmark: Sensitivities to Risk Factors

(Continued)

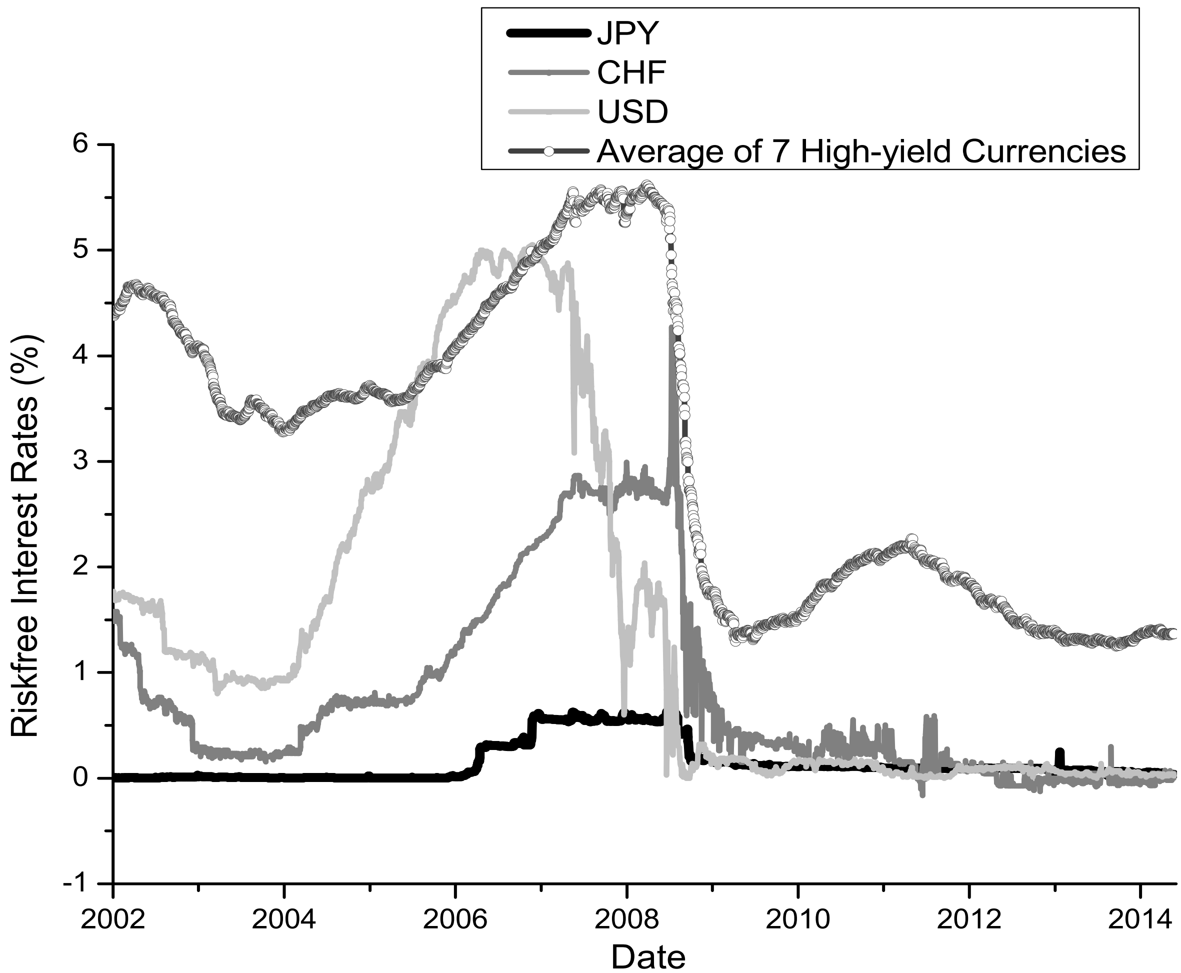
Figure 3.2: *(Continued)*



Panel C: Benchmark: Realized Returns

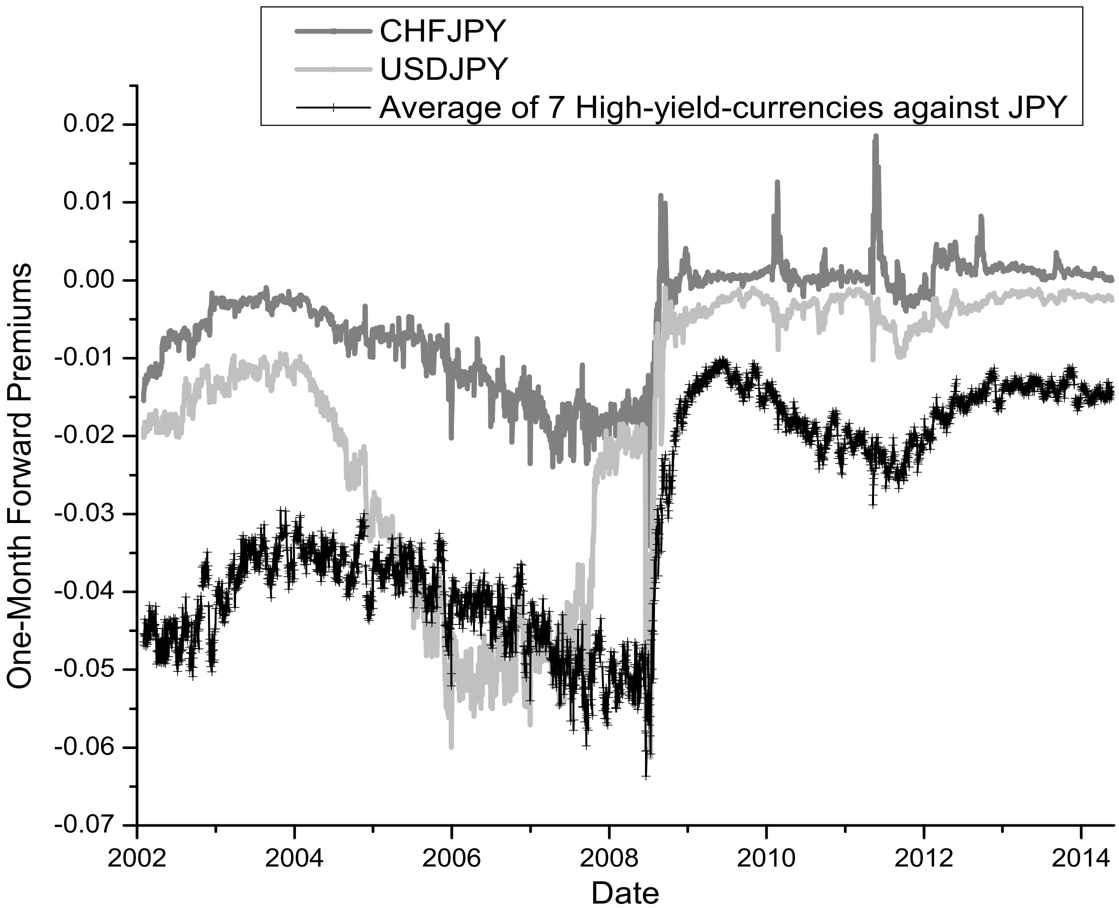
Notes: We plot the cumulative returns of individual trading strategies. An individual trading strategy is constructed by a long-short portfolio with buying and holding the most beneficial quartile and simultaneously short-selling of the least beneficial quartile based on one of the following characteristics of the international stock indices. We propose option-implied strategies: iskew (option-implied skewness) and ivol (option-implied volatility), which are plotted in all panels. The benchmarks in Panel A include the GDP growth, the inflation, and the change in REER as the macroeconomic characteristics. The benchmarks in Panel B include the sensitivities to the international market factor in the CAPM ("CAPM Market"), the loadings to the size ("FF3 SMB") and book-to-market ("FF3 HML") factors in the Fama-French international three-factor model, and the loading to the momentum factor ("FF4 Momentum") in the Fama-French and Carhart international four-factor model. The benchmarks in Panel C include the USD-based international index realized return moments: realized skewness ("rskew") and realized volatility ("rvol"). Cumulative returns are from the beginning of the sample period, January 2010, to the date on the horizontal axis.

Figure B.1: Short-Term Risk-free Interest Rates



Notes: The figure shows the short-term risk-free annualized interest rates for different currencies. JPY is the Japanese yen. CHF is the Swiss franc. USD is the US dollar. The average of seven high-yield currencies is the average of the Australian dollar, the Canadian dollar, the Euro, the British pound, the Norwegian krone, the New Zealand dollar, and the Swedish krona.

Figure B.2: One-Month Forward Premiums for Cross-JPY Pairs

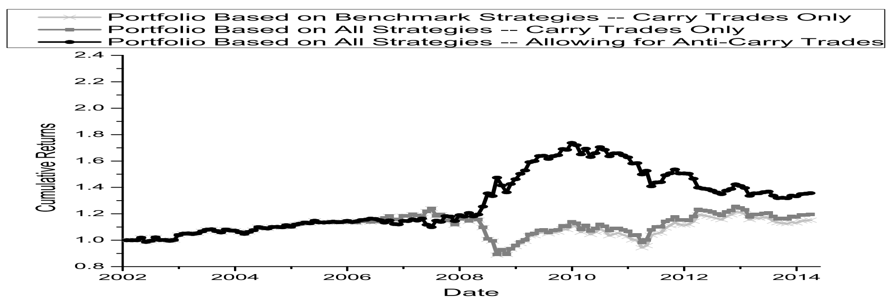


Notes: The figure plots annualized one-month forward premiums for cross-JPY pairs. Forward premiums of a currency pair approximately equal the negative interest rate differential between two currencies. "CHFJPY" is the exchange rate from the Swiss franc to the Japanese yen. "USDJPY" is the exchange rate from the US dollar to the Japanese yen. The average of seven high-yield currencies against JPY is the average of the Australian dollar, the Canadian dollar, the Euro, the British pound, the Norwegian krone, the New Zealand dollar, and the Swedish krona against the Japanese yen.

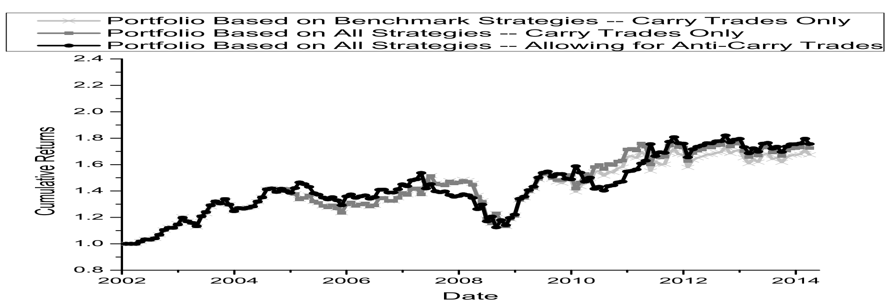
Figure C.1: Cumulative Returns of the Minimum-Variance Portfolio Strategies

Panel A: Funded by JPY

Panel B: Funded by CHF



Panel C: Funded by USD

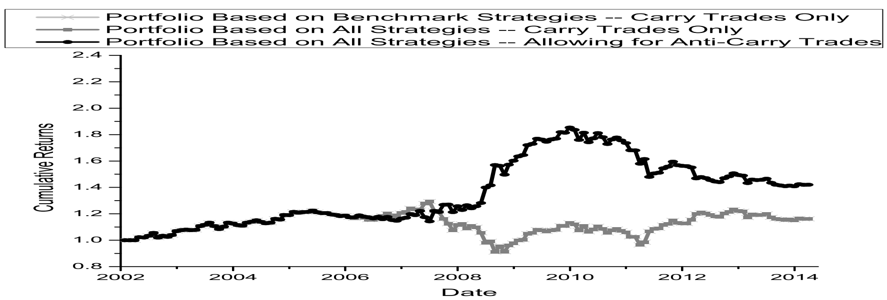


Notes: The Minimum-variance portfolio is formed by minimizing the return volatility. See Subsection 2.5.4. “Benchmark strategies” are proposed in the literature and related to realized market and economic variables, including Rate, SR, CATOGDP, and CPIMOM. We propose the option-implied information strategies, including Iskew, Ikurt, and Ivol. “All strategies” include both benchmark and the option-implied information strategies. “Allowing for anti-carry trades” means that a trader executes anti-carry trades rather than carry trades when the option-implied skewness is ranked in the bottom five over the last 36 months. See Subsection 2.6.3. Cumulative returns are from the beginning of the sample period, April 2002, to the date on the horizontal axis.

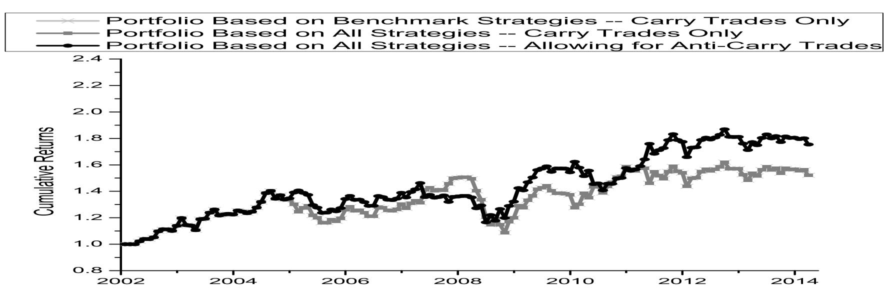
Figure C.2: Cumulative Returns of the Mean-Variance Portfolio Strategies

Panel A: Funded by JPY

Panel B: Funded by CHF



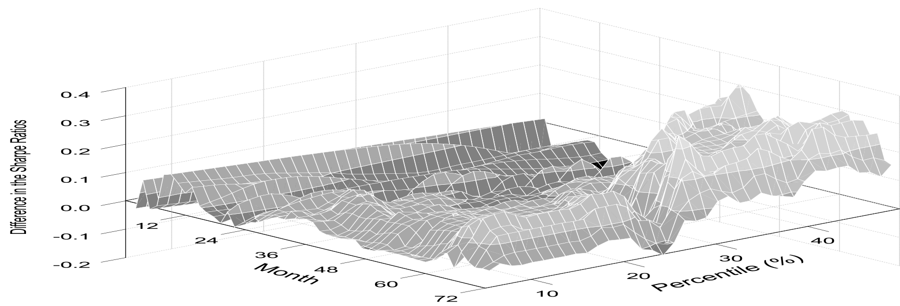
Panel C: Funded by USD



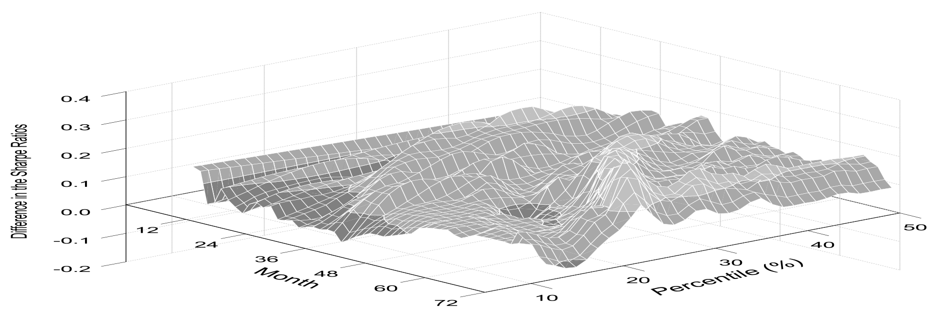
Notes: The Mean-variance portfolio is formed by balancing from the impact of the return volatilities and the returns themselves. See Subsection 2.5.4. “Benchmark strategies” are proposed in the literature and related to realized market and economic variables, including Rate, SR, CATOGDP, and CPIMOM. We propose the option-implied information strategies, including Iskew, Ikurt, and Ivol. “All strategies” include both benchmark and the option-implied information strategies. “Allowing for anti-carry trades” means that a trader executes anti-carry trades rather than carry trades when the option-implied skewness is ranked in the bottom five over the last 36 months. See Subsection 2.6.3 for details. Cumulative returns are from the beginning of the sample period, April 2002, to the date on the horizontal axis.

Figure C.3: Improvements from Allowing for Anti-Carry Trades: Minimum-Variance Portfolio Strategies

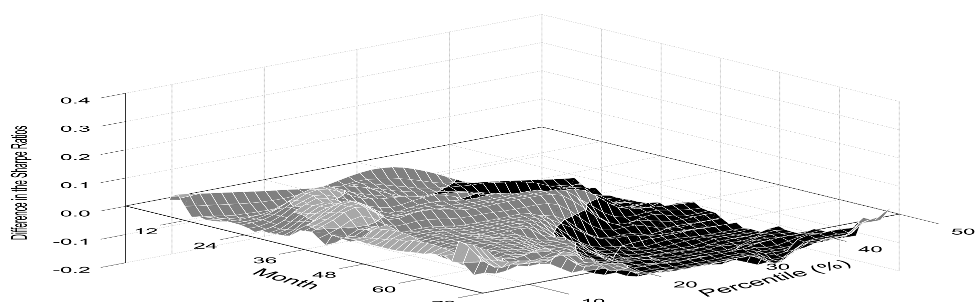
Panel A: Funded by JPY



Panel B: Funded by CHF



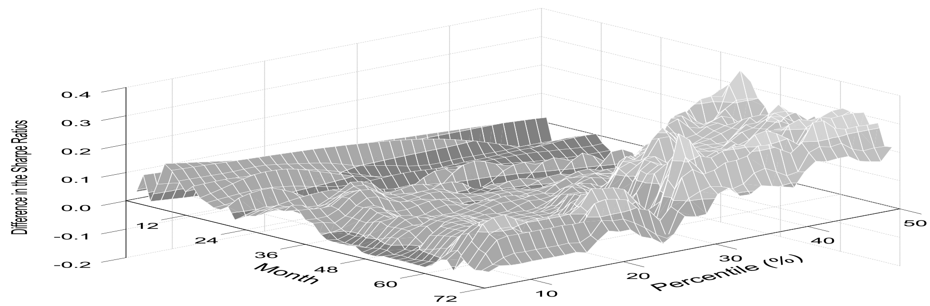
Panel C: Funded by USD



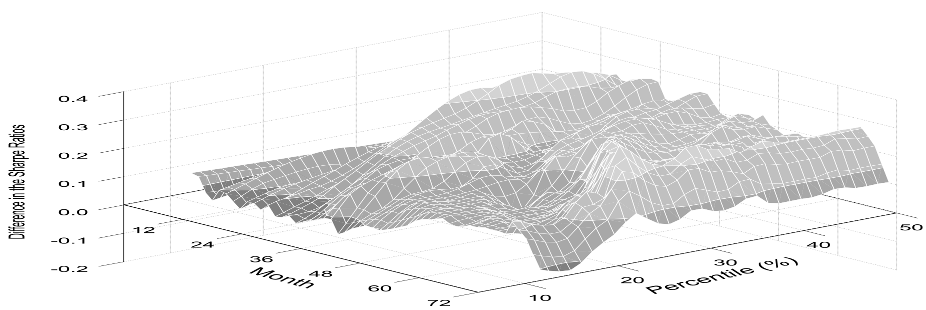
Notes: The figure plots whether a trader benefits from allowing the execution of anti-carry trades. The horizontal plane is constructed by two axes, month (m) and percentile (n): A trader executes an anti-carry trade when the option-implied skewness is ranked in the bottom nth percentile over the last m months. The vertical axis represents the difference between the Sharpe ratios of (i) the portfolio that allows for anti-carry trades and (ii) the portfolio that executes only carry trades. Black shading indicates that the difference in the Sharpe ratios is negative. Gray and light gray shading mean that the difference in the Sharpe ratios is positive. The Minimum-variance portfolio is formed by minimizing the return volatility using all strategies. See Subsections 2.5.4 and 2.6.3.

Figure C.4: Improvements from Allowing for Anti-Carry Trades: Mean-Variance Portfolio Strategies

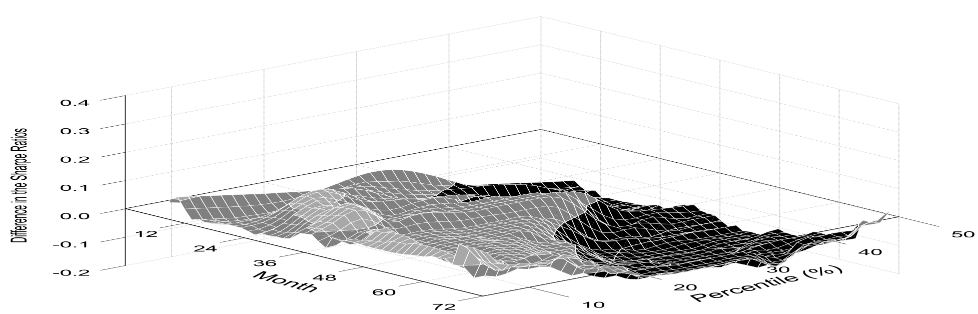
Panel A: Funded by JPY



Panel B: Funded by CHF



Panel C: Funded by USD



Notes: The figure plots whether a trader benefits from allowing the execution of anti-carry trades. The horizontal plane is constructed by two axes, month (m) and percentile (n): A trader executes an anti-carry trade when the option-implied skewness is ranked in the bottom nth percentile over the last m months. The vertical axis represents the difference between the Sharpe ratios of (i) the portfolio that allows for anti-carry trades and (ii) the portfolio that executes only carry trades. Black shading means that the difference in the Sharpe ratios is negative. Gray and light gray shading mean that the difference in the Sharpe ratios is positive. The Mean-variance portfolio is formed by balancing from the impact of the return volatilities and the returns themselves using all strategies. See Subsections 2.5.4 and 2.6.3.

Table 2.1: Descriptive Statistics: Risk-free Interest Rates

Currencies	Mean (%)	StDev (%)
JPY	0.1456	0.1857
USD	1.4248	1.6646
CHF	0.7962	0.9057
AUD	4.8813	1.3629
CAD	2.0058	1.2794
EUR	1.7013	1.4391
GBP	2.6361	2.1072
NOK	3.2927	1.6814
NZD	4.7420	2.0128
SEK	2.3443	1.2925

· Notes: Time-series averages and standard deviations. The sample period is from April 1, 2002, to August 22, 2014.

Table 2.2: Descriptive Statistics: Currency Returns and Forward Premiums

Funding	XR				FP			
Currencies	Mean	StDev	Min	Max	Mean	StDev	Min	Max
JPY	0.0520	0.4724	-4.0864	2.7034	-0.0300	0.0199	-0.2017	0.1260
USD	0.0526	0.3923	-3.1035	2.1522	-0.0131	0.0179	-0.1830	0.1282
CHF	0.0142	0.3429	-2.5226	2.9198	-0.0252	0.0167	-0.1895	0.1258

· Notes: We tabulate the time-series statistics of the excess returns and forward premiums. The sample period is from April 1, 2002, to August 22, 2014. XR is the annualized one-month excess return, and FP is the annualized one-month forward premium.

Table 2.3: Descriptive Statistics: Option-Implied Skewness

Currency Pairs	Mean	StDev	Min	Max
AUDJPY	-1.0254	0.3446	-1.7650	-0.2357
CADJPY	-0.8878	0.3633	-1.6285	-0.0605
EURJPY	-0.7737	0.4528	-1.6137	0.0513
GBPJPY	-0.8164	0.4127	-1.6931	0.0186
NOKJPY	-0.8880	0.3738	-2.4027	-0.0901
NZDJPY	-1.0732	0.2863	-1.7917	-0.2635
SEKJPY	-0.8526	0.4002	-1.5254	0.0081
AUDUSD	-0.9547	0.4018	-1.7503	0.0760
CADUSD	0.3457	0.3764	-0.8291	1.2272
EURUSD	-0.5744	0.4400	-1.3373	0.1974
GBPUSD	-0.5631	0.4078	-1.4588	0.0265
NOKUSD	0.5957	0.4198	-0.7078	1.5288
NZDUSD	-1.0942	0.3573	-1.6251	0.0716
SEKUSD	0.5453	0.4151	-0.6762	1.3336
AUDCHF	-0.8833	0.3526	-1.6673	0.1054
CADCHF	-0.5656	0.3602	-1.1372	0.0200
EURCHF	-0.4795	0.4525	-3.2981	0.1650
GBPCHF	-0.5902	0.3985	-1.5549	0.0253
NOKCHF	0.2310	0.4148	-0.7501	1.4131
NZDCHF	-0.9674	0.3214	-1.6455	0.1126
SEKCHF	0.1857	0.3873	-0.9152	1.4054

· Notes: We tabulate the time-series statistics of the option-implied skewness. The sample period is from April 1, 2002, to August 22, 2014. Option-implied skewness is annualized and extracted from one-month currency options using the method of Bakshi, Kapadia, and Madan (2003).

Table 2.4: Cross-Sectional Results of Implied Skewness

Panel A: Forward Premium

Dependent \ Independent		ImpliedSkew			
		Coef.	Std. Err	Avg R^2	AR(1)
FP_t	JPY	0.0816*	0.0023	0.544	No
		0.0015*	0.0004	0.990	Yes
	USD	0.0152*	0.0003	0.407	No
		0.0003*	0.0001	0.990	Yes
	CHF	0.0219*	0.0005	0.399	No
		0.0005*	0.0001	0.990	Yes

Panel B: Interest Rate Differential

Dependent \ Independent		ImpliedSkew		
		Coef.	Std. Err	Avg R^2
RD_t	JPY	-0.0746*	0.0021	0.458
	USD	-0.0115*	0.0003	0.300
	CHF	-0.0168*	0.0004	0.290

· Notes: FP is the annualized one-month forward premium. RD is the annualized interest rate differential between the high-yield currency and the low-yield currency. We estimate each cross-sectional regression at each time t. Then, we show the Fama-MacBeth regression results of the coefficients $\hat{\beta}$. We present robust standard errors based on Petersen (2009). Panel A shows the empirical results of Fama-MacBeth Regression (1.a): $FP_{it} = \alpha_t + \beta_{1.a,t} \cdot \text{iskew}_{it} + \varepsilon_{it}$. Panel B shows the empirical results of Fama-MacBeth Regression (1.b): $RD_{it} = \alpha_t + \beta_{1.b,t} \cdot \text{iskew}_{it} + \varepsilon_{it}$. AR(1): To check the robustness, the results alternatively add the lagged forward premium as an additional independent variable in Panel A. * indicates significance at the 5% level.

Table 2.5: Option-Implied Moments and Future Excess Returns

Panel A: Implied Skewness

Dependent \ Independent		ImpliedSkew			
		Coef.	Std. Err	Avg R^2	AR(1)
XR_{t+1}	JPY	-0.0620*	0.0270	0.247	No
		-0.0640*	0.0298	0.450	Yes
	USD	-0.0148*	0.0042	0.215	No
		-0.0225*	0.0049	0.433	Yes
	CHF	-0.0211*	0.0056	0.245	No
		-0.0288*	0.0065	0.447	Yes

Panel B: Implied Kurtosis

Dependent \ Independent		ImpliedKurt			
		Coef.	Std. Err	Avg R^2	AR(1)
XR_{t+1}	JPY	0.0662*	0.0114	0.238	No
		0.0715*	0.0139	0.448	Yes
	USD	0.0523*	0.0078	0.228	No
		0.0674*	0.0091	0.445	Yes
	CHF	0.0734*	0.0092	0.266	No
		0.0717*	0.0099	0.461	Yes

Panel C: Implied Volatility

Dependent \ Independent		ImpliedVol			
		Coef.	Std. Err	Avg R^2	AR(1)
XR_{t+1}	JPY	4.8614*	0.6023	0.218	No
		4.6011*	0.6434	0.425	Yes
	USD	3.6131*	0.4033	0.213	No
		3.5522*	0.4712	0.422	Yes
	CHF	3.5959*	0.4745	0.250	No
		3.7676*	0.4685	0.442	Yes

· Notes: XR_{t+1} is the annualized one-month excess return realized at $(t+1)$. We estimate each cross-sectional predictive regression at each time $(t+1)$. Then, we show the Fama-MacBeth regression results of the coefficients $\hat{\beta}$. We present robust standard errors based on Petersen (2009). Panel A shows the empirical results of Fama-MacBeth Regression (2.a): $XR_{i,t+1} = \alpha_t + \beta_{2.\mathrm{a},t} \cdot \mathrm{iskew}_{it} + \varepsilon_{i,t+1}$. Panel B shows the empirical results of Fama-MacBeth Regression (2.b): $XR_{i,t+1} = \alpha_t + \beta_{2.\mathrm{b},t} \cdot \mathrm{ikurt}_{it} + \varepsilon_{i,t+1}$. Panel C shows the empirical results of Fama-MacBeth Regression (2.c): $XR_{i,t+1} = \alpha_t + \beta_{2.\mathrm{c},t} \cdot \mathrm{ivol}_{it} + \varepsilon_{i,t+1}$. AR(1): To check the robustness, the results alternatively add the lagged excess return as an additional independent variable. * indicates significance at the 5% level.

Table 2.6: Carry Trade Returns and Downside Market Risk

Coefficient \ Market Factor	Dependent: $XR_{i,t} - \hat{\beta}_i \cdot r_{m,t}$	
	RX_{FX}	RX_E
$\lambda_{\text{downside}}$	0.0358*	0.8159*
	(0.0118)	(0.1109)
α	-0.0020	-0.0090
	(0.0038)	(0.0047)
R^2	0.2134	0.1965

· Notes: XR_t is the contemporaneous annualized one-month excess return. We estimate the Fama-MacBeth regression: $\left(XR_{i,t} - \hat{\beta}_i \cdot r_{m,t}\right) = \alpha_t + \lambda_{\text{downside},t} \cdot \left(\hat{\beta}_i^- - \hat{\beta}_i\right) + \varepsilon_{i,t}$. $\hat{\beta}^-$ is the sensitivity to downside market return, documented in Lettau, Maggiori, and Weber (2014). We apply two different market factors: foreign exchange market excess returns (RX_{FX}) and equity market excess returns (RX_E). The former factor documented in Lustig, Roussanov, and Verdelhan (2011) is the average excess return on all foreign currency portfolios denominated in the USD in our sample. The latter factor is defined in the CAPM with the stock index return as the proxy for the market return. We present robust standard errors based on Petersen (2009) in parentheses. * indicates significance at the 5% level.

Table 2.7: Cross-Sectional Return Predictability of the Option-Implied Moments

	Dependent: XR_{t+1}					
	(A)	(B)	(C)	(D)	(E)	(F)
ImpliedSkew	-0.0005*	-0.0004*	-0.0005*	-0.0003	-0.0005*	-0.0007*
	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0001)
ImpliedKurt	0.0007*	0.0016*	0.0009*	0.0009*	0.0007*	0.0005*
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
ImpliedVol	0.2546*	0.1551*	0.2642*	0.2292*	0.2627*	0.2535*
	(0.0146)	(0.0173)	(0.0155)	(0.0165)	(0.0145)	(0.0155)
Controls		Sensitivities to Time-Series Implied Moment Variations	Loadings to the Foreign Exchange Market Factor	Loadings to the LRV2 Factors in the FX Market	Loadings to the Equity Market Factor	Loadings to the FF3 Factors in the Equity Market
Control for DI	Yes	Yes	Yes	Yes	Yes	Yes
Control for DF	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.99992	0.99995	0.99993	0.99994	0.99993	0.99995

· Notes: XR_{t+1} is the annualized one-month excess return realized at $(t+1)$. We estimate the Fama-MacBeth regression $XR_{i,t+1} = \alpha_t + \beta_{4s,t} \cdot \mathrm{iskew}_{it} + \beta_{4k,t} \cdot \mathrm{ikurt}_{it} + \beta_{4v,t} \cdot \mathrm{ivol}_{it} + \gamma_{X,t} \cdot X_{it} + \varepsilon_{i,t+1}$, where X is the vector of control variables. We combine all the carry trades across funding currencies in one sample. In addition to the regression in column (A), we control for five sets of variables to investigate the significance of the return predictability of the option-implied moments. The regression in column (B) controls for the sensitivities to the time-series variations in the option-implied moments. The regressions in columns (C) and (D) control for the loadings to the factors in the foreign exchange market. The factor in column (C) is the foreign exchange market excess return. The factors in column (D) are the market excess return and the carry trade risk factor, where this two-factor model is documented in LRV (Lustig, Roussanov, and Verdelhan, 2011). The regressions in columns (E) and (F) control for the loadings to the factors in the equity market. The factor in column (E) is the equity market excess return. The factors in column (F) are the market, size, and book-to-market factors, where this three-factor model is documented in FF (Fama and French, 1992). The regressions in all of the six columns control for the effects of the investment currency (DI) and of the funding currency (DF). We present robust standard errors based on Petersen (2009) in parentheses. * indicates significance at the 5% level.

Table 2.8: The Performance of Individual Carry Trade Strategies

Funding currency: JPY		Mean	Std	Sharpe	CE
Benchmark Strategies	Rate	0.0750	0.4890	15.33%	5.11%
	SR	0.0321	0.4500	7.12%	1.18%
	CATOGDP	0.0404	0.4563	8.85%	1.96%
	CPIMOM	0.0482	0.4294	11.22%	2.98%
Option-Implied Information Strategies	Iskew	0.0665	0.4754	13.98%	4.39%
	Ikurt	0.0926	0.4896	18.92%	6.86%
	Ivol	0.0886	0.4968	17.84%	6.40%

Funding currency: USD		Mean	Std	Sharpe	CE
Benchmark Strategies	Rate	0.0824	0.4123	19.98%	6.54%
	SR	0.0374	0.3594	10.41%	2.45%
	CATOGDP	0.0461	0.4008	11.51%	3.01%
	CPIMOM	0.0544	0.3658	14.87%	4.10%
Option-Implied Information Strategies	Iskew	0.1006	0.3974	25.32%	8.48%
	Ikurt	0.0976	0.4260	22.91%	7.95%
	Ivol	0.0872	0.4077	21.38%	7.06%

Funding currency: CHF		Mean	Std	Sharpe	CE
Benchmark Strategies	Rate	0.0347	0.3553	9.76%	2.21%
	SR	0.0028	0.3102	0.92%	-0.68%
	CATOGDP	0.0090	0.2957	3.03%	0.02%
	CPIMOM	0.0148	0.2875	5.15%	0.65%
Option-Implied Information Strategies	Iskew	0.0692	0.3276	21.13%	5.85%
	Ikurt	0.0731	0.3620	20.18%	5.99%
	Ivol	0.0772	0.3801	20.31%	6.27%

· Notes: Each trade strategy is formed by sorting on one of the characteristics, investing in the most beneficial quartile of high-yield currencies and borrowing a low-yield currency. The characteristics are Iskew (implied skewness), Ikurt (implied kurtosis), Ivol (implied volatility), Rate (interest rate differential), SR (momentum of spot exchange rate movements), CATOGDP (current account standardized by GDP), and CPIMOM (purchasing power). Benchmark strategies are proposed in the literature and related to realized returns and economic variables, including Rate, SR, CATOGDP, and CPIMOM. We propose the option-implied information strategies, including Iskew, Ikurt, and Ivol. We compute certainty equivalent excess returns (CE) using the constant absolute risk aversion (CARA) utility function with risk aversion coefficient 5.

Table 2.9: The Performance of Portfolio Strategies: All Strategies and Benchmark Strategies

		JPY				USD				CHF			
		Mean	Std	Sharpe	CE	Mean	Std	Sharpe	CE	Mean	Std	Sharpe	CE
Equal-	Benchmark	0.0533	0.4297	12.40%	3.48%	0.0597	0.3439	17.36%	4.79%	0.0186	0.2850	6.52%	1.05%
Weighted	All Strategies	0.0578	0.4299	13.45%	3.93%	0.0654	0.3427	19.08%	5.36%	0.0272	0.2811	9.66%	1.93%
Minimum-	Benchmark	0.0655	0.4343	15.07%	4.66%	0.0551	0.3516	15.66%	4.27%	0.0124	0.2775	4.47%	0.47%
Variance	All Strategies	0.0687	0.4357	15.77%	4.97%	0.0593	0.3540	16.74%	4.67%	0.0160	0.2754	5.81%	0.84%
Mean-	Benchmark	0.0474	0.4341	10.92%	2.86%	0.0425	0.3757	11.32%	2.84%	0.0132	0.2768	4.77%	0.56%
Variance	All Strategies	0.0474	0.4341	10.92%	2.86%	0.0425	0.3757	11.32%	2.84%	0.0132	0.2768	4.77%	0.56%

· Notes: We form the portfolios by the objectives based on the available strategies. Benchmark strategies are proposed in the literature and related to realized returns and economic variables, including Rate, SR, CATOGDP, and CPIMOM. We propose the option-implied information strategies, including Iskew, Ikurt, and Ivol. "Benchmark" are the portfolios based on only the benchmark strategies. "All Strategies" are the portfolios based on both the benchmark and the option-implied information strategies. Each strategy is formed by sorting on one characteristic, investing in the most beneficial quartile of high-yield currencies and borrowing a low-yield currency. Equal-weighted portfolios are formed by investing in each strategy with an equal weight. Minimum-variance portfolios are formed by minimizing the return volatility. Mean-variance portfolios are formed by balancing the impact from the return volatilities and from the returns themselves. The optimized weights of the minimum-variance and the mean-variance portfolios are determined by the information of all the previous periods in our sample. Then, in the following period, we observe and present the out-of-sample returns of the portfolios based on the optimized weights. The sample period is from April 1, 2002, to August 22, 2014. All values are annualized. We compute certainty equivalent excess returns (CE) using the constant absolute risk aversion (CARA) utility function with risk aversion coefficient 5.

Table 2.10: Time-Series Results for Option-Implied Skewness and Carry Trade Excess Returns

Dependent	Independent	ImpliedSkew		
		Coef.	Std. Err	R^2
XR_{t+1}	AUDJPY	0.1373*	0.0344	0.0075
	CADJPY	0.1083*	0.0279	0.0071
	EURJPY	0.1430*	0.0203	0.0230
	GBPJPY	0.2135*	0.0225	0.0411
	NOKJPY	0.1451*	0.0288	0.0119
	NZDJPY	0.2725*	0.0425	0.0191
	SEKJPY	0.1208*	0.0263	0.0099
	AUDUSD	-0.0186	0.0249	0.0003
	CADUSD	0.0007	0.0189	0.0000
	EURUSD	0.0485*	0.0183	0.0033
	GBPUSD	0.0583*	0.0178	0.0051
	NOKUSD	-0.0217	0.0217	0.0005
	NZDUSD	0.1039*	0.0287	0.0062
	SEKUSD	0.0157	0.0226	0.0002
	AUDCHF	0.0552*	0.0261	0.0021
	CADCHF	0.0378	0.0239	0.0012
	EURCHF	0.0048	0.0101	0.0001
	GBPCHF	0.1305*	0.0167	0.0281
	NOKCHF	0.0025	0.0169	0.0000
	NZDCHF	0.0418	0.0290	0.0010
	SEKCHF	0.0099	0.0175	0.0002

• Notes: XR_{t+1} is the annualized one-month excess return realized in the next month $(t+1)$. We estimate the time-series regression given a currency pair i. Regression (5) $XR_{i,t+1} = \alpha_i + \beta_{5,i} \cdot \text{iskew}_{it} + \varepsilon_{i,t+1}$. * indicates significance at the 5% level.

Table 2.11: The Performance of Portfolio Strategies: Allowing for Anti-Carry Trades

All Strategies Composite		JPY				USD				CHF			
		Mean	Std	Sharpe	CE	Mean	Std	Sharpe	CE	Mean	Std	Sharpe	CE
Equal-	Carry Only	0.0578	0.4299	13.45%	3.93%	0.0654	0.3427	19.08%	5.36%	0.0272	0.2811	9.66%	1.93%
Weighted	Allowing for Anti-Carry	0.0927	0.4273	21.70%	7.45%	0.0756	0.3418	22.13%	6.40%	0.0446	0.2797	15.94%	3.68%
Minimum-	Carry Only	0.0687	0.4357	15.77%	4.97%	0.0593	0.3540	16.74%	4.67%	0.0160	0.2754	5.81%	0.84%
Variance	Allowing for Anti-Carry	0.1026	0.4287	23.93%	8.42%	0.0617	0.3502	17.62%	4.95%	0.0291	0.2717	10.71%	2.17%
Mean-	Carry Only	0.0474	0.4341	10.92%	2.86%	0.0425	0.3757	11.32%	2.84%	0.0132	0.2768	4.77%	0.56%
Variance	Allowing for Anti-Carry	0.0939	0.4330	21.69%	7.52%	0.0616	0.3653	16.86%	4.82%	0.0343	0.2869	11.97%	2.61%

· Notes: The portfolios are formed based on all strategies, including Rate, SR, CATOGDP, CPIMOM, Iskew, Ikurt, and Ivol. The "Carry Only" portfolios are formed by a trader who only executes carry trades. The "Allowing for Anti-Carry" portfolios are formed by a trader who executes an anti-carry trade instead of a carry trade when the option-implied skewness is ranked in the bottom five over the last 36 months. Equal-weighted portfolios are formed by investing in each strategy with an equal weight. Minimum-variance portfolios are formed by minimizing the return volatility. Mean-variance portfolios are formed by balancing the impact from the return volatilities and from the returns themselves. The sample period is from April 1, 2002, to August 22, 2014. All values are annualized. We compute certainty equivalent excess returns (CE) using the constant absolute risk aversion (CARA) utility function with risk aversion coefficient 5.

Table 3.1: Sample of International Index ETF Options

Country	Benchmark Index (tracked by the ETF)	Start Date
Euro Area		
Euro Area	MSCI EMU Index	03/06/2008
Germany	MSCI Germany Index	01/02/2008
France	MSCI France Index	08/10/2011
Italy	MSCI Italy 25/50 Index	07/13/2010
Spain	MSCI Spain 25/50 Index	01/02/2008
Netherlands	MSCI Netherlands Index	08/14/2013
Belgium	MSCI Belgium Capped Index	09/18/2013
Non-Euro Area Europe, the Middle East, and Africa (EMEA)		
United Kingdom	MSCI United Kingdom Index	01/02/2008
Switzerland	MSCI Switzerland 25/50 Index	02/19/2008
Sweden	MSCI Sweden Index	01/03/2008
South Africa	MSCI South Africa Index	01/02/2008
Asian-Pacific		
Japan	MSCI Japan Index	01/02/2008
Korea	MSCI Korea 25/50 Index	01/02/2008
Hong Kong	MSCI Hong Kong Index	01/02/2008
Taiwan	MSCI Taiwan Index	01/02/2008
Singapore	MSCI Singapore Index	11/18/2009
Malaysia	MSCI Malaysia Index	03/12/2008
Thailand	MSCI Thailand Index	02/07/2014
Australia	MSCI Australia Index	01/02/2008
North America		
Canada	MSCI Canada Index	01/02/2008
United States	S&P 500	01/02/2008
Latin America		
Mexico	MSCI Mexico Index	01/02/2008
Brazil	MSCI Brazil 25/50 Index	10/16/2008

· Notes: We report the benchmark index that the ETF tracks and the start date for the available option data for each country or region listed. The end dates for all indices are the end of 2017. In the U.S. data, the options are directly based on the S&P 500 index instead of the ETF. All data are retrieved from OptionMetrics.

Table 3.2: Descriptive Statistics: Option-Implied Volatility and Skewness

Country	Volatility (%)					Skewness					N
	Mean	Std	P20	P50	P80	Mean	Std	P20	P50	P80	
Euro Area	7.72	3.24	5.23	7.03	9.34	-1.16	0.38	-1.36	-1.21	-1.02	1924
Germany	7.04	2.66	5.06	6.52	8.62	-1.20	0.22	-1.32	-1.22	-1.12	1998
France	8.22	3.07	5.98	7.52	9.78	-1.26	0.33	-1.44	-1.27	-1.07	1594
Italy	8.81	5.02	6.17	7.72	10.52	-0.80	0.85	-0.76	-0.75	-0.73	1866
Spain	9.41	3.26	6.68	8.88	11.57	-1.07	0.51	-1.30	-1.16	-1.00	1998
Netherlands	6.01	1.94	4.73	5.71	6.77	-1.30	0.46	-1.55	-1.32	-1.02	1095
Belgium	7.43	1.89	5.95	7.27	8.86	-1.29	0.53	-1.61	-1.30	-0.89	1071
United Kingdom	6.09	2.98	3.99	5.39	7.61	-0.89	0.92	-0.77	-0.76	-0.75	1996
Switzerland	5.67	2.07	4.24	5.37	6.40	-1.26	0.45	-1.51	-1.26	-0.99	1460
Sweden	9.03	3.21	6.48	8.34	10.79	-1.06	0.72	-1.42	-1.21	-0.89	1534
South Africa	9.17	2.56	7.19	8.58	11.10	-1.12	0.22	-1.24	-1.13	-1.02	1998
Japan	5.12	1.35	4.14	4.99	5.90	-0.83	0.18	-0.77	-0.76	-0.76	1997
South Korea	6.92	2.27	5.20	6.33	8.16	-1.13	0.13	-1.21	-1.11	-1.03	1998
Hong Kong	5.65	1.61	4.39	5.33	6.44	-1.13	0.23	-1.28	-1.15	-1.01	1998
Taiwan	5.73	1.59	4.47	5.43	6.65	-0.82	0.15	-0.77	-0.76	-0.75	1997
Singapore	5.84	2.49	4.08	5.35	7.20	-0.83	0.60	-0.77	-0.76	-0.75	1997
Malaysia	6.12	2.93	4.43	5.44	7.32	-0.81	0.49	-0.77	-0.76	-0.75	1996
Thailand	7.71	2.28	5.73	7.38	9.72	-1.12	0.46	-1.39	-1.10	-0.91	975
Australia	7.85	2.54	5.82	7.48	9.32	-1.05	0.51	-1.25	-1.14	-0.98	1998
Canada	6.61	2.02	5.14	6.29	7.67	-1.22	0.34	-1.37	-1.23	-1.10	1997
United States	4.62	1.68	3.37	4.24	5.60	-1.40	0.15	-1.49	-1.38	-1.29	2013
Mexico	6.82	1.82	5.39	6.53	7.85	-1.17	0.10	-1.25	-1.17	-1.09	1998
Brazil	9.27	2.52	7.29	8.76	11.07	-1.04	0.17	-1.14	-1.05	-0.96	1998

· Notes: We present the descriptive statistics of option-implied volatility and skewness for each country in our sample. We report the mean, standard deviation, and the 20th, 50th, and 80th percentiles of our daily sample. The volatilities are monthly and presented as percentages. The underlying return distribution is USD-based. We calculate option-implied moments by using the methodology proposed in Bakshi, Kapadia, and Madan (2003). All data are retrieved from OptionMetrics.

Table 3.3: Performance of the Cross-Sectional Univariate Sorted Portfolios

Single Sorting		ivol	iskew	GDP growth	Inflation	Change in REER	CAPM Mkt	FF3 SMB	FF3 HML	FF4 Mom	rvol	rskew
Quartile	1 (Low)	0.0542	0.0735	0.0476	0.0334	0.0534	0.0628	0.0496	0.0346	0.0383	0.0593	0.0511
		(1.06)	(1.26)	(0.63)	(0.52)	(0.80)	(1.17)	(0.70)	(0.58)	(0.48)	(1.24)	(0.84)
	2	0.0423	0.0370	0.0529	0.0448	0.0831	0.0476	0.0571	0.0465	0.0582	0.0410	0.0271
		(0.78)	(0.59)	(0.90)	(0.81)	(1.24)	(0.87)	(0.94)	(0.86)	(0.98)	(0.74)	(0.42)
	3	0.0492	0.0265	0.0236	0.0602	0.0126	-0.0104	0.0044	0.0669	0.0362	0.0345	0.0684
		(0.80)	(0.40)	(0.37)	(0.97)	(0.20)	(-0.16)	(0.07)	(1.17)	(0.65)	(0.55)	(1.11)
	4 (High)	0.0126	0.0241	0.0350	0.0195	0.0111	0.0650	0.0546	0.0153	0.0274	0.0247	0.0163
		(0.15)	(0.39)	(0.63)	(0.27)	(0.19)	(0.86)	(0.94)	(0.19)	(0.48)	(0.30)	(0.25)
Long-Short Portfolios	Returns	0.0416	**0.0494**	0.0126	0.0139	0.0422	0.0022	0.0050	0.0193	0.0109	0.0346	0.0348
	t Stat	(0.91)	(2.08)	(0.28)	(0.34)	(1.14)	(0.05)	(0.12)	(0.47)	(0.24)	(0.74)	(0.85)
	St Dev	0.2329	0.1444	0.2058	0.1953	0.1792	0.2436	0.2211	0.2082	0.2120	0.2564	0.1811
	Sharpe	0.1744	0.3354	0.0565	0.0662	0.2301	0.0050	0.0182	0.0880	0.0468	0.1311	0.1868

· Notes: This table presents the results of univariate sorts on the characteristics. We propose the strategies based on sorting option-implied ex ante skewness and volatility. We sort countries into quartile portfolios by each univariate characteristic. Quartile 1 contains indices in the lowest quartile and Quartile 4 contains those in the highest quartile. The sorted portfolios are equally weighted and rebalanced each month. We report the expected subsequent annualized returns for each of the four portfolios and Newey and West (1987) t-statistics in parentheses for each characteristic. We report the results of buying the most beneficial quartile and short selling the least beneficial quartile in "Long-Short Portfolio." We provide the average annualized return, Newey and West (1987) t-statistics, annualized realized standard deviation, and Sharpe ratio of the long-short portfolio of each strategy. With regard to the long-short portfolios, the following strategies buy the lowest quartile and sell the highest one: ivol (option-implied volatility), iskew (option-implied skewness), GDP growth, inflation, change in REER, FF3HML (sensitivity to the book-to-market factor), FF4Mom (sensitivity to the momentum factor), rvol (realized volatility), and rskew (realized skewness). On the other hand, the following strategies buy the highest quartile and sell the lowest one: CAPMMkt (sensitivity to the market factor) and FF3SMB (sensitivity to the size factor). Significant coefficients at the 90% confidence level are boldfaced.

Table 3.4: Abnormal Returns of the Cross-Sectional Univariate Sorted Portfolios, Considering International Four Factors

	α (FF4)	ivol	iskew	GDP growth	Inflation	Change in REER	CAPM Mkt	FF3 SMB	FF3 HML	FF4 Mom	rvol	rskew
Quartile	1 (Low)	0.1988	0.4032	0.0719	-0.1079	-0.0319	0.2167	0.1430	-0.1469	-0.0226	0.1822	0.1031
		(0.32)	(0.54)	(0.08)	(-0.14)	(-0.04)	(0.31)	(0.16)	(-0.20)	(-0.02)	(0.31)	(0.14)
	2	-0.0123	0.0032	0.2357	0.2251	0.6468	0.0341	0.0977	0.2562	0.1410	0.1327	-0.0926
		(-0.02)	(0.00)	(0.31)	(0.32)	(0.79)	(0.05)	(0.13)	(0.40)	(0.21)	(0.19)	(-0.11)
	3	0.1923	-0.2032	-0.2344	0.2322	-0.3999	-0.5316	-0.5740	0.1915	0.0548	-0.1293	0.1632
		(0.26)	(-0.27)	(-0.30)	(0.30)	(-0.53)	(-0.67)	(-0.79)	(0.26)	(0.08)	(-0.17)	(0.22)
	4 (High)	-0.4498	-0.2428	-0.0364	-0.3373	-0.2427	0.2373	0.2745	-0.3949	-0.2732	-0.2734	-0.2475
		(-0.45)	(-0.31)	(-0.06)	(-0.41)	(-0.34)	(0.25)	(0.41)	(-0.42)	(-0.38)	(-0.27)	(-0.33)
Long-Short		0.6485	**0.6460**	0.1083	0.2294	0.2108	0.0207	0.1315	0.2480	0.2506	0.4556	0.3506
Portfolios		(1.13)	(1.85)	(0.19)	(0.45)	(0.47)	(0.04)	(0.24)	(0.50)	(0.45)	(0.80)	(0.67)

· Notes: This table presents the abnormal returns of univariate sorts on the characteristics that are the portfolio alphas after considering international four factors in the model proposed in Fama and French (2012). We show the alphas of the strategies based on sorting each of the univariate characteristics into quartile portfolios. Quartile 1 contains indices in the lowest quartile and Quartile 4 contains those in the highest quartile. The sorted portfolios are equally weighted and rebalanced each month. We report the alphas for each of the four portfolios and Newey and West (1987) t-statistics in parentheses for each characteristic. We also report the results of buying the most beneficial quartile and short selling the least beneficial quartile in "Long-Short Portfolio." With regard to the long-short portfolios, the following strategies buy the lowest quartile and sell the highest one: ivol (option-implied volatility), iskew (option-implied skewness), GDP growth, inflation, change in REER, FF3HML (sensitivity to the book-to-market factor), FF4Mom (sensitivity to the momentum factor), rvol (realized volatility), and rskew (realized skewness). On the other hand, the following strategies buy the highest quartile and sell the lowest one: CAPMMkt (sensitivity to the market factor) and FF3SMB (sensitivity to the size factor). Significant coefficients at the 90% confidence level are boldfaced.

Table 3.5: Cross-Sectional Predictive Double-Sorted Portfolios: Option-Implied Moments

Double Sorting		iskew Terciles			
		1 (Low)	2	3 (High)	Low-High
ivol Terciles	1 (Low)	**0.0802**	0.0164	0.0224	**0.0579**
		(5.67)	(1.14)	(1.47)	(7.21)
	2	0.0283	0.0284	0.0175	0.0109
		(1.57)	(1.53)	(0.98)	(1.00)
	3 (High)	0.0053	0.0078	0.0278	-0.0225
		(0.24)	(0.34)	(1.13)	(-1.62)
	Low-High	**0.0749**	0.0086	-0.0054	**0.0804**
		(5.67)	(0.53)	(-0.32)	(5.20)

· Notes: This table presents the results of double sorts on option-implied ex ante skewness and volatility. We independently sort countries into tercile portfolios based on ex ante skewness and volatility and then form portfolios based on the intersection of these two moments. Tercile 1 contains stocks with the lowest iskew (in columns) or ivol (in rows) and Tercile 3 contains those with the highest ones. The sorted portfolios are equally weighted and rebalanced each month. We report the expected subsequent annualized returns for each of the three-by-three portfolios and Newey and West (1987) t-statistics in parentheses. Significant coefficients at the 90% confidence level are boldfaced.

Table 3.6: Cross-Sectional Return Predictability of Option-Implied Moments: Controlling for Macroeconomic Variables

	Dependent Variable: Future Returns											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
iskew	**-0.0013**		**-0.0022**	-0.0003		**-0.0016**	**-0.0031**		**-0.0038**	**-0.0020**		**-0.0031**
	(0.0008)		(0.0008)	(0.0008)		(0.0009)	(0.0008)		(0.0008)	(0.0008)		(0.0009)
ivol		**-0.0465**	**-0.0661**		**-0.0796**	**-0.1130**		**-0.0488**	**-0.0682**		**-0.0817**	**-0.1132**
		(0.0199)	(0.0213)		(0.0184)	(0.0198)		(0.0194)	(0.0207)		(0.0184)	(0.0198)
GDP growth				-0.0018	-0.0025	-0.0014				-0.0041	-0.0073	-0.0071
				(0.0070)	(0.0059)	(0.0062)				(0.0067)	(0.0060)	(0.0064)
Inflation				0.0011	-0.0038	-0.0045				0.0165	-0.0018	-0.0001
				(0.0212)	(0.0204)	(0.0204)				(0.0208)	(0.0202)	(0.0205)
Change in REER				**-0.0142**	**-0.0139**	**-0.0117**				**-0.0135**	**-0.0113**	**-0.0103**
				(0.0061)	(0.0056)	(0.0057)				(0.0059)	(0.0055)	(0.0057)
Lagged returns							**-0.0678**	**-0.0773**	**-0.0761**	**-0.0742**	**-0.0794**	**-0.0777**
							(0.0111)	(0.0102)	(0.0105)	(0.0109)	(0.0100)	(0.0103)
Avg R^2	0.05	0.13	0.18	0.35	0.38	0.43	0.18	0.23	0.28	0.43	0.45	0.50

· Notes: The dependent variable is the non-annualized, one-month, USD-based international stock index return realized at $(t+1)$. We estimate Fama-MacBeth Regressions 6 to 8:

$$R_{i,t+1} = \alpha_t + \beta_t \cdot \text{imom}_{it} + \gamma_{Xt} \cdot X_{it} + \varepsilon_{i,t+1},$$

where R is the return, "imom" is either one of option-implied moments or a vector containing both option-implied skewness and volatility, and X is the vector of control variables. Columns (1) to (3) show the pure effects of ex ante moments. Columns (4) to (6) report the results after controlling for macroeconomic variables, including GDP growth, inflation, and changes in the REER. Columns (7) to (12) show the robust results after additionally controlling for lagged index returns. We present Newey and West (1987) standard errors in parentheses. Significant coefficients at the 90% confidence level are boldfaced.

Table 3.7: Cross-Sectional Return Predictability of Option-Implied Moments: Controlling for the CAPM Market Factor

	Dependent Variable: Future Returns					
	(1)	(2)	(3)	(4)	(5)	(6)
iskew	**-0.0014**		**-0.0021**	**-0.0033**		**-0.0037**
	(0.0007)		(0.0008)	(0.0007)		(0.0008)
ivol		**-0.0680**	**-0.0904**		**-0.0663**	**-0.0861**
		(0.0237)	(0.0253)		(0.0225)	(0.0243)
Market factor loadings	-0.0006	-0.0003	0.0003	-0.0013	-0.0001	0.0000
	(0.0016)	(0.0017)	(0.0017)	(0.0016)	(0.0017)	(0.0018)
Lagged returns				**-0.0867**	**-0.0875**	**-0.0859**
				(0.0113)	(0.0104)	(0.0108)
Avg R^2	0.19	0.23	0.28	0.29	0.32	0.37

· Notes: The dependent variable is the non-annualized, one-month, USD-based international stock index return realized at $(t+1)$. We estimate Fama-MacBeth Regressions 6 to 8:

$$R_{i,t+1} = \alpha_t + \beta_t \cdot \text{imom}_{it} + \gamma_{Xt} \cdot X_{it} + \varepsilon_{i,t+1},$$

where R is the return, "imom" is either one of option-implied moments or a vector containing both option-implied skewness and volatility, and X is the vector of control variables. Columns (1) to (3) show the predictability of ex ante skewness and volatility after controlling for the loading on the international market factor in the CAPM. Columns (4) to (6) show the robust results after additionally controlling for lagged index returns. We present Newey and West (1987) standard errors in parentheses. Significant coefficients at the 90% confidence level are boldfaced.

Table 3.8: Cross-Sectional Return Predictability of Option-Implied Moments: Controlling for the Fama-French and Carhart Momentum Factors

	Dependent Variable: Future Returns											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
iskew	**-0.0027**		**-0.0032**	**-0.0024**		**-0.0032**	**-0.0037**		**-0.0039**	**-0.0037**		**-0.0045**
	(0.0007)		(0.0008)	(0.0007)		(0.0008)	(0.0007)		(0.0009)	(0.0007)		(0.0009)
ivol		**-0.0636**	**-0.0898**		**-0.0493**	**-0.0812**		**-0.0539**	**-0.0768**		**-0.0466**	**-0.0755**
		(0.0211)	(0.0237)		(0.0194)	(0.0222)		(0.0205)	(0.0228)		(0.0194)	(0.0220)
Market factor	-0.0009	0.0002	0.0006	-0.0001	0.0011	0.0011	-0.0012	0.0001	0.0003	-0.0004	0.0016	0.0013
loadings	(0.0018)	(0.0018)	(0.0019)	(0.0018)	(0.0018)	(0.0019)	(0.0019)	(0.0019)	(0.0020)	(0.0019)	(0.0019)	(0.0021)
SMB factor	0.0014	0.0009	0.0014	0.0008	0.0007	0.0013	0.0004	-0.0004	0.0004	0.0008	0.0001	0.0012
loadings	(0.0011)	(0.0011)	(0.0011)	(0.0010)	(0.0010)	(0.0010)	(0.0011)	(0.0011)	(0.0011)	(0.0010)	(0.0010)	(0.0010)
HML factor	**-0.0047**	**-0.0052**	**-0.0040**	**-0.0058**	**-0.0056**	**-0.0049**	**-0.0043**	**-0.0045**	**-0.0028**	**-0.0050**	**-0.0048**	**-0.0034**
loadings	(0.0012)	(0.0011)	(0.0011)	(0.0012)	(0.0011)	(0.0012)	(0.0012)	(0.0011)	(0.0011)	(0.0012)	(0.0012)	(0.0012)
Momentum factor				0.0027	0.0028	0.0025				**0.0039**	0.0033	**0.0041**
loadings				(0.0022)	(0.0022)	(0.0022)				(0.0022)	(0.0022)	(0.0022)
Lagged returns							**-0.0751**	**-0.0802**	**-0.0781**	**-0.0864**	**-0.0857**	**-0.0870**
							(0.0111)	(0.0107)	(0.0109)	(0.0108)	(0.0106)	(0.0110)
Avg R^2	0.34	0.37	0.41	0.42	0.44	0.48	0.43	0.45	0.49	0.50	0.51	0.54

· Notes: The dependent variable is the non-annualized, one-month, USD-based international stock index return realized at $(t+1)$. We estimate Fama-MacBeth Regressions 6 to 8:

$$R_{i,t+1} = \alpha_t + \beta_t \cdot \text{imom}_{it} + \gamma_{Xt} \cdot X_{it} + \varepsilon_{i,t+1},$$

where R is the return, "imom" is either one of option-implied moments or a vector containing both option-implied skewness and volatility, and X is the vector of control variables. Columns (1) to (3) show the predictability of ex ante skewness and volatility after controlling for the loadings on the market, size (SMB), and book-to-market (HML) factors in the Fama-French international three-factor model. Columns (4) to (6) report the results after controlling for the loadings on the market, size, book-to-market, and momentum factors in the Fama-French-Carhart international four-factor model. Columns (7) to (12) show the robust results after additionally controlling for lagged index returns. We present Newey and West (1987) standard errors in parentheses. Significant coefficients at the 90% confidence level are boldfaced.

Table 3.9: Cross-Sectional Return Predictability of Option-Implied Moments: Controlling for Realized Moments

	Dependent Variable: Future Returns					
	(1)	(2)	(3)	(4)	(5)	(6)
iskew	**-0.0016**		**-0.0015**	**-0.0027**		**-0.0027**
	(0.0008)		(0.0009)	(0.0008)		(0.0009)
ivol		-0.0182	**-0.0634**		-0.0162	**-0.0614**
		(0.0233)	(0.0270)		(0.0234)	(0.0258)
rskew	**-0.0058**		**-0.0050**	**-0.0045**		**-0.0039**
	(0.0012)		(0.0011)	(0.0012)		(0.0011)
rvol		**-0.0203**	-0.0034		**-0.0261**	-0.0074
		(0.0089)	(0.0095)		(0.0091)	(0.0097)
Lagged returns				**-0.0658**	**-0.0806**	**-0.0762**
				(0.0110)	(0.0102)	(0.0103)
Avg R^2	0.15	0.23	0.35	0.26	0.32	0.43

· Notes: The dependent variable is the non-annualized, one-month, USD-based international stock index return realized at $(t+1)$. We estimate Fama-MacBeth Regressions 6 to 8:

$$R_{i,t+1} = \alpha_t + \beta_t \cdot \text{imom}_{it} + \gamma_{Xt} \cdot X_{it} + \varepsilon_{i,t+1},$$

where R is the return, "imom" is either one of option-implied moments or a vector containing both option-implied skewness and volatility, and X is the vector of control variables. Columns (1) to (3) show the predictability of ex ante skewness and volatility after controlling for the corresponding realized moment(s). Columns (4) to (6) show the robust results after additionally controlling for lagged index returns. We present Newey and West (1987) standard errors in parentheses. Significant coefficients at the 90% confidence level are boldfaced.

Table 3.10: Time-Series Results for Option-Implied Skewness and Future Returns

Dependent Variable: Future Returns			
Country	iskew	St Err	R^2
Euro Area			
Euro Area	**-0.0076**	(0.0022)	0.005
Germany	0.0087	(0.0069)	0.001
France	0.0059	(0.0038)	0.001
Italy	**0.0039**	(0.0020)	0.002
Spain	0.0014	(0.0030)	0.000
Netherlands	0.0020	(0.0026)	0.001
Belgium	**0.0130**	(0.0021)	0.035
Non-Euro Area EMEA			
United Kingdom	-0.0021	(0.0015)	0.001
Switzerland	**-0.0080**	(0.0018)	0.010
Sweden	**-0.0065**	(0.0023)	0.004
South Africa	**-0.0171**	(0.0041)	0.007
Asian-Pacific			
Japan	**-0.0175**	(0.0052)	0.004
South Korea	**-0.0300**	(0.0103)	0.003
Hong Kong	**-0.0130**	(0.0057)	0.002
Taiwan	**-0.0419**	(0.0071)	0.014
Singapore	**-0.0046**	(0.0019)	0.003
Malaysia	-0.0025	(0.0029)	0.000
Thailand	**-0.0144**	(0.0032)	0.020
Australia	0.0031	(0.0032)	0.000
North America			
Canada	**0.0117**	(0.0042)	0.003
United States	-0.0032	(0.0061)	0.000
Latin America			
Mexico	**0.0246**	(0.0136)	0.001
Brazil	**0.0205**	(0.0101)	0.002

· Notes: The dependent variable is the non-annualized, one-month stock index return realized in the next month $(t+1)$. We estimate the time-series regression given a country's stock index i:

$$R_{i,t+1} = \alpha_i + \beta_i \cdot \text{iskew}_{it} + \varepsilon_{i,t+1},$$

where R is the index return, and "iskew" is option-implied skewness. We present standard errors in parentheses. Significant coefficients at the 90% confidence level are boldfaced.

Table 3.11: Time-Series Results for Option-Implied Volatility and Future Returns

Dependent Variable: Future Returns			
Country	ivol	St Err	R^2
Euro Area			
Euro Area	**-0.0552**	(0.0324)	0.001
Germany	0.0124	(0.0465)	0.000
France	0.0043	(0.0416)	0.000
Italy	**0.1162**	(0.0337)	0.006
Spain	**0.3142**	(0.0468)	0.018
Netherlands	**0.2254**	(0.0619)	0.012
Belgium	**0.2085**	(0.0592)	0.011
Non-Euro Area EMEA			
United Kingdom	**0.1115**	(0.0380)	0.003
Switzerland	**-0.1011**	(0.0188)	0.015
Sweden	**0.1101**	(0.0358)	0.005
South Africa	**0.2227**	(0.0366)	0.015
Asian-Pacific			
Japan	**-0.0696**	(0.0410)	0.001
South Korea	**0.1461**	(0.0398)	0.005
Hong Kong	-0.0474	(0.0399)	0.001
Taiwan	**-0.1036**	(0.0453)	0.002
Singapore	**0.2722**	(0.0443)	0.018
Malaysia	**-0.0724**	(0.0419)	0.001
Thailand	**-0.3842**	(0.0638)	0.036
Australia	**0.0909**	(0.0433)	0.002
North America			
Canada	0.0481	(0.0449)	0.000
United States	**-0.0863**	(0.0359)	0.002
Latin America			
Mexico	**0.2414**	(0.0465)	0.011
Brazil	**0.3561**	(0.0416)	0.031

· Notes: The dependent variable is the non-annualized, one-month stock index return realized in the next month $(t+1)$. We estimate the time-series regression given a country's stock index i:

$$R_{i,t+1} = \alpha_i + \beta_i \cdot \text{ivol}_{it} + \varepsilon_{i,t+1},$$

where R is the index return, and "ivol" is option-implied volatility in this table. We present standard errors in parentheses. Significant coefficients at the 90% confidence level are boldfaced.

Table 3.12: Time-Series Results for Option-Implied Joint Moments and Future Returns

Dependent Variable: Future Returns					
Country	iskew	St Err	ivol	St Err	R^2
Euro Area					
Euro Area	**-0.0082**	(0.0027)	0.0153	(0.0396)	0.005
Germany	0.0090	(0.0073)	-0.0057	(0.0487)	0.001
France	0.0065	(0.0041)	-0.0190	(0.0441)	0.002
Italy	0.0029	(0.0020)	**0.1086**	(0.0341)	0.007
Spain	**-0.0075**	(0.0032)	**0.3605**	(0.0508)	0.020
Netherlands	-0.0029	(0.0029)	**0.2559**	(0.0692)	0.013
Belgium	**0.0123**	(0.0021)	**0.1683**	(0.0587)	0.042
Non-Euro Area EMEA					
United Kingdom	-0.0021	(0.0015)	**0.1114**	(0.0380)	0.004
Switzerland	**-0.0039**	(0.0021)	**-0.0799**	(0.0221)	0.017
Sweden	**-0.0128**	(0.0026)	**0.2043**	(0.0406)	0.016
South Africa	**-0.0451**	(0.0049)	**0.4477**	(0.0434)	0.047
Asian-Pacific					
Japan	**-0.0196**	(0.0067)	0.0265	(0.0526)	0.005
South Korea	**-0.0696**	(0.0120)	**0.2894**	(0.0466)	0.019
Hong Kong	**-0.0121**	(0.0061)	-0.0179	(0.0425)	0.002
Taiwan	**-0.0533**	(0.0092)	**0.1137**	(0.0587)	0.015
Singapore	**-0.0035**	(0.0019)	**0.2644**	(0.0445)	0.020
Malaysia	-0.0021	(0.0029)	**-0.0696**	(0.0421)	0.001
Thailand	**-0.0091**	(0.0033)	**-0.3246**	(0.0673)	0.043
Australia	0.0007	(0.0034)	**0.0875**	(0.0469)	0.002
North America					
Canada	**0.0117**	(0.0045)	0.0012	(0.0483)	0.003
United States	0.0096	(0.0078)	**-0.1219**	(0.0460)	0.003
Latin America					
Mexico	-0.0161	(0.0158)	**0.2699**	(0.0544)	0.011
Brazil	**-0.0373**	(0.0119)	**0.4412**	(0.0496)	0.035

· Notes: The dependent variable is the non-annualized, one-month stock index return realized in the next month $(t+1)$. We estimate the time-series regression given a country's stock index i:

$$R_{i,t+1} = \alpha_i + \beta_i \cdot \text{imom}_{it} + \varepsilon_{i,t+1},$$

where R is the index return, and "imom" is a vector containing option-implied skewness and volatility. We present standard errors in parentheses. Significant coefficients at the 90% confidence level are boldfaced.

Table B.1: Descriptive Statistics: Option-Implied Dispersion

Currency Pairs	ImpliedVol				ImpliedKurt			
	Mean	StDev	Min	Max	Mean	StDev	Min	Max
AUDJPY	0.0415	0.0240	0.0161	0.2440	1.9693	1.2452	0.0742	4.9768
CADJPY	0.0385	0.0176	0.0141	0.1658	1.5932	1.1245	0.0091	4.7679
EURJPY	0.0349	0.0153	0.0137	0.1612	1.4804	1.2948	0.0012	4.6605
GBPJPY	0.0355	0.0173	0.0142	0.1723	1.4714	1.2907	0.0003	4.8574
NOKJPY	0.0404	0.0180	0.0195	0.1761	1.7027	1.1688	0.0350	4.3216
NZDJPY	0.0445	0.0219	0.0184	0.2243	2.1530	1.0838	0.1085	4.8371
SEKJPY	0.0407	0.0182	0.0187	0.1733	1.7045	1.1737	0.0189	4.3075
AUDUSD	0.0350	0.0151	0.0164	0.1424	1.5605	1.1761	0.0723	4.9239
CADUSD	0.0276	0.0105	0.0119	0.0801	0.4139	0.6665	0.0000	4.0378
EURUSD	0.0299	0.0101	0.0123	0.0876	0.7784	0.9153	0.0001	3.7861
GBPUSD	0.0270	0.0106	0.0128	0.0932	0.6809	0.8917	0.0000	3.9876
NOKUSD	0.0352	0.0115	0.0168	0.0990	0.8283	0.8130	0.0004	3.9444
NZDUSD	0.0382	0.0132	0.0181	0.1236	1.8732	0.9980	0.0913	4.4919
SEKUSD	0.0355	0.0119	0.0185	0.0970	0.8158	0.8755	0.0006	3.9466
AUDCHF	0.0335	0.0139	0.0164	0.1349	1.3312	1.0718	0.0629	4.6434
CADCHF	0.0323	0.0101	0.0158	0.0833	0.7770	0.8260	0.0050	3.7972
EURCHF	0.0159	0.0094	0.0046	0.0805	0.4556	0.8902	0.0000	8.7826
GBPCHF	0.0261	0.0114	0.0113	0.0860	0.7044	0.8731	0.0000	4.1281
NOKCHF	0.0267	0.0113	0.0151	0.1014	0.3980	0.7872	0.0001	4.3432
NZDCHF	0.0365	0.0120	0.0189	0.1160	1.5304	0.9751	0.0698	4.4566
SEKCHF	0.0261	0.0122	0.0119	0.0859	0.4137	0.8583	0.0000	4.4954

Notes: We tabulate the time-series statistics of the option-implied dispersion. The sample period is from April 1, 2002, to August 22, 2014. Option-implied moments are annualized and extracted from one-month currency options using the method of Bakshi, Kapadia, and Madan (2003).

Bibliography

Akram, Q. Farooq, Dagfinn Rime, and Lucio Sarno, 2008, Arbitrage in the foreign exchange market: Turning on the microscope, *Journal of International Economics* 76, 237–253.

Amaya, Diego, Peter Christoffersen, Kris Jacobs, and Aurelio Vasquez, 2015, Does realized skewness predict the cross-section of equity returns?, *Journal of Financial Economics* 118, 135–167.

Andersen, Torben G., Tim Bollerslev, Francis X. Diebold, and Heiko Ebens, 2001, The distribution of realized stock return volatility, *Journal of Financial Economics* 61, 43–76.

Ang, Andrew, Robert J. Hodrick, Yuhang Xing, and Xiaoyan Zhang, 2006, The cross-section of volatility and expected returns, *Journal of Finance* 61, 259–299.

Ang, Andrew, Robert J. Hodrick, Yuhang Xing, and Xiaoyan Zhang, 2009, High idiosyncratic volatility and low returns: International and further US evidence, *Journal of Financial Economics* 91, 1–23.

Antonakakis, Nikolaos, Ioannis Chatziantoniou, and George Filis, 2013, Dynamic co-movements of stock market returns, implied volatility and policy uncertainty, *Economics Letters* 120, 87–92.

Askari, Hossein, and Noureddine Krichene, 2008, Oil price dynamics (2002-2006), *Energy Economics* 30, 2134–2153.

Asness, Clifford S., Tobias J. Moskowitz, and Lasse Heje Pedersen, 2013, Value and momentum everywhere, *Journal of Finance* 68, 929–985.

Backus, David K., Silverio Foresi, and Chris I. Telmer, 2001, Affine term structure models and the forward premium anomaly, *Journal of Finance* 56, 279–304.

Baillie, Richard T., and Tim Bollerslev, 2000, The forward premium anomaly is not as bad as you think, *Journal of International Money and Finance* 19, 471–488.

Bakshi, Gurdip, Nikunj Kapadia, and Dilip Madan, 2003, Stock return characteristics, skew laws, and the differential pricing of individual equity options, *Review of Financial Studies* 16, 101–143.

Bali, Turan G., Nusret Cakici, and Robert F. Whitelaw, 2011, Maxing out: Stocks as lotteries and the cross-section of expected returns, *Journal of Financial Economics* 99, 427–446.

Bali, Turan G., Jianfeng Hu, and Scott Murray, 2017, Option implied volatility, skewness, and kurtosis and the cross-section of expected stock returns, Working paper, Georgetown University.

Bansal, Ravi, 1997, An exploration of the forward premium puzzle in currency markets, *Review of Financial Studies* 10, 369–403.

Bansal, Ravi, and Magnus Dahlquist, 2000, The forward premium puzzle: Different tales from developed and emerging economies, *Journal of International Economics* 51, 115–144.

Bekaert, Geert, 1995, The time variation of expected returns and volatility in foreign-exchange markets, *Journal of Business & Economic Statistics* 13, 397–408.

Bergin, Paul R., and Ju Hyun Pyun, 2016, International portfolio diversification and multilateral effects of correlations, *Journal of International Money and Finance* 62, 52–71.

Bhansali, Vineer, 2007, Volatility and the carry trade, *Journal of Fixed Income*.

Bordalo, Pedro, Nicola Gennaioli, and Andrei Shleifer, 2013, Salience and asset prices, *American Economic Review* 103, 623–28.

Boyer, Brian, Todd Mitton, and Keith Vorkink, 2010, Expected idiosyncratic skewness, *Review of Financial Studies* 23, 169–202.

Brennan, Michael J., and H. Henry Cao, 1997, International portfolio investment flows, *Journal of Finance* 52, 1851–1880.

Brunnermeier, Markus, Stefan Nagel, and Lasse H. Pedersen, 2008, Carry trades and currency crashes, *NBER Macroeconomics Annual* 23, 313–347.

Brunnermeier, Markus K., Christian Gollier, and Jonathan A. Parker, 2007, Optimal beliefs, asset prices, and the preference for skewed returns, *American Economic Review* 97, 159–165.

Bu, Ruijun, and Kaddour Hadri, 2007, Estimating option implied risk-neutral densities using spline and hypergeometric functions, *Econometrics Journal* 10, 216–244.

Burnside, Craig, Martin Eichenbaum, and Sergio Rebelo, 2007, The returns to currency speculation in emerging markets, *American Economic Review* 97, 333–338.

Burnside, Craig, Martin Eichenbaum, and Sergio Rebelo, 2009, Understanding the forward premium puzzle: A microstructure approach, *American Economic Journal: Macroeconomics* 1, 127–54.

Burnside, Craig, Martin Eichenbaum, and Sergio Rebelo, 2011, Carry trade and momentum in currency markets, *Annual Review of Financial Economics* 3, 511–535.

Cai, Jun, Yan-Leung Cheung, Raymond S. K. Lee, and Michael Melvin, 2001, 'Once-in-a-generation' yen volatility in 1998: Fundamentals, intervention, and order flow, *Journal of International Money and Finance* 20, 327–347.

Campbell, John Y., 1996, Understanding risk and return, *Journal of Political Economy* 104, 298–345.

Campbell, John Y., Karine Serfaty-De Medeiros, and Luis M. Viceira, 2010, Global currency hedging, *Journal of Finance* 65, 87–121.

Carhart, Mark M., 1997, On persistence in mutual fund performance, *Journal of Finance* 52, 57–82.

Chang, Bo Young, Peter Christoffersen, and Kris Jacobs, 2013, Market skewness risk and the cross section of stock returns, *Journal of Financial Economics* 107, 46–68.

Chang, Eric C., and Kit Pong Wong, 2003, Cross-hedging with currency options and futures, *Journal of Financial and Quantitative Analysis* 38, 555–574.

Chen, Shu-Hsiu, 2017, Carry trade strategies based on option-implied information: Evidence from a cross-section of funding currencies, *Journal of International Money and Finance* 78, 1–20.

Chernov, Mikhail, Jeremy Graveline, and Irina Zviadadze, 2018, Crash risk in currency returns, *Journal of Financial and Quantitative Analysis* 53, 137–170.

Christensen, Bent Jesper, and Rasmus Tangsgaard Varneskov, 2016, Dynamic global currency hedging, CREATES Research Paper 2016-3.

Christoffersen, Peter, Vihang Errunza, Kris Jacobs, and Hugues Langlois, 2012, Is the potential for international diversification disappearing? A dynamic copula approach, *Review of Financial Studies* 25, 3711–3751.

Clarida, Richard, Josh Davis, and Niels Pedersen, 2009, Currency carry trade regimes: Beyond the Fama regression, *Journal of International Money and Finance* 28, 1375–1389.

Coeurdacier, Nicolas, and Stéphane Guibaud, 2011, International portfolio diversification is better than you think, *Journal of International Money and Finance* 30, 289–308.

Conrad, Jennifer, Robert F. Dittmar, and Eric Ghysels, 2013, Ex ante skewness and expected stock returns, *Journal of Finance* 68, 85–124.

Cooper, Ian, and Evi Kaplanis, 1994, Home bias in equity portfolios, inflation hedging, and international capital market equilibrium, *Review of Financial Studies* 7, 45–60.

Corrado, Charles J., and Tie Su, 1997, Implied volatility skews and stock return skewness and kurtosis implied by stock option prices, *European Journal of Finance* 3, 73–85.

Coval, Joshua D., and Tobias J. Moskowitz, 1999, Home bias at home: Local equity preference in domestic portfolios, *Journal of Finance* 54, 2045–2073.

Daniel, Kent, Robert J. Hodrick, and Zhongjin Lu, 2016, The carry trade: Risks and drawdowns, Working paper, Columbia Business School.

Daniel, Kent, and Tobias J. Moskowitz, 2016, Momentum crashes, *Journal of Financial Economics* 122, 221–247.

Datta, Deepa Dhume, Juan M. Londono, and Landon J. Ross, 2017, Generating options-implied probability densities to understand oil market events, *Energy Economics* 64, 440–457.

Della Corte, Pasquale, Tarun Ramadorai, and Lucio Sarno, 2016, Volatility risk premia and exchange rate predictability, *Journal of Financial Economics* 120, 21–40.

DeMiguel, Victor, Yuliya Plyakha, Raman Uppal, and Grigory Vilkov, 2013, Improving portfolio selection using option-implied volatility and skewness, *Journal of Financial and Quantitative Analysis* 48, 1813–1845.

Demirgüç-Kunt, Asli, and Ross Levine, 1996, Stock markets, corporate finance, and economic growth: An overview, *World Bank Economic Review* 10, 223–239.

DeSantis, Giorgio, and Bruno Gerard, 1997, International asset pricing and portfolio diversification with time-varying risk, *Journal of Finance* 52, 1881–1912.

Dornbusch, Rudiger, and Stanley Fischer, 1980, Exchange rates and the current account, *American Economic Review* 70, 960–971.

Du, Du, 2013, General equilibrium pricing of currency and currency options, *Journal of Financial Economics* 110, 730–751.

Dupuy, Philippe, 2015, The tail risk premia of the carry trades, *Journal of International Money and Finance* 59, 123–145.

Edwards, Sebastian, 2006, The relationship between exchange rates and inflation targeting revisited, NBER working paper 12163.

Eiteman, David K., Arthur I. Stonehill, and Michael H. Moffett, 2012, *Multinational Business Finance*. (Pearson Higher Ed).

Elton, Edwin J., 1999, Expected return, realized return, and asset pricing tests, *Journal of Finance* 54, 1199–1220.

Engel, Charles, Nelson C. Mark, and Kenneth D. West, 2015, Factor model forecasts of exchange rates, *Econometric Reviews* 34, 32–55.

Errunza, Vihang, Ked Hogan, and Mao-Wei Hung, 1999, Can the gains from international diversification be achieved without trading abroad?, *Journal of Finance* 54, 2075–2107.

Eun, Cheol S., Sandy Lai, Frans A. de Roon, and Zhe Zhang, 2010, International diversification with factor funds, *Management Science* 56, 1500–1518.

Fama, Eugene F., and Kenneth R. French, 1992, The cross-section of expected returns, *Journal of Finance* 47, 427–465.

Fama, Eugene F., and Kenneth R. French, 1993, Common risk factors in the returns on bonds and stocks, *Journal of Financial Economics* 33, 3–56.

Fama, Eugene F., and Kenneth R. French, 2012, Size, value, and momentum in international stock returns, *Journal of Financial Economics* 105, 457–472.

Fama, Eugene F, and James D. MacBeth, 1973, Risk, return, and equilibrium: Empirical tests, *Journal of Political Economy* 81, 607–636.

Fama, Eugene F., and William G. Schwert, 1977, Asset returns and inflation, *Journal of Financial Economics* 5, 115–146.

Farhi, Emmanuel, Samuel P. Fraiberger, Xavier Gabaix, Romain Ranciere, and Adrien Verdelhan, 2015, Crash risk in currency markets, Working paper, New York University.

Ferson, Wayne E., and Campbell R. Harvey, 1993, The risk and predictability of international equity returns, *Review of Financial Studies* 6, 527–566.

French, Kenneth R., G. William Schwert, and Robert F. Stambaugh, 1987, Expected stock returns and volatility, *Journal of Financial Economics* 19, 3–29.

Fung, William, and David A. Hsieh, 1997, Empirical characteristics of dynamic trading strategies: The case of hedge funds, *Review of Financial Studies* 10, 275–302.

Garman, Mark B., and Steven W. Kohlhagen, 1983, Foreign currency option values, *Journal of international Money and Finance* 2, 231–237.

Ghysels, Eric, Alberto Plazzi, and Rossen Valkanov, 2016, Why invest in emerging markets? The role of conditional return asymmetry, *Journal of Finance* 71, 2145–2192.

Goldberg, Linda S., and José Manuel Campa, 2010, The sensitivity of the CPI to exchange rates: Distribution margins, imported inputs, and trade exposure, *Review of Economics and Statistics* 92, 392–407.

Goyal, Amit, and Narasimhan Jegadeesh, 2018, Cross-sectional and time-series tests of return predictability: What is the difference?, Forthcoming, *Review of Financial Studies*.

Guo, Hui, 2006, The risk-return relation in international stock markets, *Financial Review* 41, 565–587.

Han, Bing, 2007, Investor sentiment and option prices, *Review of Financial Studies* 21, 387–414.

Harvey, Campbell R., 1989, Forecasts of economic growth from the bond and stock markets, *Financial Analysts Journal* 45, 38–45.

Harvey, Campbell R., and Akhtar Siddique, 2000, Conditional skewness in asset pricing tests, *Journal of Finance* 55, 1263–1295.

Heathcote, Jonathan, and Fabrizio Perri, 2013, The international diversification puzzle is not as bad as you think, *Journal of Political Economy* 121, 1108–1159.

Hodrick, Robert J., and Xiaoyan Zhang, 2014, International diversification revisited, Working paper, Columbia University.

Hossfeld, Oliver, and Ronald MacDonald, 2015, Carry funding and safe haven currencies: A threshold regression approach, *Journal of International Money and Finance* 59, 185–202.

Hou, Kewei, G. Andrew Karolyi, and Bong-Chan Kho, 2011, What factors drive global stock returns?, *Review of Financial Studies* 24, 2527–2574.

Investment Company Institute, 2017, *2017 Investment Company Fact Book*.

Jiang, George J., and Yisong S. Tian, 2005, The model-free implied volatility and its information content, *Review of Financial Studies* 18, 1305–1342.

Jurek, Jakub W., 2014, Crash-neutral currency carry trades, *Journal of Financial Economics* 113, 325–347.

Kang, J.-K., and R. M. Stulz, 1997, Why is there a home bias? An analysis of foreign portfolio equity ownership in Japan, *Journal of Financial Economics* 46, 3–28.

Kelly, Bryan, Lubos Pastor, and Pietro Veronesi, 2016, The price of political uncertainty: Theory and evidence from the option market, *Journal of Finance* 71, 2417–2480.

Koijen, Ralph S. J., Hanno Lustig, and Stijn Van Nieuwerburgh, 2017, The cross-section and time series of stock and bond returns, *Journal of Monetary Economics* 88, 50–69.

Koijen, Ralph S. J., Tobias J. Moskowitz, Lasse Heje Pedersen, and Evert B. Vrugt, 2015, Carry, Fama-Miller working paper.

Kozhan, Roman, Anthony Neuberger, and Paul Schneider, 2013, The skew risk premium in the equity index market, *Review of Financial Studies* 26, 2174–2203.

Kraus, Alan, and Robert H. Litzenberger, 1976, Skewness preference and the valuation of risk assets, *Journal of Finance* 31, 1085–1100.

Krugman, Paul, 2013, The Japan story, *New York Times,* February 5.

Lettau, Martin, Matteo Maggiori, and Michael Weber, 2014, Conditional risk premia in currency markets and other asset classes, *Journal of Financial Economics* 114, 197–225.

Liew, Jimmy, and Maria Vassalou, 2000, Can book-to-market, size and momentum be risk factors that predict economic growth?, *Journal of Financial Economics* 57, 221–245.

Londono, Juan M., and Hao Zhou, 2017, Variance risk premiums and the forward premium puzzle, *Journal of Financial Economics* 124, 415–440.

Longin, Francois, and Bruno Solnik, 2001, Extreme correlation of international equity markets, *Journal of Finance* 56, 649–676.

Lustig, Hanno, Nikolai Roussanov, and Adrien Verdelhan, 2011, Common risk factors in currency markets, *Review of Financial Studies* 24, 3731–3777.

Lustig, Hanno, Nikolai Roussanov, and Adrien Verdelhan, 2014, Countercyclical currency risk premia, *Journal of Financial Economics* 111, 527–553.

Menkhoff, Lukas, Lucio Sarno, Maik Schmeling, and Andreas Schrimpf, 2012a, Carry trades and global foreign exchange volatility, *Journal of Finance* 67, 681–718.

Menkhoff, Lukas, Lucio Sarno, Maik Schmeling, and Andreas Schrimpf, 2012b, Currency momentum strategies, *Journal of Financial Economics* 106, 660–684.

Mitton, Todd, and Keith Vorkink, 2007, Equilibrium underdiversification and the preference for skewness, *Review of Financial Studies* 20, 1255–1288.

Moskowitz, Tobias J., Yao Hua Ooi, and Lasse Heje Pedersen, 2012, Time series momentum, *Journal of Financial Economics* 104, 228–250.

Muzzioli, Silvia, 2013, The information content of option-based forecasts of volatility: Evidence from the Italian stock market, *Quarterly Journal of Finance* 3, 1–46.

Navatte, Patrick, and Christophe Villa, 2000, The information content of implied volatility, skewness and kurtosis: Empirical evidence from long-term CAC 40 options, *European Financial Management* 6, 41–56.

Neely, Christopher J., and Paul Weller, 2000, Predictability in international asset returns: A reexamination, *Journal of Financial and Quantitative Analysis* 35, 601–620.

Nelson, Charles R., 1976, Inflation and rates of return on common stocks, *Journal of Finance* 31, 471–483.

Newey, Whitney, and Kenneth West, 1987, A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix, *Econometrica* 55, 703–708.

Obstfeld, Maurice, 2012, Does the current account still matter?, *American Economic Review* 102, 1–23.

Obstfeld, Maurice, and Kenneth S. Rogoff, 2005, Global current account imbalances and exchange rate adjustments, *Brookings Papers on Economic Activity* 2005, 67–146.

Olszweski, Francis, and Guofu Zhou, 2013, Strategy diversification: Combining momentum and carry strategies within a foreign exchange portfolio, *Journal of Derivatives & Hedge Funds* 19, 311–320.

Paye, Bradley S., 2012, 'Déjà vol': Predictive regressions for aggregate stock market volatility using macroeconomic variables, *Journal of Financial Economics* 106, 527–546.

Petersen, Mitchell A., 2009, Estimating standard errors in finance panel data sets: Comparing approaches, *Review of Financial Studies* 22, 435–480.

PricewaterhouseCoopers, 2015, *Beyond Their Borders: Evolution of Foreign Investment by Pension Funds*.

PricewaterhouseCoopers, 2016, *Global Pension Funds: Best Practices in the Pension Funds Investment Process*.

Rubinstein, Mark E., 1973, The fundamental theorem of parameter-preference security valuation, *Journal of Financial and Quantitative Analysis* 8, 61–69.

Schwert, G. William, 1989, Why does stock market volatility change over time?, *Journal of Finance* 44, 1115–1153.

Solnik, Bruno, 1987, Using financial prices to test exchange rate models: A note, *Journal of Finance* 42, 141–149.

Solnik, Bruno H., 1995, Why not diversify internationally rather than domestically?, *Financial Analysts Journal* 51, 89–94.

Stowell, David P., 2017, *Investment Banks, Hedge Funds, and Private Equity*. (Academic Press).

Trolle, Anders B., and Eduardo S. Schwartz, 2009, Unspanned stochastic volatility and the pricing of commodity derivatives, *Review of Financial Studies* 22, 4423–4461.