What Makes Safe-haven Currencies? Evidence from Conditional Co-skewness

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Abstract

We examine the currency co-skewness with the global stock market (*i.e.*, covariance between currency returns and global equity volatility) and investigate its role in safe-haven currencies, which are a hedge for a portfolio of risky assets in times of financial stress. Three safe-haven currencies (USD, SWF, and JPY) have positive co-skewness, providing a hedge against global stock volatility. Moreover, currency co-skewnesses are significantly priced with the expected negative risk premium. Lower excess returns and interest rates on these safe-haven currencies can be partially attributed to their desirable hedging property of positive co-skewness, which differs from time-varying beta, volatility, and skewness.

Keywords: currency hedging; safe-haven currencies; conditional co-skewness; conditional co-kurtosis; international asset pricing

JEL codes: G11; G12; G15

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1. Introduction

Following the Lehman Brothers' collapse and financial tsunami in 2008, investors around the world have been looking for safe-haven currencies. Safe-haven currencies are those that investors flock to whenever there is a crisis, or merely an outbreak of uncertainty, and which give hedging benefits at times when financial markets are volatile. According to conventional wisdom, "When foreign exchange investors felt panicky, they head to, or back to, old faithfuls: the Swiss franc, the U.S. dollar and the Japanese yen." [1] These three currencies, the US dollar (USD), the Swiss franc (SWF), and the Japanese yen (JPY) – are thus regarded as safe-haven currencies, which are those currencies that provide a hedge for a portfolio of risky assets in times of financial stress.[2]

There are two dimensions in evaluating the hedging benefits of safe-haven currencies. The first is based on the correlation (or covariance) between the equity and the currency markets (Dumas and Solnik, 1995; De Santis and Gerard, 1998). On this dimension, investors use foreign currencies to minimize the risk of a diversified portfolio and will buy those currencies that are more negatively correlated with international equity portfolio returns to minimize expected portfolio's volatility. Campbell, Medeiros, and Viceira (2010) have shown that the USD, the Euro,[3] and the SWF tend to move against the international equity market. Thus, these currencies should be attractive to risk-minimizing global equity investors despite their lower

[1] "Dollar Stands Out as Safe Haven Currency", *Wall Street Journal*, 9 December, 2011.

[2] See Habib and Stracca (2012) for definition and discussion about safe-haven currencies. There are several possible explanations of a safe-haven status. First, a currency may be a safe haven if the country issuing it is itself safe and low risk. Second, size, liquidity and openness of a country's financial markets may support a safe-haven status. Third, what makes a safe haven currency can be simply based on self-fulfilling beliefs. Once investors believe that a currency is a safe-haven one, they will then buy that currency for hedging purpose during financial crisis, so that the currency will perform well during that period.

[3] Campbell *et al.* (2010) consider the period from 1975 to 2005. But in the Eurozone crisis, the Euro is no longer attractive to global equity investors.

average returns. A limitation of this approach is that the hedging benefits of the currency might not be fully captured by its correlation (or covariance) with the equity portfolio returns; this is because risk is not completely measured when investors display mean-variance preferences or equivalently when returns follow a multivariate normal distribution. Recently, Christiansen, Ranaldo, and Soderlind (2011) have shown that currency returns can be explained by time-varying betas, which are essentially conditional correlations and only capture linear co-movement between equity and currency markets. However, higher moments and non-linear co-movement can be also important for global asset allocation when we go beyond the mean-variance framework.

The second dimension in evaluating the hedging benefits of the currency is to accommodate non-normal return distribution and examine skewness preference for investors. A number of theoretical papers demonstrate that investors will seek higher (positive) skewness (Rubinstein, 1973; Kraus and Litzenberger, 1976). This skewness preference can be based on "prudence" (Kimball, 1990). In the portfolio context, an investor will examine an asset's contribution to the skewness of a broadly diversified portfolio, referred to as "co-skewness" with the portfolio. The recent literature has provided supportive empirical evidence that the co-skewnesses on stock, bond, and option markets are significant determinant of expected returns (Harvey and Siddque, 2000; Dittmar, 2002; Vanden, 2006; Guidolin and Timmermann, 2008; Yang, Zhou, and Wang, 2010; Conrad, Dittmar and Ghysels, 2013).[4] To evaluate the hedging benefits of a particular currency, we can therefore measure its co-skewness with the equity market.

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[4] Our "moment" approach has some benefits compared with extreme value theory and copula used in recent literature to study co-movement. Firstly, co-skewness can be directly linked to a well-defined skewness preference. Secondly, co-skewness has more intuitive economic interpretation. That is, currency co-skewness with a stock market can be explained as the relation between currency return and stock volatility.

In this paper, we examine the hedging benefits of various currencies in terms of their co-skewness with the equity market and whether co-skewness is priced. According to our best knowledge, this issue has not yet been explored in the literature. The co-skewness is measured by the covariance between currency excess returns and equity market volatility. We find that over the period from 1973 to 2010, the safe-haven currencies, namely, the USD, the JPY, and the SWF, have better co-skewness properties than other developed market currencies – they have positive co-skewness with global equity market whereas other currencies have negative co-skewness. The patterns imply that these currencies are a good hedge in a volatile market and therefore less risky than what is suggested by correlation properties (that is, the relatively low or negative correlation with stock returns), as previously explored in Campbell *et al*. (2010).

Further tests show that conditional co-skewness is priced in the currency market using time-series data and pooled data. Based on time-series regressions of each currency, we document that currency co-skewness with stock markets is priced in future currency excess returns. After controlling for conditional currency beta, idiosyncratic currency volatility, and skewness, conditional co-skewness (with the equity market) commands statistically and economically significant negative risk premia. Based on pooled regressions, we also find significant currency co-skewness pricing effects, which are stronger and more robust than beta, volatility, and skewness effects. By implication, the lower excess returns on these safe-haven currencies can be partially attributed to their desirable hedging properties of positive co-skewness, which cannot be explained by time-varying betas, volatility, and/or skewness. Therefore, this paper extends the existing literature on currency excess returns, which are typically explained by time-varying betas (Christiansen, Ranaldo, and Soderlind, 2011), or volatility risk factors (Lustig, Roussanov, and Verdelhan, 2011; Menkhoff, Sarno, Schmelling, and Schrimf, 2012), or linked to crash risk captured by (idiosyncratic) skewness (Brunnermeier, Nagel, and Pedersen, 2009; Burnside, Eichenbaum, Kleshchelshi, and Rebelo, 2010).

The paper also sheds light on the effect of currency hedging on the interest rates. It has been documented that the low interest rate currencies are less exposed to global stock market volatility (Lustig, Roussanov and Verdelhan, 2011) or global foreign exchange (FX) volatility (Menkhoff, Sarno, Schmelling, and Schrimf, 2012). We demonstrate that the positive co-skewness of safe-haven currencies with the global stock market, an indication of better hedging property against global stock volatility, is *priced* in future interest rate differential. Our result is consistent with the recent evidence (Habib and Stracca, 2012) that interest rate differential is not a fundamental driver of safe-haven status. Specifically, when an economic shock occurs in an integrated global capital market, global equity volatility increases and investors flee to safety, which is likely to be the money and bond markets of safe-haven currency economies. As a result, safe-haven currencies have lower interest rates and thus interest differentials, which contribute to lower currency excess returns.

Our analysis is based on conditional co-skewness estimated from a multivariate regime-switching framework, which has been demonstrated to better capture the joint return distribution and has become increasingly popular in the literature on international asset allocation (Ang and Bekaert, 2002; Guidolin and Timmermann, 2008). Using bivariate regime-switching models, we jointly model international equity and currency markets where currency is considered as an additional asset class in a broader portfolio, as in Dumas and Solnik (1995) and De Santis and Gerard (1998).[5] Our approach nests the time-varying beta in the empirical method. Unlike

[5] The co-movements and dynamic interaction between equity and currency markets as different assets has been of much interest in the literature (Hau and Rey, 2006; Pavlova and Rigobon, 2007). Albuquerque, De Francisco, and Marques (2008) also show that the marketwide private information in stock prices is useful in predicting currency returns. Hence, compared with the univariate modeling of either of these two markets separately, the bivariate

Christiansen, Ranaldo, and Soderlind (2011) who model time-varying betas based on the regimes of foreign exchange volatility, our time-varying betas and higher moments are driven by the joint distribution of currency and equity returns, which may contain more information in integrated global asset markets.[6] Moreover, compared to other approaches for estimating higher conditional moments (Harvey and Siddique, 2000; Dittmar, 2002; Boyer, Mitton and Vorkink, 2010), such regime-switching-model-based estimates are typically much more precise than estimates of the higher moments obtained directly from realized returns (Guidolin and Timmermann, 2008).

The rest of the paper is organized as follows. Section 2 describes data. Section 3 discusses the regime-switching models and derives their conditional moments. Section 4 presents the empirical results for developed market currencies. Section 5 makes concluding remarks.

2. Data Description

The stock data are monthly Morgan Stanley Capital International (MSCI) USD-denominated, local-currency-denominated world, and US total return indices. The MSCI world stock portfolio is a market-value weighted index which represents approximately 60% of the total equity market capitalization of each of the 22 developed country markets. The use of USD-

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modeling of both equity and currency markets jointly should be more adequate and result in a more accurate estimation of movements of either of these two markets and particularly the current market, as more information is used in such modeling, as suggested in the literature. We will also explain below that the modeling of regime switching in both markets seems to be reasonable and adequate.

[6] The smooth transition regression model used in Christiansen, Ranaldo, and Soderlind (2011) is a type of regime-switching model in its nature, while it does not explicitly allow for time-varying higher (third and fourth) moments, as in our study. The allowance for time-varying third and fourth moments has been documented to carry important implications for other asset markets such as stock and bond markets (Guidolin and Timmermann, 2008). Furthermore, the equity market information, which may also be important in this context (as discussed above), is not fully used in their modeling of currency markets.

denominated world stock returns corresponds to assessing the risk exposure faced by a USD-based investor who is not hedged against exchange rate risk.

Following Campbell, Medeiros, and Viceira (2010), we consider seven developed market currencies: the US dollar (USD), the British pound (GBP), the Japanese yen (JPY), the Swiss franc (SWF), the Canadian dollar (CAD), the Australia dollar (AUD), and the Euro (EUR).[7] The monthly exchange rate and 3-month Treasury bill rate data are from the International Financial Statistics (IFS) database published by the International Monetary Fund, except for the interest rate for the Euro[8] and the Federal Reserve major currency index of the foreign exchange value of the USD.[9] The sample periods begin in the months when the currencies started to float or the data are best available, and they all end in December 2010. In particular, the USA, the UK, Japan and Canada start their samples from January 1973. The Swiss sample starts one year later because its interest rate data is available from January 1974, while the German sample starts from July 1975 due to availability of the German interest rate. The Australian dollar began to float in 1983.

The stock returns are the log differences of the MSCI world stock return indices, and the stock excess returns are their returns over and above the US short-term interest rate, a proxy for the US and world risk-free rate. For currencies other than the USD, the total return on holding a foreign currency for a US investor is the foreign interest plus the currency appreciation so that the currency excess returns are their total return over the US interest. In other words, currency

[7] Euro is extended back to the 1970s using the Deutsche Mark with conversion rate of one Euro = 1.95583 DEM in January 1999.

[8] German 3-month Treasury bill rate is used for the Euro because there is no Eurozone Treasury bill rate.

[9] The major currency index is the successor to the previous main dollar index, the so-called G-10 index, which has no longer been maintained since the Euro was introduced as a trade currency. Moreover, the major currencies index uses trade weights that vary by year whereas the currency weights of the G-10 index are fixed. Therefore, the major currencies index is a better indictor of the evolution of the competitiveness of US products against those made in the other major currencies economies. Also, the major currencies index can be used to gauge financial pressures on the USD because the seven currencies in the index – the Euro, the Canadian dollar, the Japanese yen, the British pound, the Swiss franc, the Australian dollar, and the Swedish krona – trade widely in liquid financial markets.

excess returns are defined as one-month lagged log interest rate differentials (foreign interest rate–US interest rate) minus the log difference of exchange rate (the foreign currency of one US dollar).[10] For the USD, the excess return is the log difference of the major currency index plus the log interest differential (US interest rate-average of foreign interest rates).[11]

As shown in Panel A of Table 1, the average world stock excess returns are 3.8% and 2.9% in terms of the USD and local currency, respectively. They also display similar volatility of more than 50% and negative skewness and positive excess kurtosis. Panel B of Table 1 shows short-term interest rates, changes in log exchange rates, and currency excess returns. Firstly, short rates differ across countries, with the lowest for Japan and the highest for Australia. Their volatilities are under 4% for all countries, which is much lower than stock counterparts. All short rates have positive skewness and have no excess kurtosis except for the US, Germany, and Switzerland.

[Table 1 here]

Secondly, average changes in exchange rates with respect to the USD (quoted as foreign currency units per dollar) are negative for the JPY, the SWF, and the Euro, reflecting the depreciation of the USD against these currencies. In contrast, average exchange rate changes are positive for the UK pound and the Australian dollar, and close to zero for the Canadian dollar relative to the USD over the sample period. Exchange rates are more volatile than interest rates, ranging from 22% for the Canadian dollar to 42% for the SWF. All exchange rate changes have

[10] Under covered interest parity, the interest rate differential is equal to forward discount and the currency premium is the log return on buying a foreign currency in the forward market and then selling it in the spot market after one month.

[11] For simplicity, the average foreign interest rate is the simple average of the Japanese, UK, Eurozone (from 1999 to 2010), German (from 1975 to 1998), Canadian, Australian and Swiss interest rates. Note that the USD excess return starts from July 1975 because the Germany interest rate is available from that month.

positive skewness except for the JPY, and they have excess kurtosis, especially for the Canadian and Australian dollars, exhibiting sharp peaks and fat tails.

Thirdly, currency excess returns vary across countries, with the lowest for the USD of a negative 1% and also relatively low for the JPY of 0.4%, the Euro of 0.9% and the SWF of 1.1%. The volatility of currency excess returns is quite similar to that of exchange rate changes, caused by stable short rates. In contrast, the skewness of the currency excess returns has an opposite sign to that of the exchange rates changes, thereby suggesting that the addition of interest rate differentials to the exchange rate changes will have a significant effect on the skewness. Most notably, the excess returns on the USD and the JPY have positive skewnesses. Like their exchange rate change counterparts, all currency excess returns display fat tails, these being more pronounced for the Canadian and the Australian dollars.

3. Empirical Methodology

Following Dumas and Solnik (1995) and De Santis and Gerard (1998), we present a simultaneous modeling of international equity and currency markets where both equity and currency are considered as different asset classes. Also, motivated by the overwhelming existence of regimes in stock and currency markets, we estimate a bivariate regime-switching model for stock and currency excess returns and derive their conditional moments and co-moments. Then, we examine the pricing behavior of an estimated co-skewness series by conducting time-series regressions of the future currency excess returns over various horizons on the currency conditional co-skewness, after controlling for the conditional volatility, covariance and idiosyncratic skewness as well as correcting for the error-in-variables problem.

3.1. Regime-switching Models

The empirical framework is based on the two-state regime-switching model, with an intuitively appealing feature of high return–low volatility in the bull state and low return–high volatility in the bear state.[12] The basic bivariate regime-switching model has the following general form:

$$\begin{aligned}
&\mathbf{r_t} = \boldsymbol{\mu}_{\mathbf{it}} + \boldsymbol{\varepsilon}_{\mathbf{it}}, \\
(1) \qquad &\boldsymbol{\mu}_{\mathbf{it}} = E(\mathbf{r_t} | s_t = i, \mathbf{F_{t-1}}), \\
&\boldsymbol{\varepsilon}_{\mathbf{it}} \,|\, \mathbf{F_{t-1}} \sim (\mathbf{0}, \mathbf{H_{it}}),
\end{aligned}$$

where $\mathbf{r_t} = (r_t^s, r_t^c)'$ is a 2 × 1 vector of stock and currency excess returns at time t, s_t is the unobserved regime at time t, taking one of two values (1 or 2), $\boldsymbol{\mu}_{\mathbf{it}} = (\mu_{it}^s, \mu_{it}^c)'$ is a 2 × 1 vector of means given regime i conditioned on the past information set $\mathbf{F_{t-1}}$, where $\mathbf{F_{t-1}}$ contain past information of stock and currency joint distribution, including returns, volatilities and higher moments, but not s_t or lagged values of s_t . $\boldsymbol{\varepsilon}_{\mathbf{it}} = (\varepsilon_{it}^s, \varepsilon_{it}^c)'$ is a 2 × 1 vector of innovations given regime i. $\mathbf{H_{it}}$ is the conditional variance–covariance matrix of r_t given regime i because:

$$(2) \qquad \mathrm{var}(\mathbf{r}_t | s_t = i, \mathbf{F_{t-1}}) = \mathrm{var}(\boldsymbol{\varepsilon}_{\mathbf{it}} | \mathbf{F_{t-1}}) = \mathbf{H_{it}}, \quad i \in \{1, 2\}.$$

The latent regime s_t is usually parameterized as a first-order Markov chain. While the simplest model assumes that the state transitions are constant over time, Gray (1996) suggested that the flexibility gained by allowing time-varying transition probabilities can be very substantial. The time-varying transition probabilities conditional on $\mathbf{F_{t-1}}$ can be written as:

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[12] While it is certainly possible that the two-state regime model may only capture most but not all of the salient aspects of the stock-currency co-movement, the focus on two regimes facilitates a clearer and more straightforward economic interpretation in this case, compared to the use of more (*e.g.*, three) regimes. Furthermore, as shown below, the model seems to be reasonably adequate, as the conditional means and standard deviations of stock and currency premiums based on the regime-switching model are on average close to those of historical premiums. Finally, the use of two regimes while ignoring the possible intermediate regime would tend to include more observations in the intermediate regime in the two regimes of primary interest and weaken the otherwise stronger contrast between them, thus rendering the inference of this study to be more conservative than it should be.

(3)
$$\Pr(S_t = j \mid s_{t-1} = i, \mathbf{F_{t-1}}) = p_{ij,t}, \quad i, j \in \{1, 2\},$$
$$0 \le p_{ij,t} \le 1, \ \sum_{j=1}^{2} p_{ij,t} = 1 \ \textit{for all i}. \qquad .$$

Following the literature (Campbell, Medeiros and Viceira, 2010; Lustig, Roussanov end Verdelhan, 2011; Menkhoff, Sarno, Schmelling and Schrimf, 2012), we consider the following parsimonious specifications for foreign currencies against the USD. Specifically, the conditional means are specified as:

(4)
$$\begin{pmatrix} r_t^s \\ r_t^c \end{pmatrix} = \begin{pmatrix} \mu_i^s \\ \mu_i^c \end{pmatrix} + \begin{pmatrix} \lambda_i^s & 0 \\ 0 & \lambda_i^c \end{pmatrix} \begin{pmatrix} RF_{t-1} \\ RD_{t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{it}^s \\ \varepsilon_{it}^c \end{pmatrix},$$

where μ_i^s *and* μ_i^c are the constant means of stock and currency excess returns given regime *i*, RF_{t-1} is the first lagged risk-free rate and RD_{t-1} is the first lagged interest rate differential (foreign country interest rate minus the US interest rate for the USD, and the US interest rate minus the average of foreign interest rates for other currencies). λ_i^s *and* λ_i^c are the regression coefficients given regime *i*. The risk-free rate is closely attuned to discount rates and it is shown in the literature to have a significant predictive power for future stock returns (*e.g.*, Ang, Piazzesi, and Wei, 2006). There is also empirical evidence that interest rate differentials predict positive currency premiums (Campbell, Medeiros, and Viceira, 2010; Lustig, Roussanov end Verdelhan, 2011; Menkhoff, Sarno, Schmelling and Schrimf, 2012). It should be noted that the conditional means might not just linearly depend on the first lag of the instrument and there could be other instruments. The specification being adopted here represents a trade-off between flexibility and parsimony.

For the conditional variance–covariance matrices, we assume that $\boldsymbol{\varepsilon}_{\mathbf{it}}$ follows an i.i.d bivariate normal distribution. Then, the conditional distribution of $\mathbf{r_t}$ is a mixture of two i.i.d bivariate normal distributions, as follows:

(5) $$\mathbf{r_t} \mid \mathbf{F_{t-1}} \sim \begin{cases} IIN(\boldsymbol{\mu}_{\mathbf{1t}}, \mathbf{H_{1t}}), \ w.p. \quad p_{1t}, \\ IIN(\boldsymbol{\mu}_{\mathbf{2t}}, \mathbf{H_{2t}}), \ w.p. \quad p_{2t}. \end{cases}$$

Because mixtures of the normal distribution can approximate to a very broad set of density families, this assumption is not very restrictive. Moreover, the variances and correlation are assumed to be constant with each regime, and conditional heteroskedasticity can be generated by switches between regimes. The parsimonious specification for the conditional variance–covariance matrices is as follows:

(6) $$\mathbf{H_{it}} = \mathbf{D_{it}} \mathbf{R_{it}} \mathbf{D_{it}}, \quad \mathbf{D_{it}} = \begin{pmatrix} \sqrt{h_i^s} & 0 \\ 0 & \sqrt{h_i^c} \end{pmatrix}, \quad \mathbf{R_{it}} = \begin{pmatrix} 1 & \rho_i \\ \rho_i & 1 \end{pmatrix}, \quad i \in \{1, 2\},$$

where h_i^s and h_i^c are the constant conditional volatilities of stock and currency premiums given regime *i*. ρ_i is the constant conditional stock–currency correlation given regime *i*. Note that there is an implied currency beta with respect to global stock markets in regime *i*, as follows:

$$\beta_i = \frac{\mathrm{cov}_i}{h_i^s} = \frac{\mathrm{cov}_i}{\sqrt{h_i^c}\sqrt{h_i^s}} \bullet \frac{\sqrt{h_i^c}}{\sqrt{h_i^s}} = \rho_i \frac{\sqrt{h_i^c}}{\sqrt{h_i^s}}.$$

Nevertheless, this regime-dependent beta is different from the time-varying beta derived below.

Furthermore, we specify that the transition probabilities are a function of the lagged interest rate differentials:

(7) $$p_{ii,t} = p(S_t = i \mid S_{t-1} = i, \mathbf{F_{t-1}}) = \Phi(a_i + b_i RD_{t-1}), \quad i \in \{1, 2\},$$

where a_i and b_i are unknown parameters and Φ is the cumulative normal distribution function, which ensures that $0 < p_{ii,t} < 1$. This specification allows transition probabilities to be monotonic in the instrument, thus facilitating the interpretations of the parameters.[13]

[13] The use of international interest rate differential as the conditioning variable in defining the regimes for currency returns is consistent with the recent literature (Lustig, Roussanov end Verdelhan, 2011; Menkhoff, Sarno,

In the Appendix, we derive the conditional moments in general, and (i) the conditional covariance between stock and currency excess returns, (ii) conditional variance and standard deviation of equity and currency excess returns, (iii) conditional currency beta with respect to global stock return, and (iv) conditional currency co-skewness (*i.e.*, conditional covariance between currency excess returns and stock volatility) in particular. Note that these conditional moments are time-varying driven by the joint distribution of currency and equity returns, particularly model parameter estimates and conditional state probabilities derived recursively from transition probabilities.

3.2. Currency Co-skewness Pricing Effects

One important issue that we explore is whether currency co-skewness with the world stock market earns *ex ante* risk premiums. We estimate the following time-series regressions of future currency returns on these factor loadings:

(8) $$\bar{r}^{c}_{t,t+m} = c_0 + \mathbf{c} \bullet \hat{\mathbf{f}}^{c}_{t} + e^{c}_{t},$$

where $\bar{r}^{c}_{t,t+m}$ is the average currency excess return over the future m-month horizon [t, t+m], $\hat{\mathbf{f}}^{c}_{t}$ is a subset of the estimate of the risk factor vector for currency excess returns.

The objective of our analysis is to investigate how currency conditional co-skewness with the world stock market are priced in currency returns beyond conventional risk factors, such as conditional beta with the stock market and currency volatility. In addition, we also introduce

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Schmelling and Schrimf, 2012), where the interest rate differential or equivalently the forward discount is used to sort currencies into portfolios and then construct the carry trade risk factor based on the comparison between the portfolios of high versus low quintiles. Furthermore, Ang, Piazzesi, and Wei (2006) have shown that the short-term interest rate has a more predictive power than any term spreads in forecasting GDP out-of-sample, and thus it should be suitable for use as the conditioning variable in defining the regimes of US domestic stock market returns related to the business cycle. The interest rate differential is essentially the relative foreign short-term interest rate (to the US rate) and naturally may serve as the conditioning variable for defining the regimes of a foreign stock market returns. Thus, using interest rate differential seems to be a good balance in defining regimes of both currency and equity markets. By contrast, using alternative conditioning variables such as equity market volatility may be good for defining the regimes for the equity market but not for the currency market.

currency idiosyncratic skewness as a possible risk factor to predict future currency returns. Therefore, the model is specified as follows:

(9) $$\bar{r}^{c}_{t,t+m} = c_0 + c_1 \hat{beta}_t + c_2 \tilde{std}^c_t + c_3 \tilde{\cos}^c_t + c_4 \tilde{skew}^c_t + e^c_t,$$

The first pricing factor is the conditional beta, $\hat{beta}_t$, to control for time-varying beta risk. The second pricing factor is the conditional currency standard deviation, $\hat{std}^c_t$, to control for the potential pricing effect related to volatility. Instead of including $\hat{std}^c_t$ in the regression model directly, we separate the additional effect of idiosyncratic volatility from the beta effect and use the residual $\tilde{std}^c_t$ estimated from the following auxiliary regression:

(10) $$\hat{std}^c_t = d_0 + d_1 \hat{beta}_t + \tilde{\mathrm{var}}^c_t$$

The third pricing factor is the standardized conditional currency co-skewness ($\hat{\cos}^c_t$), *i.e.*, the conditional covariance between currency excess returns and equity market volatility. If investors display the skewness preference and returns are not normally distributed, the slope coefficient on currency co-skewness should be significantly negative. For a currency with positive $\hat{\cos}^c_t$, it appreciates when the equity market becomes more volatile. Consequently, an investor is willing to accept a negative risk premium for such a currency. Instead of using $\hat{\cos}^c_t$ directly, we again use the residual $\tilde{\cos}^c_t$ estimated from Equation (11) to examine whether future currency returns can be explained by currency conditional co-skewness in addition to beta and volatility.

(11) $$\hat{\cos}^c_t = d_0 + d_1 \hat{beta}_t + d_2 \tilde{std}^c_t + \tilde{\cos}^c_t$$

The fourth pricing factor is the conditional currency idiosyncratic skewness, $\tilde{skew}_t^c$, which is the residual estimated from Equation (12). Again, based on the skewness preference, the slope coefficient of $\tilde{skew}_t^c$ should be negative, thereby implying that the currency crash risk is priced.

(12) $$\hat{skew}_t^c = d_0 + d_1 \hat{beta}_t + d_2 \tilde{\mathrm{var}}_t^c + d_3 \tilde{\cos}_t^c + \tilde{skew}_t^c$$

The regression produces an estimate of the risk exposure vector, $\mathbf{c} = [c_1\ c_2\ c_3\ c_4]'$. We run time-series regressions for each currency first and then we adjust for serial correlation and heteroskedasticity, following Newey and West (1987).[14] To increase the power of statistical tests, we also run pooled cross-sectional time-series (PCSTS) regressions for all currencies and then we adjust for both cross sectional and time-series dependence by using two-way cluster-robust standard errors of Petersen (2009).

4. Empirical Results

4.1. Results on Regime-switching Model Estimation

The analysis will proceed with the estimation of the single-regime model as a benchmark and the two-state regime-switching model. The estimation results of the two-state regime-switching models for the USD-denominated world stock and foreign currency returns are reported in Table 2. Based on estimated likelihood functions and the resulting likelihood ratio

[14] To further account for the errors-in-variables problem caused by the use of generated regressors, we follow Yang, Zhou, and Wang (2010) and compute standard errors of coefficient estimates by using sampling-with-replacement bootstrapping with 1,000 repetitions. Similar to Yang, Zhou, and Wang (2010), the results from bootstrapped regressions are qualitatively the same as those reported here based on Newey and West's (1987) robust standard errors.

tests (not reported here), the regime-switching model for each currency fits significantly better than the corresponding single-regime model.

[Table 2 here]

Based on the parameters for the conditional variance, it appears that the second regime is a bear state with low return and higher volatility for the world stock and various currency premiums. Meanwhile, all currency excess returns are less volatile in both regimes than the world stock premium. In the second regime, the stock–currency correlations are lower for the USD, the JPY, and the SWF in Panel A, but higher for the Canadian dollar, the Australian dollar, the UK pound, and the Euro in Panel B. This suggests that these three safe-haven currencies offer better diversification opportunities in the regime of high volatility than do the other currencies. Moreover, the stock–USD correlations are negative in both regimes, thereby suggesting that the USD has a much stronger hedging property than have the other currencies.

Next, turning to the parameters for the conditional mean, the estimates of λ_1^s are all significantly negative except for the Euro in the regime of low volatility, indicating a robust negative association between the US interest rate and the world stock excess returns during the good time. However, the estimates of λ_2^s do not suggest a similar pattern during the bad time. More importantly, there is regime-dependent evidence of carry trade; this is in line with the findings of Christiansen, Ranaldo, and Soderlind (2011). Specifically, the estimates of λ_1^c are significantly greater than 1 except for the Euro,[15] and this means that higher interest rate differentials tend to predict even higher currency excess returns. This implies very profitable carry trades in the bull state. In contrast, in the bear state, following higher interest rate differentials, currency excess returns in the next period for the UK pound, the JPY, the SWF, and

[15] In the case of Euro, the estimate is positive but not statistically significant.

the Australian dollar tend to be significantly lower, whereas such a negative association is not significant for the USD and the Canadian dollar. There is the exception of the Euro, for which currency excess returns tend to increase as the interest rate differential increases in the bear state.

Lastly, focusing on the parameters about the transition probabilities, the coefficient a_i measures the constant probability of staying in the regime *i* if the interest rate differential is zero. For all currencies under consideration, a_1 is significantly positive whereas a_2 is significantly negative, implying that it is more likely to stay in the low volatility regime even if the time variation of the probability is ignored. The coefficient b_i measures the further time-variation of the probability of staying in regime *i* depending on the interest rate differential. Except for the JPY, the estimates of b_1 are all negative and mostly significant. The evidence suggests that when interest rate differentials increase, the probability of staying in the lower volatility regime declines, thus pointing to the inherent risk of the carry trade. For the JPY, b_1 is significantly positive while b_2 is significantly negative. Hence, when the Japanese interest rate declines against the US interest rate, the probability of staying in the higher (lower) volatility regime increases (decreases). For the USD, the UK pound, the Canadian and Australian dollars, the estimates of b_2 are significantly positive, suggesting that the world stock and currency excess returns become more volatile as interest rate differentials increase.

4.2. Results on Conditional Currency Co-skewness

The summary statistics of conditional foreign currency excess returns are presented in Table 3. Results show that the USD excess returns have a negative conditional beta (or correlation) and positive (standardized) conditional co-skewness with the world stock returns on average. The patterns imply that the USD is clearly a "safe" currency because they are not only a good hedge against the world stock market decline but also a good hedge against the world stock volatility.

In addition to the USD, the JPY, and SWF excess returns have positive but relatively lower conditional betas (or correlations) with the world stock returns, thereby suggesting a better diversification benefit than other currencies. Moreover, the JPY and SWF (standardized) co-skewnesses are positive whereas other currency co-skewnesses are negative, implying increasing JPY and SWF excess returns and decreasing excess returns for other currencies when the world stock market becomes more volatile. The patterns imply that the JPY and the SWF are also "safe-haven" currencies because they have relatively good hedging effectiveness when the world stock market is down, or volatile.

[Table 3 here]

We also compare time-varying patterns of hedging benefits across currencies. Figure 1 plots the conditional betas between various currency excess returns and the world stock excess returns. Whereas the USD beta is negative in the whole sample, the other currency betas are mostly positive. Figure 2 plots the standardized conditional co-skewnesses of various currencies with the world stock market. The USD co-skewness is almost always positive and it has also increased sharply since the global financial crisis, and the JPY and SWF co-skewnesses are mostly positive. This shows that the USD, the JPY, and the SWF are safe-haven currencies from the perspective of hedging against stock market volatility. The EUR co-skewness has a time-varying pattern similar to the SWF counterpart. It has been mostly negative since the Euro was launched in 1999 and mostly positive when the Deutsche Mark is used for the period before 1999, suggesting that the Euro is not as safe as the Deutsche Mark. In contrast, the other currency co-skewnesses have displayed negative values during most of the time period.

[Figures 1-2 here]

4.3. Results on Pricing Effects of Currency Conditional Co-skewness

We regress future currency excess returns of various horizons (3-month, 6-month, and 12-month) on the various risk variables, as specified in Equation (9). The estimation results of pricing effects of higher moments in the currency markets are reported in Table 4. It is important to note that higher R-squared for a longer horizon forecasts highlights that pricing effects become stronger for a longer holding period. In general, the coefficient estimates of beta ($\widehat{beta}$), idiosyncratic volatility ($\widetilde{std}$), and skewness ($\widetilde{skew}$) are neither significant nor robust for all currencies. On the other hand, the coefficient estimates of standardized currency co-skewness ($\widetilde{\cos}_t^c$) are statistically negative across various horizons. This is consistent with the investor preference for currencies of positive and higher co-skewness with the world stock market portfolio, so that the co-skewness risk premium is negative. As shown in Table 3, safe-haven currencies have higher co-skewnesses with positive values on average. As suggested in Table 4, such a desirable co-skewness property is negatively *priced* in the currency returns and it leads to lower expected excess returns on these safe-haven currencies. Specifically, when global equity volatility increases, investors would fly to the money and bond markets of safe-haven currency economies, driving up their exchange rates and driving down their interest rates. Thus, investors are willing to accept a lower interest rate and expected return for the safe-haven currency because of the good hedging property. In contrast, the co-skewnesses of other currencies are lower and their averages are negative. Such an undesirable co-skewness property is priced in currency returns so that expected returns on other currencies are higher. The higher expected return is to compensate for the co-skewness risk, as investors will flee these currencies which will depreciate during the volatile market.

[Table 4 here]

Besides the statistical significance, we also evaluate the economic significance of the co-skewness effect on future currency excess returns. Panel A of Table 5 summarizes one standard deviation of orthogonalized conditional co-skewness and its impact on future currency excess return. The values in the table are the products of the regression coefficients of co-skewness in Table 4 and the corresponding standard deviations of orthogonalized conditional co-skewness. In general, the co-skewness effects are economically large, especially for the three safe-haven currencies (*i.e.*, USD, JPY, and SWF). For example, at a 3-month horizon, one standard deviation increases in the USD, the JPY, and the SWF co-skewnesses induce a decrease of 3.3%, 7.3%, and 5.6% in the future USD, JPY, and SWF excess returns, respectively. The impact of currency co-skewness decreases gradually as the forecast horizon increases. At a 12-month horizon, the future USD, JPY, and SWF excess returns will have a decrease of 2.6%, 5.5%, and 5.2%, respectively, if the USD, JPY, and SWF co-skewnesses increase by one standard deviation. For other currencies, the magnitudes of the co-skewness pricing effects lead to at least the change of 0.8% in the expected currency premium. Overall, currency co-skewnesses command statistically and economically significant negative *ex ante* excess returns.

[Table 5 here]

We also regress the interest rate differentials of currency on various risk variables, and Panel B of Table 5 summarizes currency co-skewness effects on the interest differential component. Across various horizons, all currency co-skewnesses are significantly priced in interest differentials with the expected negative risk premiums, which are economically large and account for a significant portion of the expected currency premium. In particular, the co-skewness effect on US interest differential (US interest minus average of foreign interest rate) is even larger than that on USD excess return. This implies that lower interest differentials on safe-haven currencies can be attributed to their desirable co-skewness property. Intuitively, safe haven currencies have lower interest rates (and thus interest rate differentials) because investors would flight to the Treasury bond markets of safe-haven currency economies, when global equity volatility increases.

4.4. Robustness Check

In this section, we provide further evidence of the robustness of conditional co-skewness and co-kurtosis pricing effects. Firstly, we conduct similar analyses based on the local-currency MSCI stock world index. With the local-currency-denominated index, the world stock excess returns are not compounded by the exchange risk fluctuation. Therefore, the results should reveal the co-movement between currency and pure stock excess returns. The estimation results for the regime-switching model (available on request) are generally in line with the main findings in Table 2.

As presented in Table 6, the averages of conditional moments of currency excess returns are also consistent with the previous results. The most notable statistics are that the average USD, JPY, and SWF co-skewnesses are all positive, whereas the patterns are opposite for other currencies. This implies that these three safe-haven currencies are a good hedge against the stock market. Moreover, beside the USD, the SWF beta is negative with respect to the equity market returns in terms of local currency, which is not shown up in the case using USD-denominated returns.

[Table 6 here]

Figures 3 and 4 plot the conditional betas and standardized co-skewnesses of various currencies with the world stock excess returns. The three safe-haven currencies exhibit stronger hedging patterns than those in Figures 1 and 2. Typically, the USD, JPY, and SWF excess returns have positive co-skewnesses with the local-currency-denominated world stock excess returns.

[Figures 3-4]

Table 7 summarizes the estimation results of pricing effects. Consistent with the previous result, currency co-skewnesses are still negatively priced although some coefficients are not or less statistically significant. Over the future 6-month and longer horizons, USD, JPY, and SWF co-skewnesses earn statistically negative excess returns, with magnitudes comparable to those in Table 4.

[Table 7 here]

Table 8 reports the economic significance of the conditional co-skewness effect. In Panel A, the impact of currency co-skewness on future currency excess returns is still economically large but relatively smaller than those in Table 5. For example, one standard deviation increases in the USD, the JPY, and the SWF co-skewnesses induce a decrease of 1.4%, 5.5%, and 4.3% in the future 12-month USD, JPY, and SWF excess returns, respectively. For the pricing effects on other currencies, the magnitudes are at least 0.9%, except for three insignificant beta estimates. In Panel B, safe-haven currency co-skewnesses earn statistically and economically significant and negative *ex ante* interest differentials, which are economically large and account for a significant portion of the expected currency premium. Overall, the co-skewness effect remains quite robust for safe-haven currencies.

[Table 8 here]

We have also estimated the pricing effects of co-skewness and co-kurtosis by pooling all seven currencies together in a cross-sectional time-series regression. An advantage of the pooled regression is that the estimated risk premiums will be common to all currencies, thus increasing the power of the test. The results are reported in Table 9, where Panel A is based on USD-denominated world stock excess returns and Panel B is based on local-currency-denominated world stock excess returns. All the T-values reported are have been adjusted and they are robust to both cross-sectional and time-series dependence.

[Table 9 here]

In Panel A, which is based on USD-denominated world stock excess returns, both currency beta and co-skewness are significantly priced with expected positive risk premiums for beta and negative risk premiums for co-skewness in various horizons (3-month, 6-month, and 12-month ahead). The co-skewness pricing effect is stronger than the beta effect because the regression coefficients of co-skewness have bigger magnitudes than beta counterparts. Also, the co-skewness effect is more robust than the beta effect because co-skewness pricing is very statistically significant at less than the 1% level in various horizons whereas beta pricing is significant at the 10% level for the 3-month horizon and the 5% level for the 6-month horizon. Consistent with the previous results, the adjusted-R-squares increase with the length of horizon, from 4.5% for 3-month ahead to 11.1% for 12-month ahead.

In Panel B, which is based on local-currency-denominated world stock excess returns, currency co-skewness remains very significantly priced in various horizons, and currency beta pricing coefficients become more significant at the 1% level with bigger magnitudes. Also, currency idiosyncratic volatility and skewness are negatively priced in some horizons. Therefore, we document very strong and robust currency co-skewness pricing effects. Recall that safe-haven currencies have higher and positive co-skewness and lower excess returns. By implication of the co-skewness effect, the lower excess returns on these safe-haven currencies can be partially attributed to their desirable hedging properties of positive co-skewness, and this cannot be explained by time-varying betas, volatility, and/or skewness.

6. Concluding Remarks

By using a bivariate regime-switching model and conditional higher moments, we examined the hedging benefits of currencies in terms of co-skewness with the equity market (*i.e.*, covariance between currency returns with the stock market volatility). Among the developed markets, the three safe-haven currencies – the USD, the JPY, and the SWF – earn lower risk premiums, which can be partially caused by their positive co-skewness. For a world equity market investor, holding long positions in these three safe-haven currencies can significantly hedge the volatility of equity portfolios. Moreover, we find that conditional currency co-skewness with the world stock market commands statistically and economically significant negative future excess returns, reflecting the hedging demand for currencies under skewness preference. It would also be interesting to explore the optimal hedging problem of various currencies for a particular international stock portfolio, particularly under higher moment preference. We leave these topics for future research.

Appendix

This appendix derives the conditional moments of the bivariate regime-switching model in general, and the conditional covariance, volatility, skewness, co-skewness, and currency beta in particular.

Proposition 1. Suppose $\mathbf{r_t}$ *follows the bivariate Markov switching process* $\mathbf{r_t} = \boldsymbol{\mu}_{\mathbf{it}} + \boldsymbol{\varepsilon}_{\mathbf{it}}$, $i \in \{1, 2\}$, *then the centered conditional moments of the process are given by:*

$$
\text{(A1)} \qquad \begin{aligned} & E[(r_t^s - \mu_t^s)^k (r_t^c - \mu_t^c)^l \mid \mathbf{F_{t-1}}, \boldsymbol{\theta}] \\ &= \sum_{i=1}^{2} p_{it} \{ \sum_{m=0}^{k} \sum_{n=0}^{l} [C_k^m C_l^n \left(\mu_{it}^s - \mu_t^s\right)^{k-m} \left(\mu_{it}^c - \mu_t^c\right)^{l-n} \varphi(m, n; i)]\}, \end{aligned}
$$

where $\boldsymbol{\theta}$ is a vector of parameters in the regime-switching model. $p_{it} = \Pr(s_t = i \mid \mathbf{F_{t-1}}, \boldsymbol{\theta})$ is the conditional state probabilities, which can be derived recursively from transition probabilities. $C_k^m = \dfrac{k!}{(k-m)!m!}$ *and* $C_l^n = \dfrac{l!}{(l-n)!n!}$. $\varphi(m, n; i) = E[\left(\varepsilon_{it}^s\right)^m \left(\varepsilon_{it}^c\right)^n]$ *follows the two-dimensional recursion below:*

$$
\begin{aligned}
&\varphi(0, 0; i) = 1, \\
&\varphi(1, 0; i) = \varphi(0, 1; i) = 0, \\
&\varphi(1, 1; i) = \sqrt{h_i^s h_i^c}\, \rho_i, \\
&\varphi(m, 0; i) = (m-1) h_i^s \varphi(m-2, 0; i), \quad \text{if } m \geq 2, \\
&\varphi(0, n; i) = (n-1) h_i^c \varphi(0, n-2; i), \quad \text{if } n \geq 2, \\
&\varphi(m, n; i) = n\sqrt{h_i^s h_i^c}\, \rho_i \varphi(m-1, n-1; i) + (m-1) h_i^s \varphi(m-2, n; i), \quad \text{if } \ m, n \geq 2.
\end{aligned}
$$

Proof of Proposition 1

From the law of iterated expectations we have:

$$
\begin{aligned}
&E[(r_t^s-\mu_t^s)^k(r_t^c-\mu_t^c)^l \mid \mathbf{F_{t-1}},\boldsymbol{\theta}] \\
&= E\{E[(r_t^s-\mu_t^s)^k(r_t^c-\mu_t^c)^l \mid \mathbf{F_{t-1}},\boldsymbol{\theta}, S_t]\} \\
&= \sum_{i=1}^{2} p_{it}E[(\mu_{it}^s+\varepsilon_{it}^s-\mu_t^s)^k(\mu_{it}^c+\varepsilon_{it}^c-\mu_t^c)^l] \\
&= \sum_{i=1}^{2} p_{it}E[(\mu_{it}^s+\varepsilon_{it}^s-\mu_t^s)^k(\mu_{it}^c+\varepsilon_{it}^c-\mu_t^c)^l] \\
&= \sum_{i=1}^{2} p_{it}\{\sum_{m=0}^{k}\sum_{n=0}^{l} C_k^m C_l^n \left(\mu_{it}^s-\mu_t^s\right)^{k-m}\left(\mu_{it}^c-\mu_t^c\right)^{l-n} E[\left(\varepsilon_{it}^s\right)^m\left(\varepsilon_{it}^c\right)^n]\}
\end{aligned}
$$

where we use Newton's binomial formula and the assumption that the *ex ante* probabilities apply.

By assumption, $\boldsymbol{\varepsilon_{it}} = (\varepsilon_{it}^s, \varepsilon_{it}^c)'$ follows an iid bivariate normal distribution with zero means, the constant conditional volatilities and correlation, h_i^s, h_i^c and ρ_i, given regime *i*. Then the moment-generating function of $\boldsymbol{\varepsilon_{it}} = (\varepsilon_{it}^s, \varepsilon_{it}^c)'$ can be expressed as:

(A2) $$M(e_i^s, e_i^c) = \exp\left[\frac{1}{2}\left(h_i^s(e_i^s)^2 + 2\sqrt{h_i^s h_i^c}\,\rho_i e_i^s e_i^c + h_i^b(e_i^c)^2\right)\right].$$

Repeated partial differentiation of Equation (A2) and evaluation of the resultant expressions at $e_i^s = e_i^c = 0$ yields Equation (A1).

Q.E.D.

Because researchers are often particularly interested in conditional beta, covariance (correlation), volatility (standard deviation), co-skewness, and skewness, we characterize these moments more explicitly for the specified mixture normal model.

Corollary 1 (Conditional variances and standard deviations)

As a proxy for currency volatilities, conditional standard deviations of currency excess returns are given by:

(A3) $$std_t^c = \sqrt{E[(r_t^c-\mu_t^c)^2 \mid \mathbf{F_{t-1}},\boldsymbol{\theta}]} = \sqrt{p_{1t}h_1^c + p_{2t}h_2^c + p_{1t}p_{2t}(\mu_{1t}^c-\mu_{2t}^c)^2},$$

where "c" for currency, and $p_{2t} = 1 - p_{1t}$. h_1^c *and* h_2^c *are conditional currency variances at states 1 and 2, as defined in Equation (6).*

Cconditional variances of stock excess returns are given by:

(A4) $$\text{var}_t^s = E[(r_t^s - \mu_t^s)^2 \mid \mathbf{F_{t-1}}, \boldsymbol{\theta}] = p_{1t} h_1^s + p_{2t} h_2^s + p_{1t} p_{2t} (\mu_{1t}^s - \mu_{2t}^s)^2,$$

where "s" for stock, and $p_{2t} = 1 - p_{1t}$. h_1^s *and* h_2^s *are conditional stock variances at states 1 and 2, as defined in Equation (6).*

Proof of Corollary 1

For currency volatility $k = 0$ and $l = 2$. Following Proposition 1, we have:

$$\begin{aligned}
&E[(r_t^c - \mu_t^c)^2 \mid \mathbf{F_{t-1}}, \boldsymbol{\theta}] \\
&= \sum_{i=1}^{2} p_{it} \{ \sum_{m=0}^{2} [C_2^m \left(\mu_{it}^c - \mu_t^c\right)^{2-m} \varphi(m, 0; i)] \\
&= \sum_{i=1}^{2} p_{it} \{ \left(\mu_{it}^c - \mu_t^c\right)^2 \varphi(0,0;i) + 2\left(\mu_{it}^c - \mu_t^c\right)\varphi(1,0;i) + \varphi(2,0;i)\} \\
&= \sum_{i=1}^{2} p_{it} \{ \left(\mu_{it}^c - \mu_t^c\right)^2 + h_i^c \} \\
&= p_{1t} h_1^c + p_{2t} h_2^c + p_{1t} (\mu_{1t}^c - \mu_t^c)^2 + p_{2t} (\mu_{2t}^c - \mu_t^c)^2 \\
&= p_{1t} h_1^c + p_{2t} h_2^c + p_{1t} (p_{2t})^2 (\mu_{1t}^c - \mu_{2t}^c)^2 + p_{2t} (p_{1t})^2 (\mu_{2t}^c - \mu_{1t}^c)^2 \\
&= p_{1t} h_1^c + p_{2t} h_2^c + p_{1t} p_{2t} (\mu_{1t}^c - \mu_{2t}^c)^2
\end{aligned}$$

where $\mu_t^c = \sum_{i=1}^{2} p_{it} \mu_{it}^c$, $\sum_{i=1}^{2} p_{it} = 1$, $\varphi(0,0;i) = 1$, $\varphi(1,0;i) = 0$ and

$\varphi(0,2;i) = (2-1) h_i^c \varphi(0,2-2;i) = h_i^c \varphi(0,0;i) = h_i^c$ apply.

Therefore, $std_t^c = \sqrt{E[(r_t^c - \mu_t^c)^2 \mid \mathbf{F_{t-1}}, \boldsymbol{\theta}]} = \sqrt{p_{1t} h_1^c + p_{2t} h_2^c + p_{1t} p_{2t} (\mu_{1t}^c - \mu_{2t}^c)^2}$.

For stock volatility $k = 0$ and $l = 2$, the derivation is similar to the above.

Q.E.D.

Note that volatilities are time-varying driven by the conditional state probabilities and parameter estimates, even though conditional variances are assumed to be constant in each regime.

Corollary 2 (Conditional covariance and correlation)

The conditional covariance between stock and currency excess returns is given by:

$$\text{(A5)} \qquad \operatorname{cov}_t = E[(r_t^s - \mu_t^s)(r_t^c - \mu_t^c) \mid \mathbf{F_{t-1}}, \boldsymbol{\theta}] = p_{1t}\operatorname{cov}_1 + p_{2t}\operatorname{cov}_2 + p_{1t}p_{2t}\left[\left(\mu_{1t}^s - \mu_{2t}^s\right)\left(\mu_{1t}^c - \mu_{2t}^c\right)\right],$$

where $\operatorname{cov}_i = \rho_i\sqrt{h_i^s h_i^c}$ *is the covariance in regime i.*

Thus the conditional correlation is given by:

$$\rho_t = \frac{p_{1t}\operatorname{cov}_1 + p_{2t}\operatorname{cov}_2 + p_{1t}p_{2t}\left[\left(\mu_{1t}^s - \mu_{2t}^s\right)\left(\mu_{1t}^c - \mu_{2t}^c\right)\right]}{[p_{1t}h_1^s + p_{2t}h_2^s + p_{1t}p_{2t}(\mu_{1t}^s - \mu_{2t}^s)^2]^{1/2}[p_{1t}h_1^c + p_{2t}h_2^c + p_{1t}p_{2t}(\mu_{1t}^c - \mu_{2t}^c)^2]^{1/2}}.$$

Proof of Corollary 2

For the conditional covariance, $k = l = 1$. Following Proposition 1, we have:

$$\begin{aligned}
&E[(r_t^s - \mu^s)(r_t^c - \mu^c) \mid \mathbf{F_{t-1}}, \boldsymbol{\theta}] \\
&= \sum_{i=1}^{2} p_{it}\{\sum_{m=0}^{1}\sum_{n=0}^{1}[C_1^k C_1^l\left(\mu_{it}^s - \mu_t^s\right)^{1-m}\left(\mu_{it}^c - \mu_t^c\right)^{1-n}\varphi(m,n;i)]\} \\
&= \sum_{i=1}^{2} p_{it}\{\left(\mu_{it}^s - \mu_t^s\right)\left(\mu_{it}^c - \mu_t^c\right)\varphi(0,0;i) + \left(\mu_{it}^s - \mu_t^s\right)\varphi(0,1;i) + \left(\mu_{it}^c - \mu_t^c\right)\varphi(1,0;i) + \varphi(1,1;i)\} \\
&= \sum_{i=1}^{2} p_{it}\{\left(\mu_{it}^s - \mu_t^s\right)\left(\mu_{it}^c - \mu_t^c\right) + \sqrt{h_i^s h_i^c}\,\rho_i\} \\
&= p_{1t}\sqrt{h_1^s h_1^c}\,\rho_1 + p_{2t}\sqrt{h_2^s h_2^c}\,\rho_2 + p_{1t}\left(\mu_{1t}^s - \mu_t^s\right)\left(\mu_{1t}^c - \mu_t^c\right) + p_{2t}\left(\mu_{2t}^s - \mu_t^s\right)\left(\mu_{2t}^c - \mu_t^c\right) \\
&= p_{1t}\sqrt{h_1^s h_1^c}\,\rho_1 + p_{2t}\sqrt{h_2^s h_2^c}\,\rho_2 + p_{1t}(p_{2t})^2\left(\mu_{1t}^s - \mu_{2t}^s\right)\left(\mu_{1t}^c - \mu_{2t}^c\right) + p_{2t}(p_{1t})^2\left(\mu_{2t}^s - \mu_{1t}^s\right)\left(\mu_{2t}^c - \mu_{1t}^c\right) \\
&= p_{1t}\sqrt{h_1^s h_1^c}\,\rho_1 + p_{2t}\sqrt{h_2^s h_2^c}\,\rho_2 + p_{1t}p_{2t}\left(\mu_{1t}^s - \mu_{2t}^s\right)\left(\mu_{1t}^c - \mu_{2t}^c\right) \\
&= p_{1t}\operatorname{cov}_1 + p_{2t}\operatorname{cov}_2 + p_{1t}p_{2t}\left(\mu_{1t}^s - \mu_{2t}^s\right)\left(\mu_{1t}^c - \mu_{2t}^c\right),
\end{aligned}$$

where $\mu_t^s = \sum_{i=1}^{2} p_{i,t}\mu_{it}^s$, $\mu_t^c = \sum_{i=1}^{2} p_{i,t}\mu_{it}^c$, $\sum_{i=1}^{2} p_{i,t} = 1$, $\varphi(0,0;i) = 1$, $\varphi(1,0;i) = \varphi(0,1;i) = 0$, and

$\varphi(1,1;i) = \sqrt{h_i^s h_i^c}\,\rho_i = \operatorname{cov}_i$ apply.

The derivation of the conditional correlation is just by definition. Note that the conditional correlation is time-varying driven by the conditional state probabilities and parameter estimates, even though correlation in each regime is assumed to be constant.

Q.E.D.

Corollary 3 (Conditional currency beta)

The conditional currency beta with respect to global stock market is given by:

$$\text{(A6)}\ \beta_t^c = \frac{E[(r_t^s-\mu_t^s)(r_t^c-\mu_t^c)\,|\,\mathbf{F_{t-1}},\theta]}{E[(r_t^s-\mu_t^s)^2\,|\,\mathbf{F_{t-1}},\theta]} = \frac{p_{1t}\,\mathrm{cov}_1 + p_{2t}\,\mathrm{cov}_2 + p_{1t}p_{2t}\left[\left(\mu_{1t}^s-\mu_{2t}^s\right)\left(\mu_{1t}^c-\mu_{2t}^c\right)\right]}{p_{1t}h_1^s + p_{2t}h_2^s + p_{1t}p_{2t}(\mu_{1t}^s-\mu_{2t}^s)^2},$$

Proof of Corollary 3

Following (A4) and (A5), it is straightforward to get (A6).

Q.E.D.

Note that conditional currency beta is time-varying driven by the conditional state probabilities and parameter estimates, even though beta in each regime is constant implicitly. Compared to Christiansen, Ranaldo, and Soderlind (2011), who model time-varying betas in a regime of foreign exchange volatility, our time-varying beta and higher moments are driven by the joint distribution of currency and equity returns, which may contain more information of integrated capital market and broader portfolio.

Corollary 4 (Conditional currency skewness and co-skewness)

The conditional currency skewness is given by:

$$\text{(A7)}\ skew_t^c = \frac{E[\left(r_t^c-\mu_t^c\right)^3\,|\,F_{t-1},\theta]}{\left(\sqrt{E[(r_t^c-\mu_t^c)^2\,|\,F_{t-1},\theta}\right)^3} = \frac{p_{1t}p_{2t}\left(\mu_{1t}^c-\mu_{2t}^c\right)\left[\left(p_{2t}-p_{1t}\right)\left(\mu_{1t}^c-\mu_{2t}^c\right)^2+3\left(h_1^c-h_2^c\right)\right]}{\left[p_{1t}h_1^c+p_{2t}h_2^c+p_{1t}p_{2t}\left(\mu_{1t}^c-\mu_{2t}^c\right)^2\right]^{3/2}}$$

The standardized currency co-skewness is:

(A8) $$\cos_t^c = \frac{E[(r_t^s-\mu_t^s)^2(r_t^c-\mu_t^c)\mid F_{t-1},\theta]}{E[(r_t^s-\mu_t^s)^2\mid F_{t-1},\theta]\{E[(r_t^c-\mu_t^c)^2\mid F_{t-1},\theta]\}^{1/2}},$$

where the conditional currency co-skewness with the stock market is given by:

$$\begin{aligned}&E[(r_t^s-\mu_t^s)^2(r_t^c-\mu_t^c)\mid \mathbf{F_{t-1}},\boldsymbol{\theta}]\\&= p_{1t}p_{2t}\left[(p_{2t}-p_{1t})(\mu_{1t}^s-\mu_{2t}^s)^2(\mu_{1t}^c-\mu_{2t}^c)+(\mu_{1t}^c-\mu_{2t}^c)(h_1^s-h_2^s)+2(\mu_{1t}^s-\mu_{2t}^s)(\text{cov}_1-\text{cov}_2)\right]\end{aligned}$$

Proof of Corollary 4

For the conditional currency skewness, k = 0 and l = 3. Following Proposition 1, we have:

$$\begin{aligned}&E[(r_t^c-\mu_t^c)^3\mid \mathbf{F_{t-1}},\boldsymbol{\theta}]\\&=\sum_{i=1}^{2}p_{it}\{\sum_{n=0}^{3}[C_3^n(\mu_{it}^c-\mu_t^c)^{3-n}\varphi(0,n;i)]\\&=\sum_{i=1}^{2}p_{it}\{(\mu_{it}^c-\mu_t^c)^3\varphi(0,0;i)+3(\mu_{it}^c-\mu_t^c)^2\varphi(1,0;i)+3(\mu_{it}^c-\mu_t^c)\varphi(0,2;i)+\varphi(0,3;i)\}\\&=\sum_{i=1}^{2}p_{it}\{(\mu_{it}^c-\mu_t^c)^3+3(\mu_{it}-\mu_t)h_i^c\}\\&=p_{1t}[(\mu_{1t}^c-\mu_t^c)^3+3(\mu_{1t}^c-\mu_t^c)h_1^c]+p_{2t}[(\mu_{2t}^c-\mu_t^c)^3+3(\mu_{2t}^c-\mu_t^c)h_2^c]\\&=p_{1t}p_{2t}(\mu_{1t}^c-\mu_{2t}^c)[(p_{2t}-p_{1t})(\mu_{1t}^c-\mu_{2t}^c)^2+3(h_1^c-h_2^c)]\end{aligned}$$

where $\mu_t^c=\sum_{i=1}^{2}p_{i,t}\mu_{it}^c$, $\sum_{i=1}^{2}p_{it}=1$, $\varphi(0,0;i)=1$, $\varphi(1,0;i)=\varphi(0,1;i)=0$, $\varphi(0,2;i)=h_i^c$, and

$\varphi(0,3;i)=(3-1)h_i^c\varphi(0,3-2;i)=2h_1^c\varphi(0,1;i)=0$ apply.

Then the currency skewness in Equation (A7) is derived by definition.

$$skew_t^c=\frac{E[(r_t^c-\mu_t^c)^3\mid F_{t-1},\theta]}{\left(\sqrt{E[(r_t^c-\mu_t^c)^2\mid F_{t-1},\theta}\right)^3}=\frac{p_{1t}p_{2t}(\mu_{1t}^c-\mu_{2t}^c)\left[(p_{2t}-p_{1t})(\mu_{1t}^c-\mu_{2t}^c)^2+3(h_1^c-h_2^c)\right]}{\left[p_{1t}h_1^c+p_{2t}h_2^c+p_{1t}p_{2t}(\mu_{1t}^c-\mu_{2t}^c)^2\right]^{3/2}}$$

For the conditional currency co-skewness, k = 2 and l = 1. Following Proposition 1, we have:

$$
\begin{aligned}
&E[(r_t^s-\mu^s)^2(r_t^c-\mu^c)\,|\,\mathbf{F_{t-1}},\boldsymbol{\theta}] \\
&=\sum_{i=1}^{2}p_{it}\{\sum_{m=0}^{2}\sum_{n=0}^{1}[C_2^m C_1^n\left(\mu_{it}^s-\mu_t^s\right)^{1-m}\left(\mu_{it}^c-\mu_t^c\right)^{2-n}\varphi(m,n;i)]\} \\
&=\sum_{i=1}^{2}p_{it}\{\left(\mu_{it}^s-\mu_t^s\right)^2\left(\mu_{it}^c-\mu_t^c\right)\varphi(0,0;i)+2\left(\mu_{it}^s-\mu_t^s\right)\left(\mu_{it}^c-\mu_t^c\right)\varphi(1,0;i)+ \\
&\qquad\left(\mu_{it}^c-\mu_t^c\right)\varphi(2,0;i)+\left(\mu_{it}^s-\mu_t^s\right)^2\varphi(0,1;i)+2\left(\mu_{it}^s-\mu_t^s\right)\varphi(1,1;i)+\varphi(2,1;i)\} \\
&=\sum_{i=1}^{2}p_{it}\{\left(\mu_{it}^s-\mu_t^s\right)^2\left(\mu_{it}^c-\mu_t^c\right)+\left(\mu_{it}^c-\mu_t^c\right)h_i^s+2\left(\mu_{it}^c-\mu_t^c\right)\sqrt{h_i^s h_i^c}\,\rho_i\} \\
&=p_{1t}p_{2t}\left[(p_{2t})^2\left(\mu_{1t}^s-\mu_{2t}^s\right)^2\left(\mu_{1t}^d-\mu_{2t}^d\right)+\left(\mu_{1t}^c-\mu_{2t}^c\right)h_1^s+2\left(\mu_{1t}^c-\mu_{2t}^c\right)\sqrt{h_1^s h_1^c}\,\rho_1\right]+ \\
&\quad p_{2t}p_{1t}\left[(p_{1t})^2\left(\mu_{2t}^s-\mu_{1t}^s\right)^2\left(\mu_{2t}^c-\mu_{1t}^c\right)+\left(\mu_{2t}^c-\mu_{1t}^c\right)h_2^s+2\left(\mu_{2t}^c-\mu_{1t}^c\right)\sqrt{h_2^s h_2^c}\,\rho_2\right] \\
&=p_{1t}p_{2t}\left[\left(p_{2t}-p_{1t}\right)\left(\mu_{1t}^s-\mu_{2t}^s\right)^2\left(\mu_{1t}^c-\mu_{2t}^c\right)+\left(\mu_{1t}^c-\mu_{2t}^c\right)\left(h_1^s-h_2^s\right)+2\left(\mu_{1t}^c-\mu_{2t}^c\right)\left(\mathrm{cov}_1-\mathrm{cov}_2\right)\right]
\end{aligned}
$$

where $\mu_t^s=\sum_{i=1}^{2}p_{it}\mu_{it}^s$, $\mu_t^c=\sum_{i=1}^{2}p_{i,t}\mu_{it}^c$, $\sum_{i=1}^{2}p_{it}=1$, $\varphi(0,0;i)=1$, $\varphi(1,0;i)=\varphi(0,1;i)=0$, $\varphi(2,0;i)=(2-1)h_i^s\varphi(2-2,0;i)=h_i^s\varphi(0,0;i)=h_i^s$, $\varphi(1,1;i)=\sqrt{h_i^s h_i^c}\,\rho_i=\mathrm{cov}_i$ and $\varphi(2,1;i)=\sqrt{h_i^s h_i^c}\,\rho_i\varphi(1,0;i)+h_i^s\varphi(0,1;i)=0$ apply.

For the standardized conditional currency co-skewness in (A8), we just divide the above conditional currency co-skewness by (A3) and (A4).

Q.E.D.

As defined, standardized currency co-skewness is unit-free and analogous to a factor loading. Note that Harvey and Siddique (2000) argue that standardized co-skewness is similar to the traditional CAPM beta. They formulated stock co-skewness as the relation between individual stock return and stock market volatility. The co-skewness measure in their study came from a hidden assumption: that stocks co-skew in the same direction because they belong to the same asset class. This assumption should be relaxed for a stock–currency portfolio because the world stock and currency are two different asset classes. Equation (A8) shows that conditional currency co-skewness is the conditional covariance between currency premium and stock volatility. The conditional currency co-skewness is not necessarily zero if the covariance in Equation (A5) is zero. This suggests that co-skewness captures certain extreme co-movements which correlation does not; this is because co-skewness is about the co-movement in the long tail.

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Table 1: Summary Statistics

This table reports summary statistics for the monthly world and US stock excess returns, interest rates, exchange rates, and currency excess returns of developed economies. Stock market indices are from the Morgan Stanley Capital International (MSCI) Database. All other variables are from the IMF's IFS database, except for the USD index from the Federal Reserve and the Eurozone interest rate from Datastream. Stock excess returns are the log differences of MSCI indices minus the US 3-month Treasury bill rate, a proxy for the US and world risk-free rate. Interest rates are the log 3-month Treasury bill rates with the exception of the 3-month Euro Euro-currency rate. For currencies other than the USD, excess returns are the log interest rate differentials (foreign interest rate–US interest rate) minus the rates of foreign currency depreciation against the USD. USD excess return is the log difference of the major currency index plus the log difference between the US interest rate and the average of foreign interest rates, which is the simple average of interest rates in Japan, UK, Eurozone (from 1999 to 2010), Germany (from 1975 to 1998), Canada, Switzerland, and Australia. Note that USD excess return starts from 1975 because of the availability of German interest rates. All measures are annualized.

Panel A: The world stock excess returns (1973–2010)

Statistics	Mean	Std dev.	Skewness	Excess kurtosis
World stock excess returns (USD)	0.035	0.534	-0.756	2.179
World stock excess returns (local currency)	0.029	0.502	-0.958	2.955

Panel B: Interest rates, exchange rates, and currency excess returns

Currency	Eurozone (75–10)	Australia (83–10)	Canada (73–10)	Japan (73–10)	Switzerland (74–10)	UK (73–10)	US (75–10)
Log interest rates							
Mean	0.045	0.076	0.066	0.026	0.031	0.076	0.053
Std dev.	0.022	0.037	0.037	0.023	0.025	0.035	0.031
Skewness	0.468	1.010	0.524	0.243	0.947	0.040	0.600
Excess kurtosis	0.107	-0.218	-0.010	-1.507	0.187	-0.715	0.585
Change in log exchange rate							
Mean	-0.018	-0.001	0.000	-0.032	-0.032	0.012	-0.009
Std dev.	0.394	0.403	0.221	0.385	0.423	0.358	0.254
Skewness	0.095	0.961	0.681	-0.267	0.066	0.150	0.097
Excess kurtosis	1.127	3.513	8.312	1.408	0.953	2.007	0.584
Currency excess returns							
Mean	0.007	0.033	0.012	0.004	0.011	0.009	-0.010
Std dev.	0.389	0.405	0.222	0.388	0.428	0.360	0.256
Skewness	-0.139	-0.902	-0.722	0.220	-0.081	-0.101	0.086
Excess kurtosis	0.954	3.225	8.156	1.277	0.968	1.882	0.512

Table 2: Regime-switch Model Estimation for the World Stock (USD-denominated) and Currency Excess Returns

This table estimates regime switching model for the monthly world stock market and developed market currency excess returns $\begin{pmatrix} r_t^s \\ r_t^c \end{pmatrix} = \begin{pmatrix} \mu_i^s \\ \mu_i^c \end{pmatrix} + \begin{pmatrix} \lambda_i^s & 0 \\ 0 & \lambda_i^c \end{pmatrix} \begin{pmatrix} RF_{t-1} \\ RD_{t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{it}^s \\ \varepsilon_{it}^c \end{pmatrix}$, where $\begin{pmatrix} \varepsilon_{it}^s \\ \varepsilon_{it}^c \end{pmatrix} \sim \text{IIN}(\mathbf{0}, \mathbf{H}_{it})$, and $\mathbf{H_{it}} = \mathbf{D_{it}} \mathbf{R_{it}} \mathbf{D_{it}}$, $\mathbf{D_{it}} = \begin{pmatrix} \sqrt{h_i^s} & 0 \\ 0 & \sqrt{h_i^c} \end{pmatrix}$, $\mathbf{R_{it}} = \begin{pmatrix} 1 & 0 \\ \rho_i & 1 \end{pmatrix}$, $i \in \{1, 2\}$, and transition probabilities $p_{ii,t} = p(s_t = i \mid s_{t-1} = i, \mathbf{F_{t-1}}) = \Phi(a_i + b_i RD_{t-1})$, $i \in \{1, 2\}$, where RF_{t-1} is the first lagged US risk-free rate and RD_{t-1} is the first lagged interest rate difference (US interest rate–average of foreign interest rates for the USD, and foreign interest rate–US interest rate for other currencies). S_t is the unobserved regime at time t. $\mathbf{F_{t-1}}$ is the past information set. Φ is the cumulative normal distribution function. The parameter estimates are the QMLE. The t-statistics are reported in parentheses. *, **, and *** denote significance at 10%, 5%, and 1%, respectively. USD denotes the USD against other currencies, while JPY, GBP, EUR, SWF, CAD, and AUD denote the Japanese yen, the UK pound, the Euro, the Swiss franc, the Canadian dollar, and the Australian dollar against the USD, respectively.

Panel A: Safe-haven currencies

	USD (1975–2010)		JPY (1973–2010)		SWF (1974–2010)	
	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2
μ_i^s	0.171***	-0.231	0.224***	-0.115**	0.275***	-0.319***
t-stat.	(6.847)	(-1.468)	(9.206)	(-1.984)	(11.366)	(-4.405)
μ_i^c	-0.003	-0.049	0.091***	0.060	0.090***	0.085
t-stat.	(-0.239)	(-1.393)	(5.329)	(1.424)	(4.255)	(1.527)
λ_i^s	-0.008**	-0.026	-0.029***	0.019**	-0.027***	0.029***
t-stat.	(-2.321)	(-1.050)	(-7.869)	(2.024)	(-7.572)	(2.703)
λ_i^c	-0.024***	0.009	5.697***	-2.776**	4.858***	-2.937**
t-stat.	(3.668)	(0.487)	(12.136)	(-2.342)	(8.885)	(-2.139)
h_i^s	0.158***	0.628***	0.140***	0.516***	0.149***	0.531***
t-stat.	(12.721)	(5.832)	(9.742)	(10.265)	(10.619)	(8.038)
h_i^c	0.056***	0.099***	0.068***	0.236***	0.111***	0.299***
t-stat.	(13.639)	(6.237)	(9.987)	(10.088)	(9.523)	(9.908)
ρ_i	-0.471***	-0.488***	0.327***	0.183**	0.237***	0.218**
t-stat.	(-6.538)	(-10.881)	(5.014)	(2.423)	(3.600)	(2.093)
a_i	1.609***	-0.341	1.630***	-1.325***	1.077***	-0.655***
t-stat.	(9.983)	(-0.900)	(12.825)	(-8.558)	(8.055)	(-3.359)
b_i	-0.161*	0.531**	15.633***	-20.326***	-7.094*	-3.036
t-stat.	(-1.684)	(2.461)	(5.027)	(-4.308)	(-1.933)	(-0.521)

Table 2 (continued)

Panel B: Other currencies

	GBP (1973–2010)		CAD (1973–2010)		AUD (1983–2010)		EUR (1999–2010)	
	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2
μ_i^s	0.190***	-0.256***	0.168***	0.053	0.169***	-0.408***	0.065	0.053
t-stat.	(8.241)	(-2.664)	(6.502)	(1.137)	(6.371)	(-5.051)	(1.640)	(0.797)
μ_i^c	-0.058***	0.126**	-0.030***	0.033	-0.029	0.047	0.049	-0.032
t-stat.	(-3.503)	(2.015)	(-3.725)	(1.372)	(-1.550)	(0.738)	(1.298)	(-0.744)
λ_i^s	-0.017***	0.007	-0.008**	-0.050***	-0.013**	0.064***	-0.001	-0.044**
t-stat.	(-4.906)	(0.449)	(-2.218)	(-5.564)	(-2.516)	(4.574)	(-0.097)	(-2.007)
λ_i^c	3.427***	-3.337**	2.404***	-0.408	3.534***	-2.918**	2.055	5.615***
t-stat.	(5.152)	(-2.400)	(5.921)	(-0.296)	(6.153)	(-2.417)	(0.592)	(2.614)
h_i^s	0.164***	0.708***	0.185***	0.416***	0.150***	0.645***	0.070***	0.450***
t-stat.	(11.761)	(5.799)	(12.821)	(11.202)	(9.320)	(6.376)	(3.935)	(6.185)
h_i^c	0.086***	0.292***	0.018***	0.110***	0.076***	0.384***	0.061***	0.183***
t-stat.	(12.718)	(7.258)	(11.789)	(13.482)	(9.461)	(6.820)	(4.175)	(7.621)
ρ_i	0.227***	0.345***	0.291***	0.579***	0.246***	0.528***	0.166	0.281***
t-stat.	(3.813)	(3.507)	(5.508)	(12.656)	(3.508)	(7.466)	(1.328)	(3.369)
a_i	2.063***	-0.650**	1.658***	-1.551***	2.127***	-1.287***	2.465***	-2.497***
t-stat.	(13.286)	(-2.714)	(11.883)	(-8.658)	(12.192)	(-5.631)	(4.285)	(-4.589)
b_i	-30.783***	15.698**	-3.761	29.399***	-25.231***	18.613***	-129.96**	31.942
t-stat.	(-6.270)	(2.218)	(-0.566)	(2.857)	(-6.223)	(3.530)	(-2.342)	(0.864)

Table 3: Average of Conditional Moment Estimates derived from the world stock-currency regime-switching models and orthogonal regressions

This table reports the average of conditional moment estimates for currency excess returns. USD denotes the US dollar against other currencies, while JPY, GBP, EUR, SWF, CAD, and AUD denote the Japanese yen, the UK pound, the Euro, the Swiss franc, the Canadian dollar, and the Australian dollar against the USD, respectively. The sample period is from 1973 to 2010 for JPY, GBP, and CAD, but starts in a later year for SWF (1974), USD (1975), and AUD (1983). EUR is extended back to 1975 using the Deutsche Mark. Conditional moment estimates are derived as in Equations (A3)–(A8).

Variable name	USD	JPY	SWF	GBP	EUR	CAD	AUD
Conditional beta	-0.220	0.164	0.157	0.181	0.199	0.166	0.292
Conditional standard deviation	0.252	0.376	0.416	0.354	0.379	0.209	0.395
Conditional skewness	-0.037	0.391	0.210	0.006	0.192	0.097	-0.265
Conditional correlation with the world stock excess returns	-0.433	0.227	0.195	0.267	0.268	0.405	0.391
Conditional covariance with the world stock excess returns	-0.055	0.045	0.043	0.053	0.055	0.050	0.092
Conditional standardized co-skewness with the world stock excess returns	0.060	0.146	0.052	-0.087	0.020	-0.151	-0.216
Conditional co-skewness with the world stock excess returns	0.004	0.015	0.004	-0.012	-0.001	-0.008	-0.030

Table 4: Pricing effects of Currency Conditional Co-skewness with the world stock market

This table presents results of the following regressions for currency risk premiums:

$$\bar{r}^{c}_{t,t+m} = c_0 + c_1 \hat{beta}_t + c_2 \tilde{std}^c_t + c_3 \tilde{\cos}^c_t + c_4 \tilde{skew}^c_t + e^c_t ,$$

where $\bar{r}^{c}_{t,t+m}$, is the average future m-month currency excess return. $\hat{beta}_t$ is the estimated conditional currency beta with respect to world stock excess returns. $\tilde{std}^c_t$ is estimated currency volatility, proxied by conditional standard deviation and, orthogonal to $\hat{beta}_t$. $\tilde{\cos}^c_t$ is estimated currency standardized conditional co-skewness with world stock excess returns, orthogonal to $\hat{beta}_t$ and $\tilde{std}^c_t$. $\tilde{skew}^c_t$ is the estimated currency conditional skewness, orthogonal to $\hat{beta}_t$, $\tilde{std}^c_t$ and $\tilde{\cos}^c_t$. T-values are reported beneath each coefficient estimate are adjusted for Newey-West robust standard errors. *, **, and*** denote significance at 10%, 5%, and 1%, respectively. Adj-R^2 is adjusted R-squares. USD, JPY, GBP, EUR, SWF, CAD, and AUD denote the US dollar, the Japanese yen, the UK pound, the Euro, the Swiss franc, the Canadian dollar, and the Australian dollar, respectively. The sample period is from 1973 to 2010 for JPY, GBP, CAD, but starts in a later year for SWF (1974), USD (1975), and AUD (1983). The EUR is extended back to 1975 using the Deutsche Mark.

Panel A: Pricing effects on future 3-month currency excess returns

Currency	Intercept	$\hat{beta}_t$	$\tilde{std}^c_t$	$\tilde{\cos}^c_t$	$\tilde{skew}^c_t$	Adj-R^2
USD	0.125	0.621	-2.924***	-1.218***	2.547	9.5%
(75–10)	(1.29)	(1.43)	(-2.65)	(-3.26)	(1.43)	
JPY	0.101	-0.595	-0.424*	-0.581***	1.633***	9.8%
(73–10)	(1.55)	(-1.56)	(-1.72)	(-2.89)	(3.65)	
SWF	0.059	-0.321	0.414	-0.448***	-0.394	5.0%
(74–10)	(0.56)	(-0.46)	(1.17)	(-2.89)	(-0.97)	
GBP	-0.128	0.758	0.480	-0.610**	-0.584*	2.9%
(73–10)	(-0.97)	(0.99)	(0.82)	(-2.05)	(-1.67)	
EUR	-0.066	0.377	0..416	-0.411***	-0.377	4.3%
(73–10)	(-0.47)	(0.54)	(1.10)	(-2.93)	(-0.88)	
CAD	-0.042	0.327*	-1.064*	-0.221***	-0.048	4.5%
(73–10)	(-1.60)	(1.76)	(-1.65)	(-2.75)	(-0.76)	
AUD	-0.141	0.604	0.784	-0.465***	0.137	8.1%
(83–10)	(-1.38)	(1.61)	(0.88)	(-3.32)	(1.18)	

Table 4 (continued)

Panel B: Pricing effects on future 6-month currency excess returns

Currency	Intercept	$\hat{beta}_t$	$\tilde{std}_t^c$	$\tilde{\cos}_t^c$	$\tilde{skew}_t^c$	Adj-R^2
USD (75–10)	0.132* (1.74)	0.650* (1.93)	-2.816*** (-3.10)	-1.183*** (-3.78)	1.421 (1.19)	15.9%
JPY (73–10)	0.075 (1.57)	-0.434 (-1.52)	-0.581*** (-2.89)	-0.464*** (-5.41)	1.622*** (3.65)	17.5%
SWF (74–10)	0.047 (0.58)	-0.246 (-0.48)	0.160 (0.58)	-0.417*** (-3.53)	-0.478 (-1.39)	8.3%
GBP (73–10)	-0.080 (-0.78)	0.497 (0.84)	0.665* (1.72)	-0.513* (-1.81)	-0.728*** (-2.59)	5.6%
EUR (73–10)	-0.059 (-0.80)	0.346 (0.97)	0.235 (1.00)	-0.311*** (-4.26)	0.115 (0.50)	6.4%
CAD (73–10)	-0.032 (-1.43)	0.263* (1.66)	-1.171** (-2.25)	-0.168*** (-2.69)	0.040 (0.88)	5.9%
AUD (83–10)	-0.153* (-1.85)	0.649** (2.13)	0.846 (0.987)	-0.428*** (-3.85)	0.114 (1.49)	14.6%

Panel C: Pricing effects on future 12-month currency excess returns

Currency	Intercept	$\hat{beta}_t$	$\tilde{std}_t^c$	$\tilde{\cos}_t^c$	$\tilde{skew}_t^c$	Adj-R^2
USD (75–10)	0.096** (2.13)	0.492** (2.37)	-2.769*** (-4.91)	-0.967*** (-4.99)	1.297* (1.865)	22.9%
JPY (73–10)	0.045 (1.30)	-0.246 (-1.20)	-0.539*** (-3.63)	-0.439*** (-7.21)	1.089*** (3.59)	25.2%
SWF (74–10)	0.038 (0.79)	-0.196 (-0.68)	0.054 (0.32)	-0.411*** (-6.09)	-0.068 (-0.37)	14.0%
GBP (73–10)	-0.041 (-0.51)	0.283 (0.63)	0.322 (1.21)	-0.410** (-2.03)	-0.376 (-1.64)	4.1%
EUR (73–10)	-0.059 (-0.80)	0.346 (0.967)	0.235 (1.00)	-0.311*** (-4.25)	0.115 (0.49)	8.1%
CAD (73–10)	-0.023 (-1.35)	0.214* (1.82)	-1.234*** (-2.83)	-0.103* (-1.95)	0.057 (1.44)	8.9%
AUD (83–10)	-0.157*** (-2.72)	0.661*** (3.29)	0.375 (0.82)	-0.404*** (-6.33)	0.085* (1.78)	25.2%

Table 5: Economic Significance of Pricing effects for Currencies' Conditional Co-skewness with the world stock excess returns (USD-denominated)

This table summarizes the impacts on expected currency excess returns of a one standard deviation increase in orthogonal conditional co-skewness derived in Equations (A8). In Panel A, the impacts on currency excess return are the products of the regression coefficients for orthogonal conditional co-skewness in Table 4 and the corresponding standard deviations in this table. In Panel B, the impacts on interest differential component are the products of the untabulated regression coefficients of interest differential on orthogonal conditional co-skewness and the corresponding standard deviations in Panel A. The percentages of the impacts on interest differential relative to the impacts on currency returns are also calculated. *, **, and*** denote significance at 10%, 5%, and 1%, respectively. USD, JPY, GBP, EUR, SWF, CAD, and AUD denote the US dollar, the Japanese yen, the UK pound, the Euro, the Swiss franc, the Canadian dollar, and the Australian dollar, respectively.

Panel A: Impacts on currency excess return

Currency	One std dev. of orthogonal co-skewness	Impact on 3-month currency return	Impact on 6-month currency return	Impact on 12-month currency return
USD (75–10)	0.027	-0.033***	-0.032***	-0.026***
JPY (73–10)	0.126	-0.073***	-0.058***	-0.055***
SWF (74–10)	0.126	-0.056***	-0.053***	-0.052***
GBP (73–10)	0.049	-0.030**	-0.025*	-0.020**
EUR (73–10)	0.116	-0.048***	-0.036***	-0.036***
CAD (73–10)	0.077	-0.017*	-0.013***	-0.008*
AUD (83–10)	0.125	-0.058***	-0.054***	-0.051***

Panel B: Impacts on interest differential component

Currency	Impact on 3-month interest differential	Percentage of impact on interest differential	Impact on 6-month interest differential	Percentage of impact on interest differential	Impact on 12-month interest differential	Percentage of impact on interest differential
USD (75–10)	-0.055***	166.7%	-0.054***	168.8%	-0.043***	165.4%
JPY (73–10)	-0.018***	24.7%	-0.017***	29.3%	-0.015***	27.3%
SWF (74–10)	-0.024***	42.9%	-0.023***	43.4%	-0.022***	42.3%
GBP (73–10)	-0.006***	20%	-0.005***	20%	-0.004***	20%
EUR (73–10)	-0.014***	29.2%	-0.012***	33.3%	-0.011***	30.6%
CAD (73–10)	-0.011***	64.7%	-0.010***	76.9%	-0.008***	100%
AUD (83–10)	-0.008***	13.8%	-0.007***	13.0%	-0.005***	9.8%

Table 6: Average Conditional Moment Estimates derived from the (local currency denominated) world stock-currency regime-switching models

This table reports the averages of conditional moment estimates for the US dollar risk premium and foreign currency risk premium with respect to the US dollar. USD denotes the US dollar against other currencies, while JPY, GBP, EUR, SWF, CAD and AUD denote the Japanese yen, the UK Pound, the Euro, the Swiss franc, the Canadian dollar, and the Australian dollar against the USD, respectively. Conditional moment estimates are derived as in Equations (A3)–(A8). The sample period is from 1973 to 2010 for JPY, GBP, and CAD, but starts in a later year for SWF (1974), USD (1975), and AUD (1983). The EUR is extended back to 1975 using the Deutsche Mark.

Variable name	USD	JPY	SWF	GBP	EUR	CAD	AUD
Conditional beta	-0.072	0.005	-0.046	0.205	0.004	0.155	0.229
Conditional standard deviation	0.251	0.377	0.416	0.354	0.381	0.209	0.394
Conditional skewness	-0.040	0.394	0.213	-0.022	0.156	0.123	-0.297
Conditional correlation with the world stock excess returns	-0.135	0.005	-0.053	0.045	0.008	0.356	0.287
Conditional covariance with the world stock excess returns	-0.017	0.000	-0.010	0.010	0.004	0.041	0.065
Conditional standardized co-skewness with the world stock excess returns	0.017	0.160	0.097	-0.048	0.024	-0.154	-0.272
Conditional co-skewness with the world stock excess returns	0.004	0.015	0.008	-0.007	-0.001	-0.007	-0.029

Table 7: Pricing effects of Currency Conditional Co-skewness with the world stock excess returns (local currency)

This table presents results of the following regressions for currency risk premiums:

$$\bar{r}^{c}_{t,t+m} = c_0 + c_1 \hat{beta}_t + c_2 \tilde{std}^c_t + c_3 \tilde{\cos}^c_t + c_4 \tilde{skew}^c_t + e^c_t ,$$

where $\bar{r}^{c}_{t,t+m}$, is the average future m-month currency excess return. $\hat{beta}_t$ is the estimated conditional currency beta with respect to world stock excess returns. $\tilde{std}^c_t$ is estimated currency volatility, proxied by conditional standard deviation and, orthogonal to $\hat{beta}_t$. $\tilde{\cos}^c_t$ is estimated currency standardized conditional co-skewness with world stock excess returns, orthogonal to $\hat{beta}_t$ and $\tilde{std}^c_t$. $\tilde{skew}^c_t$ is the estimated currency conditional skewness, orthogonal to $\hat{beta}_t$, $\tilde{std}^c_t$ and $\tilde{\cos}^c_t$. T-values reported beneath each coefficient estimate are adjusted for Newey-West robust standard errors. *, **, and*** denote significance at 10%, 5%, and 1%, respectively. Adj-R^2 is adjusted R-squares. USD, JPY, GBP, EUR, SWF, CAD, and AUD denote the US dollar, the Japanese yen, the UK pound, the Euro, the Swiss franc, the Canadian dollar, and the Australian dollar, respectively. The sample period is from 1973 to 2010 for JPY, GBP, CAD, but starts in a later year for SWF (1974), USD (1975), and AUD (1983). The EUR is extended back to 1975 using the Deutsche Mark.

Panel A: Pricing effects on future 3-month currency excess returns

Currency	Intercept	$\hat{beta}_t$	$\tilde{std}^c_t$	$\tilde{\cos}^c_t$	$\tilde{skew}^c_t$	Adj-R^2
USD	0.149***	2.216	2.264	-0.508	-0.027	8.1%
(75–10)	(3.11)	(3.26)	(5.37)	(-1.26)	(-0.04)	
JPY	0.004	0.026	-0.447*	-0.580***	0.317	8.8%
(73–10)	(0.26)	(0.06)	(-1.81)	(-4.90)	(0.72)	
SWF	0.052*	0.962*	0.105	-0.701*	-0.110	3.8%
(74–10)	(1.66)	(1.85)	(0.282)	(-1.87)	(-0.27)	
GBP	-0.054	0.309	-0.748	-0.229	-0.097	2.0%
(73–10)	(-1.32)	(1.53)	(-1.42)	(-1.23)	(-1.06)	
EUR	0.006	0.510*	-0.097**	-0.886*	-0.103	2.0%
(73–10)	(0.41)	(1.70)	(-0.29)	(-1.87)	(-0.27)	
CAD	-0.042	0.348*	-0.361**	-0.256***	-0.039	3.5%
(73–10)	(-1.62)	(1.83)	(-1.01)	(-3.26)	(-0.60)	
AUD	-0.074	0.480*	0.046	-0.868***	-0.013	7.4%
(83–10)	(-1.40)	(1.88)	(0.08)	(-3.88)	(-0.09)	

Table 7 (continued)

Panel B: Pricing effects on future 6-month currency excess returns

Currency	Intercept	$\hat{beta}_t$	$\tilde{std}_t^c$	$\tilde{\cos}_t^c$	$\tilde{skew}_t^c$	Adj-R^2
USD (75–10)	0.134*** (3.54)	1.996*** (3.68)	2.337*** (4.05)	-0.611* (-1.94)	-0.493 (-0.97)	14.7%
JPY (73–10)	0.003 (0.23)	0.111 (0.36)	-0.648*** (-3.22)	-0.488*** (-5.34)	-0.380 (-1.03)	14.3%
SWF (74–10)	0.045* (1.89)	0.798** (2.09)	-0.097 (-0.32)	-0.75*** (-2.83)	-0.124 (-0.43)	7.1%
GBP (73–10)	-0.048 (-1.55)	0.281* (1.82)	-0.700* (-1.77)	-0.252* (-1.67)	-0.105 (-1.37)	4.4%
EUR (73–10)	0.006 (0.52)	0.472** (2.27)	-0.153 (-0.58)	-0.468 (-1.40)	-0.273 (-0.83)	2.7%
CAD (73–10)	-0.034* (-1.66)	0.299* (1.94)	-0.513** (-1.99)	-0.200*** (-3.56)	-0.050 (1.14)	5.1%
AUD (83–10)	-0.090** (-2.27)	0.547*** (2.87)	0.421 (0.92)	-0.817*** (-5.24)	-0.060 (-0.58)	15.3%

Panel C: Pricing effects on future 12-month currency excess returns

Currency	Intercept	$\hat{beta}_t$	$\tilde{std}_t^c$	$\tilde{\cos}_t^c$	$\tilde{skew}_t^c$	Adj-R^2
USD (75–10)	0.130*** (4.43)	1.952*** (4.72)	1.667*** (4.08)	-0.558*** (-2.75)	-0.459 (-1.05)	21.3%
JPY (73–10)	0.003 (0.27)	0.220 (1.17)	-0.576*** (-4.27)	-0.456*** (-7.00)	0.674** (2.36)	26.1%
SWF (74–10)	0.037*** (2.87)	0.664*** (3.06)	-0.172 (-0.967)	-0.812*** (-6.91)	0.311* (1.85)	15.0%
GBP (73–10)	-0.050 (-2.22)	0.294*** (2.70)	-0.833*** (-3.36)	-0.201** (-2.43)	-0.025 (-0.49)	7.9%
EUR (73–10)	0.006 (0.71)	0.432*** (3.13)	-0.156 (-0.76)	-0.579*** (-2.81)	0.157 (0.75)	5.1%
CAD (73–10)	-0.027* (-1.75)	0.254** (2.26)	-0.646*** (-3.26)	-0.127*** (-2.60)	0.058 (1.60)	7.9%
AUD (83–10)	-0.084*** (-2.98)	0.520*** (4.10)	0.081 (0.32)	-0.719*** (-7.44)	-0.041 (-0.60)	24.8%

Table 8: Economic Significance of Pricing effects for Currencies' Conditional Co-skewness with the world stock market (local currency)

This table summarizes the impacts on expected currency excess returns of a one standard deviation increase in orthogonal conditional co-skewness derived in Equations (A8). In Panel A, the impacts on currency excess return are the products of the regression coefficients for orthogonal conditional co-skewness in Table 7 and the corresponding standard deviations in this table. In Panel B, the impacts on interest differential component are the products of the untabulated regression coefficients of interest differential on orthogonal conditional co-skewness and the corresponding standard deviations in Panel A. The percentages of the impacts on interest differential relative to the impacts on currency returns are also calculated. *, **, and*** denote significance at 10%, 5%, and 1%, respectively. USD, JPY, GBP, EUR, SWF, CAD, and AUD denote the US dollar, the Japanese yen, the UK pound, the Euro, the Swiss franc, the Canadian dollar, and the Australian dollar, respectively.

Panel A: Impacts on currency excess return

Currency	One std. dev. of orthogonal co-skewness	Impact on 3-month currency return	Impact on 6-month currency return	Impact on 12-month currency return
USD (75–10)	0.025	-0.013	-0.015*	-0.014***
JPY (73–10)	0.121	-0.070***	-0.059***	-0.055***
SWF (74–10)	0.053	-0.037*	-0.040***	-0.043***
GBP (73–10)	0.09	-0.021	-0.023*	-0.018**
EUR (73–10)	0.029	-0.026*	-0.014	-0.017***
CAD (73–10)	0.069	-0.018***	-0.014***	-0.009***
AUD (83–10)	0.074	-0.064***	-0.060***	-0.053***

Panel B Impacts on interest differential component

Currency	Impact on 3-month interest differential	Percentage of impact on interest differential	Impact on 6-month interest differential	Percentage of impact on interest differential	Impact on 12-month interest differential	Percentage of impact on interest differential
USD (75–10)	-0.018	138.5%	-0.024	160%	-0.021**	150%
JPY (73–10)	-0.019***	27.1%	-0.018***	30.5%	-0.012***	29.1%
SWF (74–10)	-0.014***	37.8%	-0.013***	32.5%	-0.012***	27.9%
GBP (73–10)	0.001	-	0.001	-	0.001	-
EUR (73–10)	-0.002***	7.7%	-0.002***	7.7%	-0.001***	5.9%
CAD (73–10)	-0.012***	66.7%	-0.011***	78.6%	-0.009***	100%
AUD (83–10)	-0.004***	6.3%	0.004	-	0.001	1%

Table 9: Pooled regression results of pricing effects of Currency Conditional Co-skewness with the world stock market

This table presents results of the following pooled cross sectional time-series regressions of 7 developed market currencies (JPY, GBP, CAD, SWF, USD, AUD, EUR), adjusted for both cross sectional and time series dependence:

$$\bar{r}^{c}_{t,t+m} = c_0 + c_1 \hat{beta}_t + c_2 \tilde{std}^c_t + c_3 \tilde{\cos}^c_t + c_4 \tilde{skew}^c_t + e^c_t,$$

where $\bar{r}^{c}_{t,t+m}$, is the average future m-month currency excess return. $\hat{beta}_t$ is the estimated conditional currency beta with respect to world stock excess returns. $\tilde{std}^c_t$ is estimated currency volatility, proxied by conditional standard deviation and, orthogonal to $\hat{beta}_t$. $\tilde{\cos}^c_t$ is estimated currency standardized conditional co-skewness with world stock excess returns, orthogonal to $\hat{beta}_t$ and $\tilde{std}^c_t$. $\tilde{skew}^c_t$ is the estimated currency conditional skewness, orthogonal to $\hat{beta}_t$, $\tilde{std}^c_t$ and $\tilde{\cos}^c_t$. T-values reported beneath each coefficient estimate are adjusted for two-way cluster-robust standard errors of Petersen (2009). *, **, and*** denote significance at 10%, 5%, and 1%, respectively. Adj-R^2 is adjusted R-squares. USD, JPY, GBP, EUR, SWF, CAD, and AUD denote the US dollar, the Japanese yen, the UK pound, the Euro, the Swiss franc, the Canadian dollar, and the Australian dollar, respectively. The sample period is from 1973 to 2010 for JPY, GBP, CAD, but starts in a later year for SWF (1974), USD (1975), and AUD (1983). The EUR is extended back to 1975 using the Deutsche Mark.

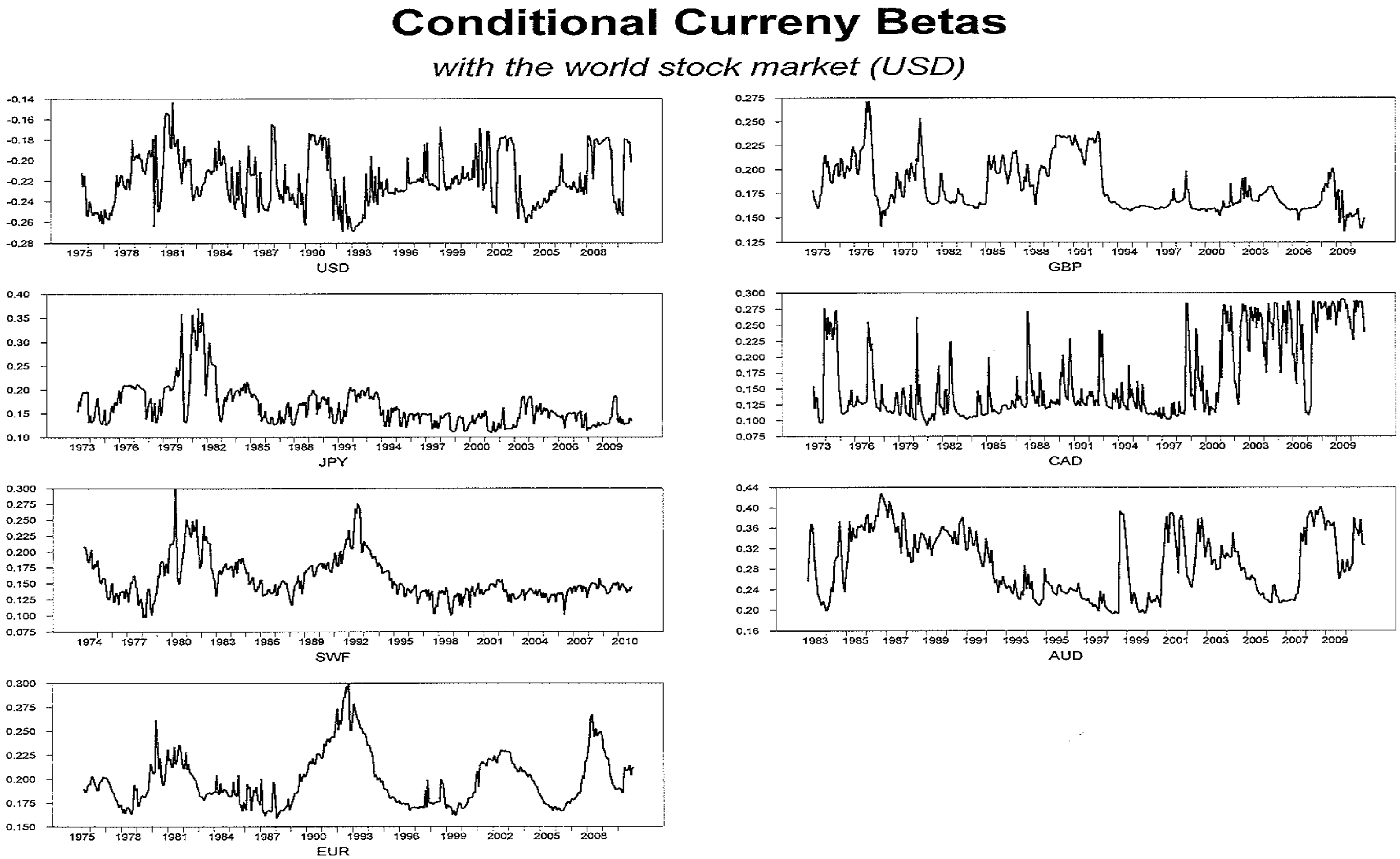
Panel A: USD-denominated world stock market

Currency excess return	Intercept	$\hat{beta}_t$	$\tilde{std}^c_t$	$\tilde{\cos}^c_t$	$\tilde{skew}^c_t$	Adj-R^2
3-month ahead	-0.002 (-1.071)	0.079* (1.868)	0.066 (0.242)	-0. 456*** (-8.11)	0.044 (0.531)	4.5%
6-month ahead	-0.002 (-0.532)	0.078** (2.087)	-0.073 (-0.272)	-0.404*** (-8.895)	0.040 (0.587)	6.4%
12-month ahead	-0.002 (-0.466)	0.078*** (2.335)	-0.158 (-0.751)	-0.372*** (-9.180)	0.065*** (2.707)	11.1%

Panel B: Local-currency-denominated world stock market

Currency excess return	Intercept	$\hat{beta}_t$	$\tilde{std}^c_t$	$\tilde{\cos}^c_t$	$\tilde{skew}^c_t$	Adj-R^2
3-month ahead	-0.001 (-0.119)	0.144*** (3.595)	-0.221 (-1.117)	-0.504*** (-4.418)	-0.071*** (-3.173)	3.6%
6-month ahead	-0.001 (-0.153)	0.141*** (3.757)	-0.316 (-1.535)	-0.456*** (-4.865)	-0.075* (-1.938)	5.7%
12-month ahead	-0.001 (-0.207)	0.141*** (4.613)	-0.372*** (-2.631)	-0.416*** (-4.567)	0.001 (0.037)	9.9%

Figure 1

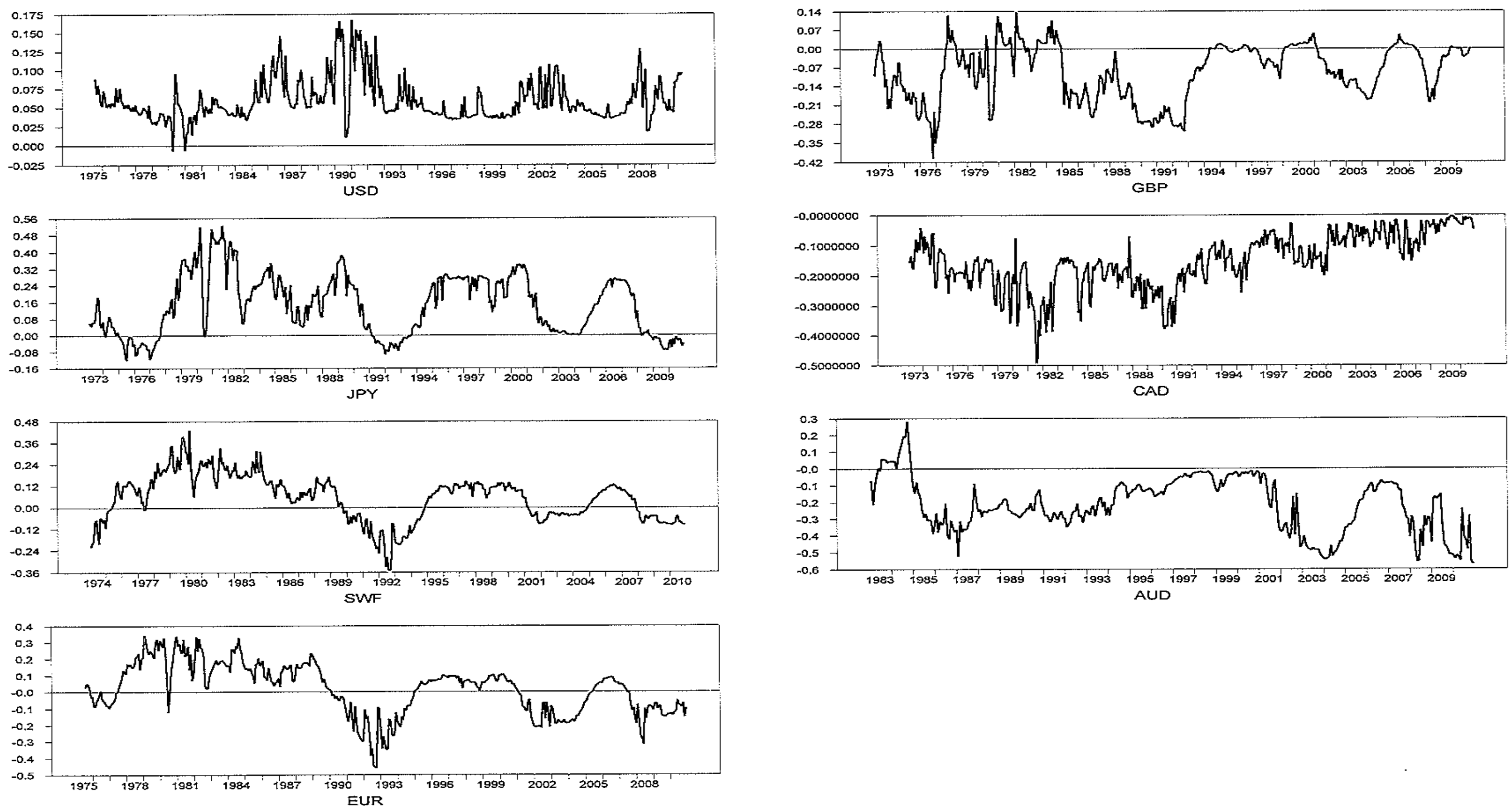


This figure plots the monthly conditional betas between currency returns and USD-denominated world stock excess returns. The time series are derived from the results of the bivariate regime-switching model in Table 2 and Corollary 3 in the Appendix.

Figure 2

Standardized Conditional Currency Co-skewness

with the world stock market (USD)

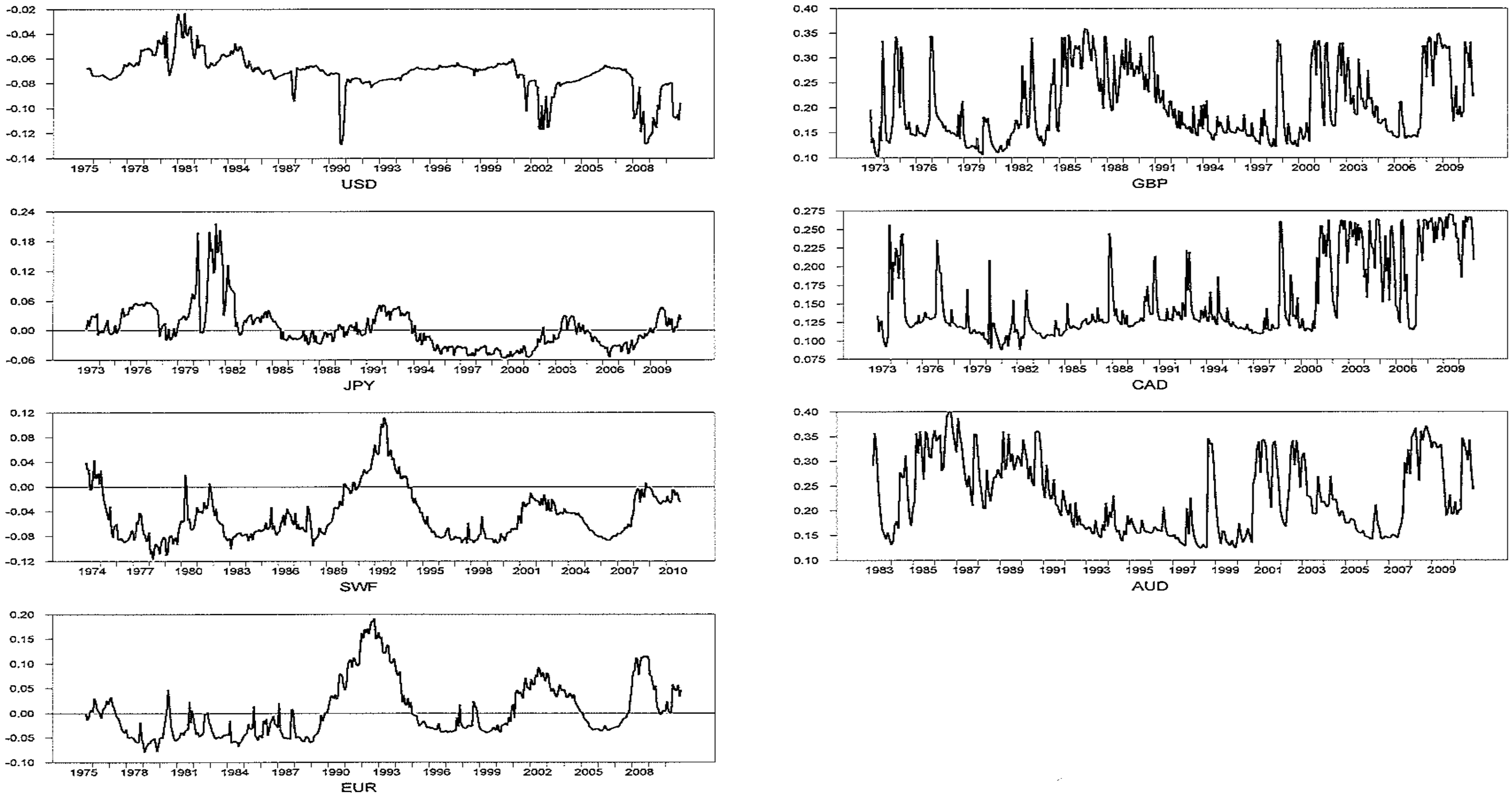


This figure plots the monthly standardized conditional co-skewness between currency excess returns and USD-denominated world stock excess returns. The time series are derived from the results of the bivariate regime-switching model in Table 2 and Corollary 4 in the Appendix.

Figure 3

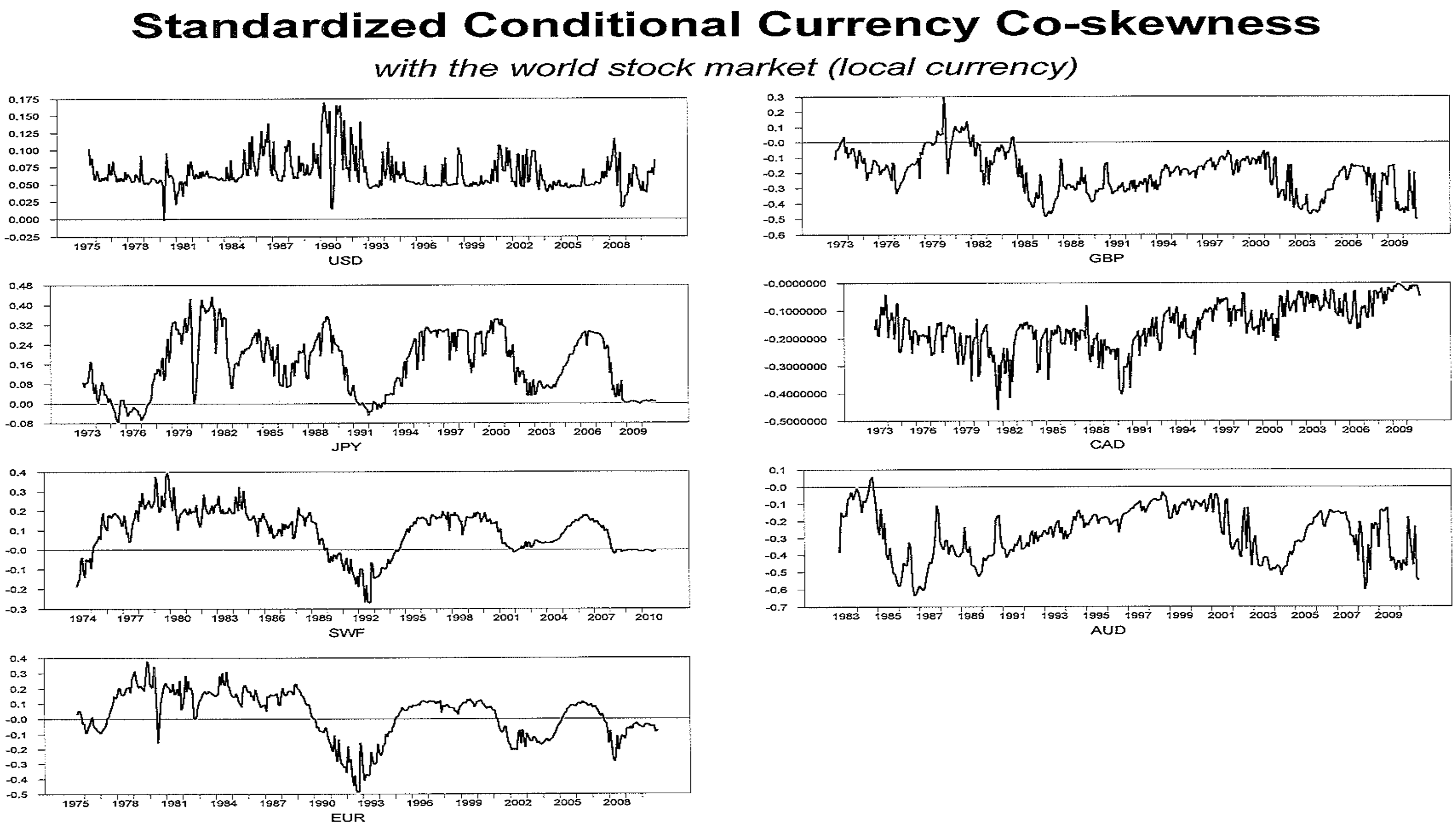
Conditional Curreny Betas

with the world stock market (local currency)



This figure plots the monthly conditional betas between currency returns and local currency-denominated world stock excess returns. The time series are derived from the results of the bivariate regime-switching model in Table 2 and Corollary 3 in the Appendix.

Figure 4



This figure plots the monthly standardized conditional co-skewness between currency and local currency-denominated world stock excess returns. The time series are derived from the results of the bivariate regime-switching model in Table 2 and Corollary 4 in the Appendix.