DISCUSSION PAPER SERIES

No. 7249

SAFE HAVEN CURRENCIES

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INTERNATIONAL MACROECONOMICS

Centre for Economic Policy Research

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Available online at: **www.cepr.org/pubs/dps/DP7249.asp**

ISSN 0265-8003

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Discussion Paper No. 7249
April 2009

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CEPR Discussion Paper No. 7249

April 2009

ABSTRACT

Safe Haven Currencies

We study high-frequency exchange rate movements over the sample 1993-2007. We document that the (Swiss) franc, euro, Japanese yen and the pound tend to appreciate against the U.S. dollar when (a) S&P has negative returns; (b) U.S. bond prices increase; and (c) when currency markets become more volatile. In these situations, the franc appreciates also against the other currencies, while the pound depreciates. The safe haven properties correspond to the carry trader's losses. They materialize over different time granularities (from a few hours to several days), during both "ordinary days" and crisis episodes and show some non-linear features.

JEL Classification: F31 and G15
Keywords: crisis episodes, high-frequency data and non-linear effects

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Submitted 28 March 2009

The views expressed herein are those of the authors and not necessarily those of the Swiss National Bank, which does not accept any responsibility for the contents and opinions expressed in this paper. We thank Benedikt Germanier, Paolo Giordani, Tommaso Mancini-Griffoli, Lukas Menkhoff, Marcel Savioz and the participants of the SNB-IMF conference in Zuerich 24-25 Nov 2008 for comments. We also thank Swiss-Systematic Asset Management SA, Zurich for providing data.

1 Introduction

There is a remarkable disproportion between media coverage and financial market literature on safe-haven currencies. While the debate on which and why currencies represent safe-haven assets is burgeoning in the financial press, the scientific literature has been mostly silent. Furthermore, media views appear highly changeable and conflicting. A currency considered secure at one point in time may not be considered safe just few months later. For instance, on 30 August 2002, the Straits Times run the title "(The) Greenback still a safe haven currency" and three months later the International Herald Tribune argued that "U.S. dollar loses its appeal as world's 'safe haven' currency." Similarly, at the end of May 1993, the Business Times highlighted that "(The) Mark loses shine as safe haven currency," but one year later the France Press Agency titled one of its reports on 26 May 1994 "Mark lifts as safe-haven currency."

There are several (related) ways to define a "safe haven" asset. For instance, Kaul and Sapp (2006) define it as an asset that investors purchase when uncertainty increases. Similarly, Upper (2000) defines a safe haven asset as an instrument that is perceived as having a low risk and being highly liquid. In this view, a safe haven asset is akin to any hedging asset, that is, an instrument which is uncorrelated or negatively correlated with its reference asset. In contrast, Baur and Lucey (2006) define it as an asset that does not co-move with other assets *in times of stress*. In this study, we consider all these ideas.

Our paper addresses two questions: first, which currencies can actually be considered safe-haven assets and, second, how safety effects materialise. To answer the first question, we provide an empirical analysis that relates currencies' risk-return profiles to equity and bond markets. Our empirical specification is meant to be parsimonious but still capture two important safe-haven drivers. First, it captures depreciations of safe-haven currencies due to gradual erosions of risk aversion inherent in phases of equity markets upturns. Second, it accounts for risk episodes of more extreme nature—when risk perception rises suddenly. To shed light on how safety effects materialise, our study looks into the characteristics and timing of the safe-haven mechanism. We find a systematic relation between risk increases, stock market downturns and safe-haven currencies' appreciations. In particular, the relation between return and volatility is non-linear—supporting Plantin and Shin (2008) in which the carry trade performance "goes up with the stairs, and comes down in the elevator." By changing the time granularity of our analysis, we also provide evidence that this risk-return transmission mechanism is operational from an intraday basis up to several days.

Our study is related to three main fields of the financial literature. First, the literature on safe-haven currencies provides only limited and occasional evidence of this phenomenon. For instance, Kaul and Sapp (2006) show that the US dollar was used as a safe vehicle around the millennium change. Here, we provide empirical evidence that safe-haven effects override specific events and market conditions. Thus, sporadic loss and gain of safe-haven attributes of a given currency is only the visible part of an iceberg. Safe-haven quality might be latent.

Second, our paper contributes to the carry trade literature (e.g. Burnside, Eichenbaum, Kleshchelski, and Rebelo (2006) and Burnside, Eichenbaum, and Rebelo (2007a)[1]). As in Brunnermeier, Nagel, and Pedersen (2008), we look at the excess performance of exchange rates as appreciations of counter currency plus the interest rate differential. Thus, performance of safe haven currencies mirror the losses of the carry trade speculation. Our results show that the market conditions associated with a reduction of safe haven effects correspond to a rise in carry trade attractiveness.

Third, our study provides empirical support to flight-to-quality and contagion phenomena. The flight-to-quality literature argues that an increase in perceived riskiness engenders conservatism and demand for safety (e.g. Caballero and Krishnamurthy (2007)). At the same time, the contagion literature shows that risk and market crashes spill over across countries, international markets and, possibly, asset classes (e.g. Hartmann, Straetmans, and De Vries (2001)). Here, we show that there exists a significant, systematic transmission among risk-performance payoffs of international currencies, equities and bond markets.

Two main results emerge from our work. First, it shows that by its nature, the fortune of the US dollar goes hand-in-hand with risk appetite pervading financial markets. On the other hand, the Swiss franc and to a smaller extent, the Japanese yen and the euro have significant safe-haven characteristics and move inversely with international equity markets and risk perception. These results appear stable across time and they hold also after controlling for several factors such as the performance of local equity markets or allocation into investment vehicles commonly considered safe assets. These effects are

[1] See also Burnside, Eichenbaum, and Rebelo (2007b), Burnside, Eichenbaum, Kleshchelski, and Rebelo (2008) and Lustig, Roussanov, and Verdelhan (2008).

not only statistical but also economically significant. For instance, on 2% of the days in our sample 1993–2007 (that is, on around 60 days), the equity price drop is so large that our regression equation predict at least a 0.33% appreciation of the Swiss franc (against the US dollar). Similarly, on 2% of the days (not necessarily the same days as before), the increase in the currency market volatility is so large that the regressions predict at least a 1% percent appreciation. Second, our study delivers insights on how safe-haven effects materialise: the safe haven effects are evident in hourly as well as weekly data, but seem to be strongest at frequencies of one to two days.

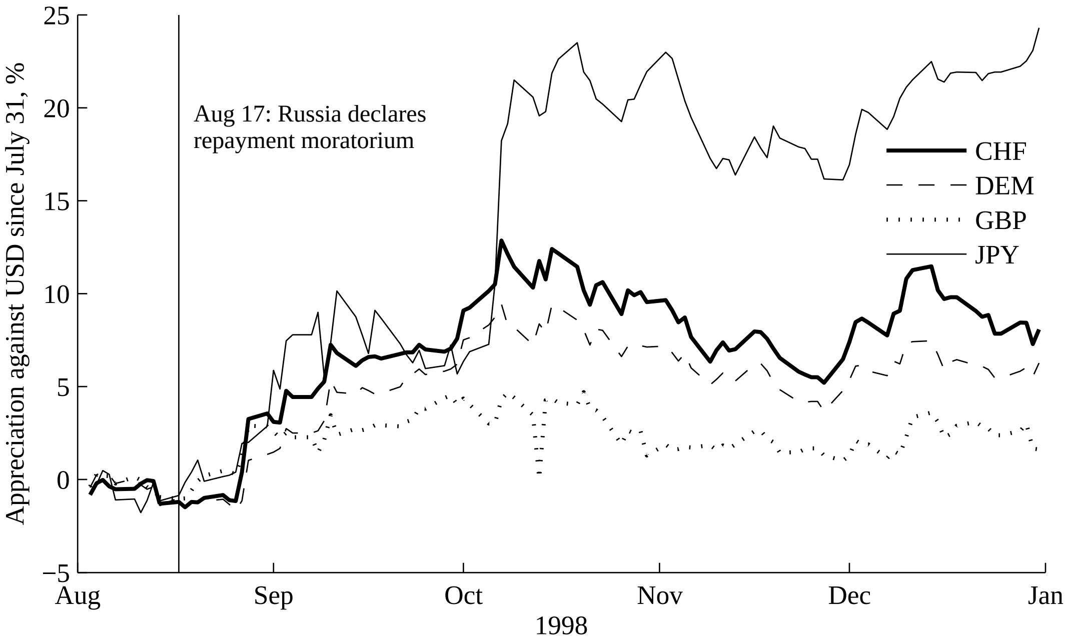

Figure 1: **Exchange rate development around the Russia crisis.**

The paper proceeds as follows: Section 2 presents some illustrative episodes, Section 3 presents the data sources, Section 4 discusses our econometric method, Section 5 presents the results and Section 6 concludes.

2 Events

As a preliminary analysis, we present some illustrative episodes that notoriously affected international financial markets. On the basis of a subjective choice, we have selected three

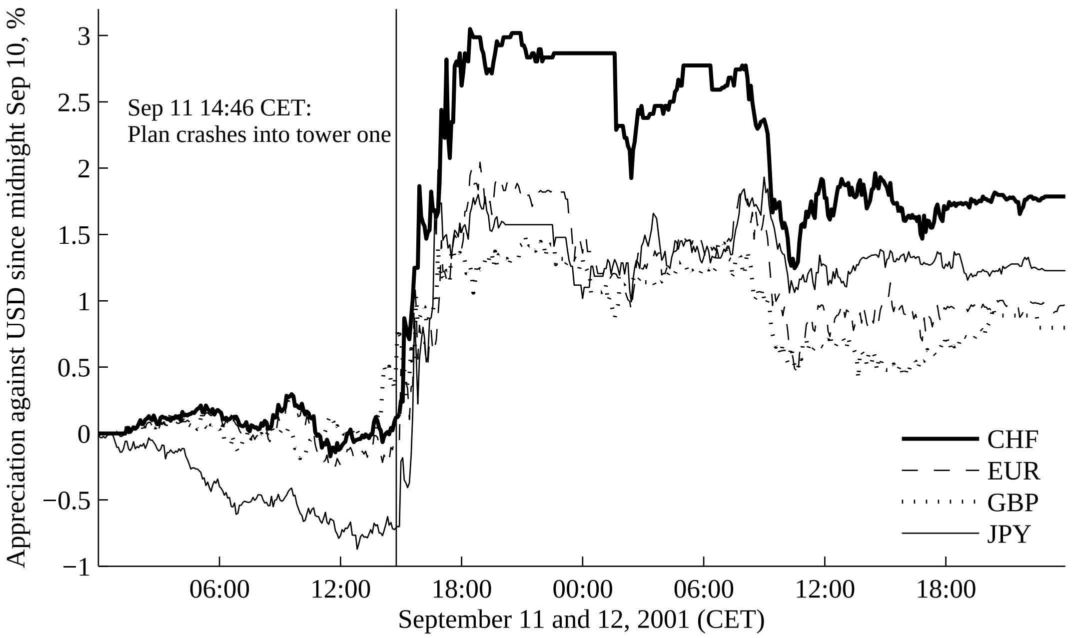

Figure 2: **Exchange rate development around 9/11.**

events that can undoubtedly be considered natural experiments to observe the foreign exchange market reaction to international shocks. In chronological order, the three events are the so-called "Russian financial crisis," "9/11" and "Madrid attacks."

The Russian crisis was preceded by a decline in world commodity prices. Being heavily dependent on raw materials, Russia experienced a sharp decrease in exports and government tax revenue. Russia entered a political crisis when the Russian president Boris Yeltsin suddenly dismissed Prime Minister Viktor Chernomyrdin and his entire cabinet on March 23, 1998. On August 17 Russia declared a repayment moratorium. *Figure 1* shows the evolution of cumulative daily appreciations against the dollar starting from the beginning of August until the end of December 1998. Four exchange rates (against the US dollar) are shown, namely the Swiss franc, Deutsche mark, British pound and Japanese yen. The graph clearly shows that all these currencies (and especially the yen) gained value against the dollar. The appreciations during the initial phase, say from mid-August to mid-October 1998, were pretty significant. The particular behaviour of the yen deserves some comments. There were two instances of sharp appreciation of the yen against the dollar: about 9% in the period between 31 August and 7 September, and then

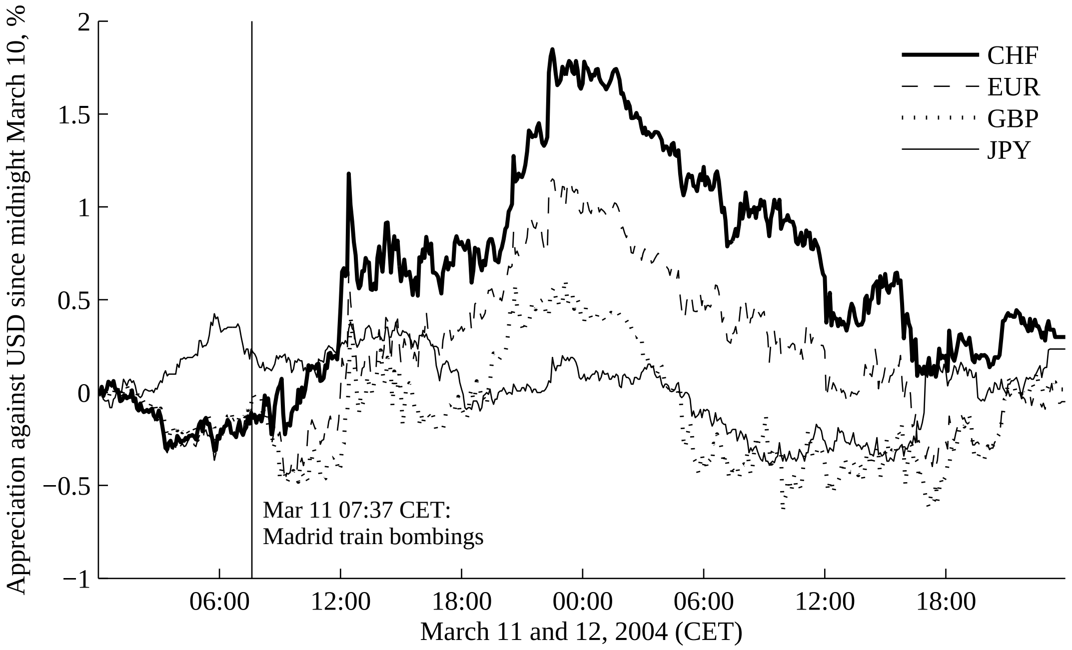

Figure 3: **Exchange rate development around the Madrid bombings.**

by a further 12% on 7 and 8 October. A Bank for International Settlements (1999) study and market commentaries at that time attributed these movements (at least partially) to the unwinding of yen carry trades by hedge funds and other institutional investors.

The two other events considered in this preliminary analysis are 9/11 and the Madrid bombings' attack. For these episodes, it is possible to go back to precise event-times. Therefore, it is also possible to conduct an intraday event analysis. We consider a two-day event-window starting from the day of the terrorist attacks until the end of the day after (more precisely, 11–12 September 2001 and 11–12 March 2004). On the basis of five-minute data, *Figures 2* and *3* show the appreciations of same currencies as considered in the Russian crisis (the euro replacing the mark). In both cases, the Swiss franc experienced by far the strongest appreciation. It appreciated by 3% within two hours after the first plan crash at 14:46 CET (08:46 a.m. EST). During 9/11 crisis, however, all the counter currencies of the US dollar appreciated significantly. During the Madrid attacks, only the Swiss franc and to some extent, the euro appreciated—and the response was slower. This may be due to the fact that it took longer than during the 9/11 event to get a comprehensive picture of the situation. For instance, as later reported, thirteen explosive devices were placed on the trains travelling between Alcalá de Henares and the Atocha station in Madrid.

These episodes give an intuitive picture of the safe haven effect. Below, we will analyse if the safe haven phenomenon is systematic and how it materialises.

3 Data

We analyse the link between foreign exchange rates, equity and bond markets by using high-frequency data for the period 1 Jabuary 1993 to 31 December 2007. We will report results for three-, six- and twelve-hour as well as one-, two- and four-day time frames.

We use spot exchange rates for the following currency pairs: USD/CHF, USD/DEM, USD/EUR, USD/JPY and USD/GBP. On the basis of these exchange rates, we calculate various USD rates as well as cross rates. We construct a synthetic "EUR" series by splicing the DEM (1993–1998) with the EUR data (1999–2007).

A study of intraday market co-movements requires observations on synchronised and homogeneously spaced time series. We therefore organise our database in 288 five-minute intervals for each day excluding weekends. The five-minute data is calculated from the tick-by-tick FXFX Reuters midquote price (the average price between the last representative ask and bid quotes of the five-minute interval). Although indicative quotes have their shortcomings[2], the microstructure literature shows that for frequencies shorter than tick-frequency, the indicative mid-quote is well representative (Danielsson and Payne (2002)).

We track the equity and bond markets by means of futures contract data. We mainly analyse the futures contracts on the Standard & Poor's 500 Stock Price Index and 10-Year US Treasury notes, quoted on the Chicago Mercantile Exchange and Chicago Board of Trade, respectively.[3] The data contain the time stamp to the nearest second and transaction price of all trades that occurred during the sample period—and we organise it as 5-minute data to match the exchange rates. We use the most actively traded nearest-to-maturity or cheapest-to-delivery futures contract, switching to the next-maturity contract five days before expiration. If no trades occur in a given 5-minute interval, we copy down the last

[2]See Lyons (1995) for a discussion about the limitations related to Reuters indicative quotes. All these supposed limitations have no substantial bearings on our main results since we use larger time frequencies than minutes and profitability is not our concern.

[3]We have also analysed S&P500 futures contract coming from the open-outcry auction system and the GLOBEX electronic trading platform. The inclusion or exclusion of GLOBEX data does not affect our results.

trading price in the previous time interval (see Andersen, Bollerslev, Diebold, and Vega (2004) and Christiansen and Ranaldo (2007)).

These futures markets have overnight non-trading times. For the *intraday* analysis we try to fill the gaps as far as possible. Unfortunately, this proved difficult for the bond market data. However, for the equity market we were able to construct a nearly round-the-clock equity market time series by combining equity futures data from different regions. We do this by using futures contract prices on the DAX and NIKKEI 225 indices traded on the Eurex and Singapore exchanges. The regular time length of a trading day for the "round-the-clock" equity index is as follows: from midnight to 8:00 a.m. (GMT) the NIKKEI futures, from 9:00 a.m. to 16:00 p.m. DAX futures and from 16:00 to 22:00 p.m. S&P futures. This leaves three hours uncovered.[4]

In our study, we analyse returns and realised volatility.[5] We investigate these over different time granularities, from a few hours to almost a week. Thus, for example, the three-hour time frame relies on the return and realised volatility that occurred over the last three hours. We use the usual method proposed by Andersen and Bollerslev (1998) to calculate realised volatility as the sum of consecutive squared log price changes.[6] Since intraday realised volatility has a time-of-day seasonality, it needs to be adjusted for these patterns. We have considered different methods.[7] Here, we present our findings based on the simple method adjustment represented by $ARV_{i,t} = RV_{i,t} / \sum_{t=1}^{T} RV_{i,t} / T$, where $ARV_{i,t}$ is the adjusted realised volatility at intraday time i of day t where $t = 1, ..., T$. The denominator represents the regular (average) volatility at that intraday time.[8] In the

[4]This corresponds to the shortest time length for a regular trading day at the beginning of our sample. Later in the nineties, all the three exchanges extended their trading sessions and today electronic trading platforms allow investors to trade 24 hours. The various structures and definitions of "round-the-clock" equity index we have tested provide us with similar and consistent findings. Here, we present the intraday findings based on the three-phase construction described above.

[5]Andersen, Bollerslev, Diebold, and Labys (2001) and Andersen, Bollerslev, Diebold, and Labys (2003), among others, provide empirical evidence that realised volatility is an accurate estimate of intraday volatility.

[6]We compared the Aït-Sahalia, Mykland, and Zhang (2005) method and the Andersen and Bollerslev (1998) method to compute realised volatility over a subsample period of year 2007. Despite some improvement in measuring realised volatility, the main findings about its links with currency excess returns remain essentially the same.

[7]Other adjustment techniques can be applied. However, as shown by Omrane and de Bodt (2007), the adjustment method based on intraday average observations succeeds in estimating periodicities almost perfectly.

[8]We have considered different definitions of T, in particular the last one up to six months and the whole sample. All these definitions provide similar results. Here, we show the findings based on the entire sample.

regressions, we use the logarithm of the realised volatility since that assures a more Gaussian distribution and better statistical properties (see e.g. Andersen, Bollerslev, Diebold, and Labys (2003)).

4 Method

An asset is often considered a safe haven if is does not co-move (positively) with the "market." We will consider two versions of this idea: the first focuses on the unconditional covariance (estimated by a linear regression), while the second studies if the covariance is different in different market situations (estimated by a non-linear regression). We also allow for time-varying market risk to directly affect the exchange rates. This means that the safe haven component does not necessarily emerge only in political turmoil but that it depends on anything that has some significant effect on risk.

Our goal is to study how exchange rates are related to equity and bond markets. We start the analysis by a linear factor model for the excess return from investing in a foreign money market instrument (R_t^e)

$$R_t^e = \beta' f_t + \alpha + u_t, \tag{1}$$

where f_t is a vector of factors and u_t are the residuals. The excess return R_t^e equals the return from investing in a counter currency in excess of the return from investing in the base currency: the appreciation of the counter currency plus the interest rate differential (counter minus base currency interest rates). Brunnermeier, Nagel, and Pedersen (2008) use the same definition to measure the performance of a carry trade speculator. Thus, performance of a safe haven currency corresponds to the losses of the carry trade speculation. For instance, for the CHF/USD this is the appreciation of the CHF relative to USD plus the difference between the Swiss and US interest rates, that is, the USD return on a long position in the Swiss money market, plus the return on a short position in the US money market.

The interest differentials between short-term bonds denominated in US dollar against those denominated in Swiss franc and yen were almost always positive. For instance, the interest rate differentials between US dollar and the yen (franc) 3-month LIBOR rates were 98% (92%) of time positive. On average, the differentials were 3.7% (2.3%)

for the dollar-yen (dollar-franc) LIBOR rate differentials.[9] Therefore, the JPY/USD and CHF/USD can be seen as potential carry trade positions. This is consistent with Galati, Heath, and McGuire (2007) who indicate that the yen and Swiss franc are indeed the main funding currency used by carry trade speculators.The factors in our model include returns on equity and bond markets as well as proxies for time-varying risk. We think of this model as a linearised version of a "true" factor model. In this true model, the only factors are the equity and bond markets, but they have time-varying betas. We approximate this true (time-varying) model by specifying a time-invariant model with extra factors: the proxies for time-varying risk (from measures of market volatility) and lags are meant to capture the movements in the true betas. To get long samples with high-quality data (also on high frequencies), we approximate the equity and bond markets by (futures on) the S&P 500 and 10-year U.S. Treasury notes.

Our factor model can be given several interpretations. The most narrow version is that we are taking the perspective of a U.S. investor and use a somewhat extended CAPM—or that equities and bonds substitute for consumption in CCAPM.[10] A broader interpretation is to think of the U.S. equity and bond markets as convenient proxies for global markets or consumption: the U.S. markets have long available samples of high-frequency data—and are highly correlated with international markets. If so, our factors should capture the key aspects of a global asset pricing model.[11]

Our focus is on understanding the short-run (from a few hours to almost a week) returns from bets on exchanges rates. This has two important implications. First, all our factors are financial. This is because financial factors are likely to dominate the short-run movements of exchange rates—and there is no high-frequency macro data. We therefore have little to say about long run movements of exchange rates, which are likely to be influenced also by macro factors (for instance, inflation, income growth and money supply). Second, we use the factor model mostly to estimate the betas—to study the safe haven effects (if any). We do also test the cross-sectional pricing implications, but the main focus

[9]The USD-JPY and USD-CHF 3-month LIBOR differentials were negative only at the beginning of our sample period, i.e. from January 1993 up to May 1993 (March 1994) for the yen (franc). The main findings of our analysis remain the same by leaving out these initial periods.

[10]See, for instance, Mark (1988) for a CAPM model of currency returns and Baekaert (1996) for a consumption-based model.

[11]See, for instance McCurdy and Morgan (1991), Dahlquist and Bansal (2000), Sarkassian (2003), Groen and Balakrishnan (2006) and Lustig, Roussanov, and Verdelhan (2008) for equity and/or consumption based factor models of exchange rates.

is on the betas.

We have tried several different specifications of the factor model, but in the end we use the following form

$$\begin{aligned} R_t^e = {} & \beta_1 \mathrm{S\&P}_t + \beta_2 \mathrm{TreasNote}_t + \beta_3 \mathrm{FXVol}_t + \\ & \beta_4 \mathrm{S\&P}_{t-1} + \beta_5 \mathrm{TreasNote}_{t-1} + \beta_6 \mathrm{FXVol}_{t-1} + \beta_7 R_{t-1}^e + \alpha + \varepsilon_t, \end{aligned} \tag{2}$$

where $\mathrm{S\&P}_t$ is the return on a Standard and Poor's futures, $\mathrm{TreasNote}_t$ is the return on a Treasury note futures and FXVol_t is a measure of currency market volatility.[12] The dependent variable and the regressors are always measured over identical time intervals. For instance, when we study the 24-hour frequency, then the returns are measured over 24 hours and the FX volatility is the realised volatility over the same 24 hours. (For the x-hour frequency, substitute x for 24.)

The currency market volatility (FXVol_t) is defined as the first principal component of the logarithm of realised volatilities of the exchange rates (against the USD)—excluding the currency in the dependent variable (R_t^e). For instance, when CHF/USD returns is the dependent variable, then FXVol_t is based on the log realised volatilities of EUR/USD, JPY/USD and GBP/USD.[13] The exchange rate quotes are stale on a few days, which creates large negative outliers in the log realised volatility. For that reason, we delete around 10 days. These days happen to lack other data as well, so in the end this procedure effectively cuts out only 3 days of data.

We arrived at the regression equation (2) after noticing several things. First, we also tried to include the lagged interest rate differential as a regressor, but it was hardly significant and had virtually no effect on the other estimated coefficients. Second, alternative measures of currency market volatility (for instance, JP Morgan's (2006) implied volatility index and the UBS FX Risk Index) gave similar results to those presented in the table. Third, proxies for bond market risk (in particular, the Merrill Lynch's Move index) also gave results similar to those presented in the table. Fourth, various proxies for stock mar-

[12]For the daily analysis, we have replicated the regression analysis by using return data based on the underlying assets of the S&P index and Treasury notes rather than futures contract data. We also tried several definitions of return such as close-to-close and open-to-close returns. The results remain virtually the same.

[13]The first principal component accounts for more than 70% of the overall volatility in the 4 exchange rates and the loadings are very similar across curriencies. Therefore, a straight average realised volatility gives very similar results.

ket risk (for instance, realized S&P volatility and CBOE's VIX and spreads on corporate bonds) turned out to be insignificant. This can be explained by prolonged periods of volatility patterns mainly due to stock-specific circumstances such as the so-called "accounting scandals" and "dot-com bubble." Fifth, further lags were not significant. Sixth and finally, adding stock market returns for the counter currency did not change the results significantly.

We estimate (2) with ordinary least squares (and a few other methods)—for different currencies and data frequencies. The significance tests use the Newey-West estimator of the covariance matrix, which accounts for both heteroskedasticity (which is present) and autocorrelation (which actually isn't present).

The linear factor model (2) allows us to study several aspects of safe haven effects: if the exchange rate is negatively related to stock returns ($\beta_1 < 0$) and it is positively related to market uncertainty ($\beta_3 > 0$)—which would be typical patterns for a safe haven asset. However, we are agnostic about how the Treasury notes (futures) returns ought to be related to a safe haven asset. It could be argued that we should apply the same reasoning as for stock returns. Alternatively, it could be argued that Treasury notes are themselves considered safe havens, so other safe haven assets should be positively related to them.

To study non-linear effects (for instance, if the betas are different in dramatic down-markets) we also estimate a sequence of partial linear models, where one (at a time) of the regressors in (2) is allowed to have a non-linear effect of unknown form. This non-linear effect is estimated by a kernel method, using a gaussian kernel and a cross-validation technique to determine the proper band width (see Pagan and Ullah (1999)).[14] We apply this by first allowing only the current S&P futures returns to have non-linear effects, then only the current Treasury notes futures returns and finally only the current currency market volatility. Based on the results from these estimations, we proceed by estimating a piecewise linear regression where each regressor is (endogenously) assigned two segments—and separate slope is estimated for each segment (see Hastie, Tibshirani, and Friedman (2001)).[15]

[14]For instance, a partial linear model with a vector of regressors in x_{1t} and a single regressor in x_{2t} is $y_t = x_{1t}'\beta + g(x_{2t}) + u_t$. The estimation is done by the "double residual" method where $g(x_{2t})$ is estimated by a kernel regression technique.

[15]For instance, a piecewise linear regression with just one regressor could be specified as $y_t = \beta_0 + \beta_1 x_t + \beta_2 \max(x_t - \xi, 0) + \varepsilon_t$, where the coefficients $\beta_0, \beta_1, \beta_2$ as well as the knot ξ are estimated.

Because of the restricted trading hours of the Treasury notes futures (before 2004), we have to make some adjustments when we use the *intraday* data (below, we report results for 3–,6– and 12–hour horizons, in addition to 1–,2– and 4–day horizons). For instance, for the three-hour horizon, the Treasury note futures returns are only available for 4 of the 8 three-hour intervals of a day (and night), while the most of the other data is available for 7 or 8 intervals. (In contrast, for the equity market we are able to construct an almost round-the-clock series by using also the NIKKEI and DAX, see Section 3.) To avoid losing too much data in the intraday regressions, we do two things. First, the lagged Treasury note futures is excluded (that is, β_5 in (2) is restricted to zero). Second, we apply the Griliches (1986) two-step approach to handle the still missing data points of the Treasury note futures. Effectively, this means that we estimate the β_2 coefficient in (2) on the 4 three-hour intervals with complete data, but the other coefficients on the 7 or 8 three-hour intervals.

5 Results

5.1 Results for Daily Data

Table 1 shows results from estimating the regression equation (2) on daily data. Different exchange rates (against USD) are shown in the columns. All these exchange rates show significant safe haven patterns: they tend to appreciate when *(a)* S&P has negative returns; *(b)* U.S. bond prices increase; and *(c)* when currency markets become more volatile. The perhaps strongest safe haven patterns are found for the CHF and EUR and the weakest for GBP. These effects appear to be partly reversed after a day: the lagged coefficients (for S&P and FX volatility) typically have the opposite sign. While the reversal of the effects of stocks is only partial, the reversal of the effect from FX volatility is almost complete.[16] In any case, this suggests that there is some predictability—and there is also some further predictability coming from the negative autoregressive coefficient.

We also test the cross-sectional asset pricing implications of the factor model, that $\mathrm{E}\, R_t^e = \beta'\lambda$, where λ are the factor risk premia. To do so we drop all lags to get three factors and four exchange rates, that is, one overidentifying restriction. A (one-step)

[16]For stocks, the null hypothesis that the sum of the coeffcients of the contemporaneous and lagged regressors is zero can be rejected at traditional significance levels. In contrast, the hypothesis cannot be rejected for for the FX volatility coefficients (except for JPY/USD). Details are are available upon request.

	CHF/USD	EUR/USD	JPY/USD	GBP/USD
S&P	−0.14	−0.11	−0.03	−0.06
	(−11.30)	(−8.91)	(−2.50)	(−6.92)
Treasury notes	0.23	0.16	−0.01	0.15
	(6.63)	(4.72)	(−0.24)	(5.67)
FX volatility	1.03	0.62	0.97	0.32
	(3.79)	(2.55)	(3.55)	(1.81)
S&P$_{t-1}$	0.05	0.05	−0.00	0.04
	(3.76)	(4.52)	(−0.04)	(4.93)
Treasury notes$_{t-1}$	0.10	0.08	0.17	0.06
	(3.58)	(2.74)	(5.16)	(2.38)
FX volatility$_{t-1}$	−0.92	−0.55	−0.61	−0.40
	(−4.22)	(−2.65)	(−2.84)	(−2.59)
Own lag	−0.06	−0.07	−0.01	−0.05
	(−2.81)	(−3.50)	(−0.49)	(−2.46)
Constant	0.00	−0.00	−0.00	0.00
	(0.32)	(−0.10)	(−0.93)	(2.05)
R^2	0.08	0.06	0.02	0.04
n obs	3127.00	3131.00	3135.00	3169.00

Table 1: **Regression results, excess returns of different exchange rates (in columns) as dependent variables.** The table shows regression coefficients and t-statistics (in parentheses) for daily data 1993–2007. The t-statistics are based on a Newey-West estimator with two lags. The excess return of exchange rate xxx/yyy is the appreciation of xxx against yyy plus the interest rate differential (xxx interest rate minus yyy interest rate). The data for S&P and Treasury notes are returns on futures; FX volatility is the first principal component of the realised volatilites for several exchange rate excess returns.

GMM based test shows that the model cannot be rejected at conventional significance levels.[17] This suggests that our analysis of the betas (the focus of this paper) is not based on a misspecified factor model.

The R^2 are low (8% for the CHF/USD is the highest), so most of the daily exchange rate movements are driven by other factors. This is not surprising, given the noisiness of FX markets on a daily basis. What is important is that Table 1 shows distinct and

[17] The GMM system is set up to generate the same point estimates as the factor model (1) and LS estimates of λ in $\mathrm{E}\, R^e_t = \beta'\lambda$ (see, for instance, Cochrane (2005)). Two lags are used in the covariance estimator. Such tests on exchange rates are also done in, among others, McCurdy and Morgan (1991) and Dahlquist and Bansal (2000).

	β_1S&P	β_2Treasury notes	β_3FX Volatility
0.005	−0.48	−0.32	−0.25
0.010	−0.39	−0.26	−0.21
0.020	−0.31	−0.21	−0.18
0.980	0.33	0.18	0.21
0.990	0.38	0.22	0.24
0.995	0.44	0.24	0.29

Table 2: **Quantiles of effect of contemporaneous regressors on CHF/USD excess returns, %.** The table shows quantiles of regression coefficients times the demeaned contemporaneous regressors for 1993–2007. The regression coefficients are from Table 1.

(statistically) significant safe haven effects—and that those effects also have economic significance. To illustrate the latter, *Table 2* shows selected quantiles of the "effect" of the contemporaneous regressors on the CHF/USD excess returns. That is, in terms of the regression equation (2) it shows quantiles of $\beta_1\text{S\&P}_t$ (demeaned), $\beta_2\text{TreasNote}_t$ (demeaned) and $\beta_3\text{FXVol}_t$ (demeaned). For instance, the results for the 0.98 quantile show that on 2% of the days (around 60 days from our sample), the S&P returns (Treasury notes) are associated with at least a 0.33% (0.18%) return of the CHF/USD exchange rate while the FX volatility is associated with at least a 0.21% return. (It can be shown that adding the effect of the lagged regressor produces similar quantiles.)

A pertinent question is whether the dollar (rather than its counter currency) determines the results. That is, one can wonder whether the dollar has some pro-cyclical patterns rather than CHF or EUR conveying safe-haven effects. To address this question, *Table 3* shows results for all cross rates. Once again, the CHF shows safe haven patterns: it appreciates (significantly) against the other cross currencies in the same situations as it appreciates against the USD (negative S&P returns, U.S. bond price increases and currency market volatility). Also similar to the previous results, the GBP is perhaps the least safe haven. The EUR and JPY are mixed cases, since the JPY/EUR rate appreciates when the S&P strengthens and the Treasury note futures weakens (opposite to the CHF/EUR pattern), but it also appreciates when the currency market volatility increases (similar to the CHF/EUR pattern). It can also be noticed that both the "reversal effect" and the negative autocorrelation are weaker on the cross-rates.

To illustrate the stability (over time) of our results *Figure 4* shows regression results

	JPY/EUR	GBP/EUR	CHF/EUR	GBP/JPY	CHF/JPY	CHF/GBP
S&P	0.08	0.05	−0.03	−0.03	−0.11	−0.08
	(5.09)	(4.32)	(−4.16)	(−2.08)	(−7.69)	(−7.33)
Treasury notes	−0.15	−0.01	0.08	0.14	0.23	0.09
	(−3.50)	(−0.26)	(4.10)	(3.67)	(5.82)	(3.26)
FX volatility	0.60	−0.22	0.45	−1.09	−0.56	0.74
	(2.28)	(−1.23)	(3.34)	(−3.85)	(−1.91)	(3.98)
S&P$_{t-1}$	−0.06	−0.01	−0.01	0.04	0.05	0.01
	(−3.75)	(−1.22)	(−0.99)	(2.84)	(3.54)	(0.60)
Treasury notes$_{t-1}$	0.10	−0.02	0.03	−0.11	−0.08	0.04
	(2.81)	(−0.60)	(1.71)	(−3.21)	(−2.30)	(1.74)
FX volatility$_{t-1}$	−0.35	0.01	−0.45	0.53	0.19	−0.54
	(−1.51)	(0.06)	(−3.00)	(2.38)	(0.83)	(−3.40)
Own lag	0.02	−0.05	−0.02	0.00	0.03	−0.04
	(0.89)	(−2.11)	(−0.63)	(0.02)	(1.22)	(−1.83)
Constant	−0.00	0.00	0.00	0.00	0.00	−0.00
	(−0.66)	(1.92)	(0.44)	(2.23)	(1.09)	(−1.81)
R^2	0.03	0.01	0.02	0.03	0.05	0.04
n obs	3086.00	3130.00	3089.00	3102.00	3062.00	3119.00

Table 3: **Regression results, excess returns of different exchange rates (in columns) as dependent variables.** The table shows regression coefficients and t-statistics (in parentheses) for daily data 1993–2007. The t-statistics are based on a Newey-West estimator with two lags. See Table 1 for details on the data.

from different subsamples of daily data (with CHF/USD excess returns as the dependent variable). The importance of the regressors has changed somewhat over time. In particular, it seems as if the S&P has recently had a smaller effect, while the Treasury notes has become increasingly important. However, the overall safe-haven effects appear reasonably stable across time. The same conclusion holds for the other exchange rates (not reported, available upon request).

Overall, the results for daily data seem to corroborate the traditional view of the Swiss franc as a safe-haven asset. Kugler and Weder (2004) find that Swiss franc denominated assets have lower returns than comparable assets denominated in other currencies. In the spirit of our study, this may be due to the safe-haven risk premium inherent in Swiss franc denominated assets. Campbell, Serfaty-de Medeiros, and Viceira (2007) also show the hedging quality of the Swiss franc. Another reason that might play a significant role for

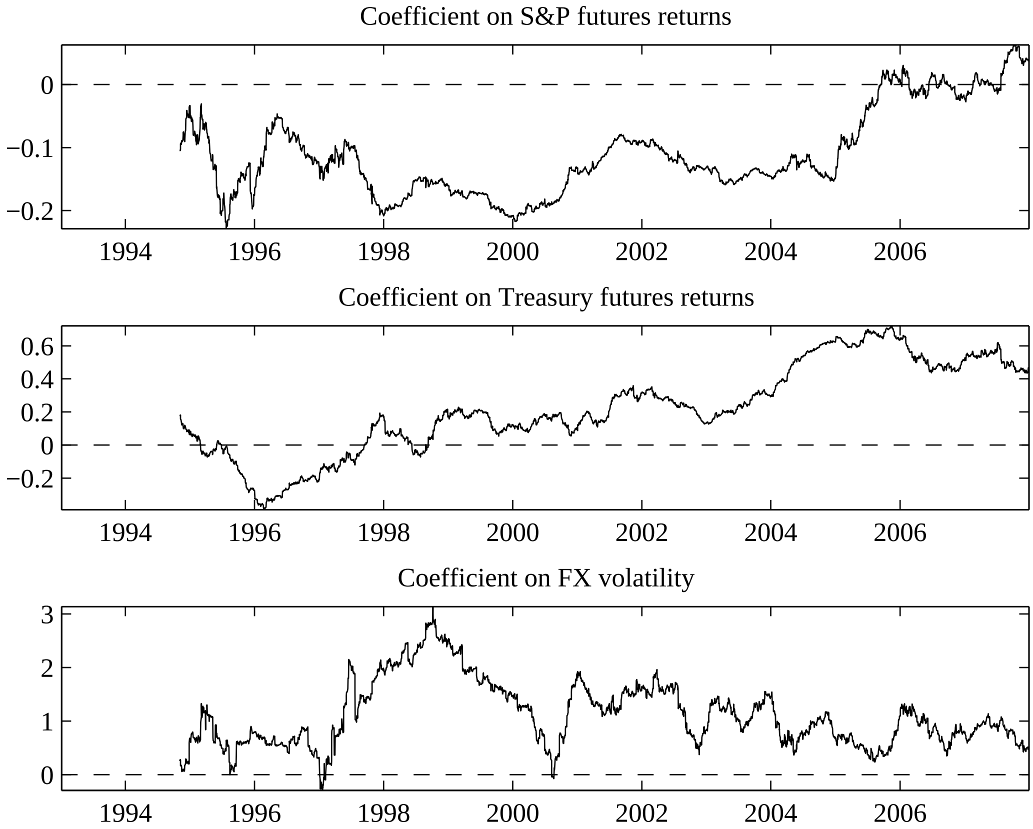

Figure 4: **Regression coefficients (with CHF/USD excess returns as the dependent variable) from a moving data window of 480 days.** This figure shows estimates for the contemporaneous regressors, estimated on moving 480 days samples (ending on the date in the plot). See Table 1 for details on the data.

its appreciations during market turmoils is the so-called "(espresso) coffee cup effect," that is, the phenomenon whereby investors switch from a large to a small currency area, which has a greater impact on the small currency area than on the large one. This idea emphasises the relevance of an elastic supply of liquidity, especially in times of market turmoil.

5.2 Results for other Data Frequencies

Based on the findings so far, we now study how the safe haven effects look at different time frames, in different time periods, in crisis periods—and if there are any non-linear patterns.

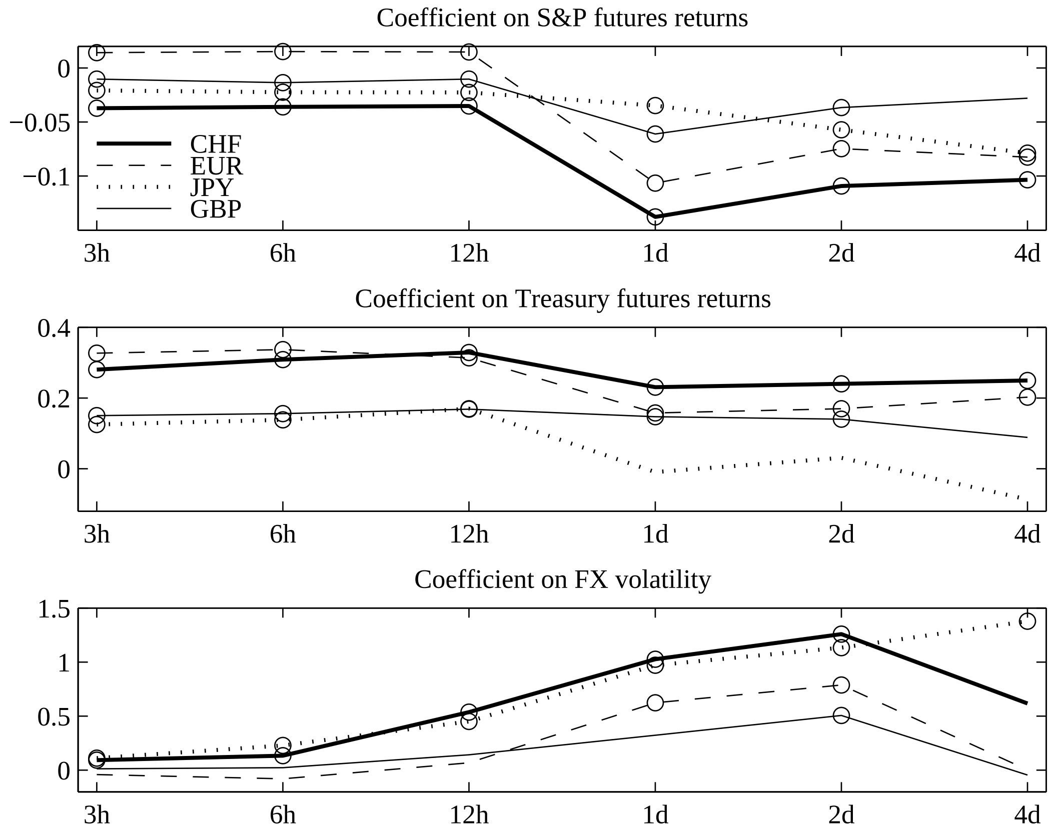

Figure 5: **Regression results for different horizons, excess returns of different exchange rates as dependent variables.** The figure shows regression coefficients for 1993–2007. In addition, t-statistics (based on a Newey-West estimator with two lags) with absolute values above 1.96 are indicated by circles. The regressions on intra-day data do not include the lagged Treasury notes futures as a regressor, and apply Griliches (1986) two-step approach to handle the still missing data points for the Treasury notes. See Table 1 for details on the data.

Figure 5 reports results from estimating the regression equation (2) for different horizons: from 3 hours up to 4 days. For the intraday data we use a global equity series (NIKKEI, DAX, and S&P) instead of only S&P to get an almost round-the-clock series and apply the Griliches (1986) two-step approach to handle the still missing data points of the Treasury note futures (see Section 4). The figure only reports results for the contemporaneous regressors, but the lags play virtually the same role as before, that is, inducing partial reversal (details are available upon request).

For the CHF, the safe haven effect is clearly visible on all these horizons, even if magnitude of the coefficients of S&P and currency market volatility is considerably smaller at the shorter horizons—and seem to peak around 1 to 2 days. However, the coefficients are strongly significant also for shorter maturities (circles indicate that the coefficient is significant at the 5% level). The results for the other exchange rates are also very consistent with the results from daily data. These results suggest three main points. First, FX, equity and bond markets are effectively inter-connected even at high frequencies. These links appear significant in statistical and economic terms. For instance, on the three-hour horizon, a 1% decrease of the S&P is associated with a roughly four basis points excess return (appreciation plus interest rate differential) of the CHF and a 1% increase of the Treasury notes with a thirty basis points excess return. Second, currency market risk appears priced into the currency values at any time granularity. Third, the safe haven properties of the Swiss franc seems to dominate (the other currencies) on all frequencies.

5.3 Results from Non-Linear Estimation and Dummy Variable Regressions

Figure 6 shows results for non-linear estimations of daily CHF/USD returns. The dots are results from a partial linear model, where only one variable at a time is allowed to have a non-linear effect (estimated by a kernel regression technique). The lines are the fitted values and a 90% confidence band from a piecewise linear model. In the latter model, each regressor is (endogenously) assigned two segments—and separate slope is estimated for each segment. In contrast to the partial linear model, all variables may (simultaneously) have non-linear effects and it is relatively straightforward to calculate confidence bands. Initial estimates suggest virtually linear effects of the lagged variables, so this is imposed in the results we report below.

The evidence suggests that both the S&P and Treasury notes returns have almost linear effects. This means, among other things, that the effects from S&P are similar in up and down markets. In contrast, there may be some non-linear effects of currency market volatility. In particular, it seems as if it takes a high currency volatility to affect the CHF/USD exchange rate, but that the effect is then much stronger than estimated by the linear model.[18] The economic importance of this is non-trivial: while the linear model showed that on 2% of the days the FX volatility is associated with at least a 0.21% return of the CHF/USD exchange rate (see Table 2), the non-linear model would instead suggest at least a 0.8% return. These patterns are in line with the common wisdom that sudden increase in risk aversion fuel flight-to-quality and to safety that, in turn, lead to unwinding carry trade.

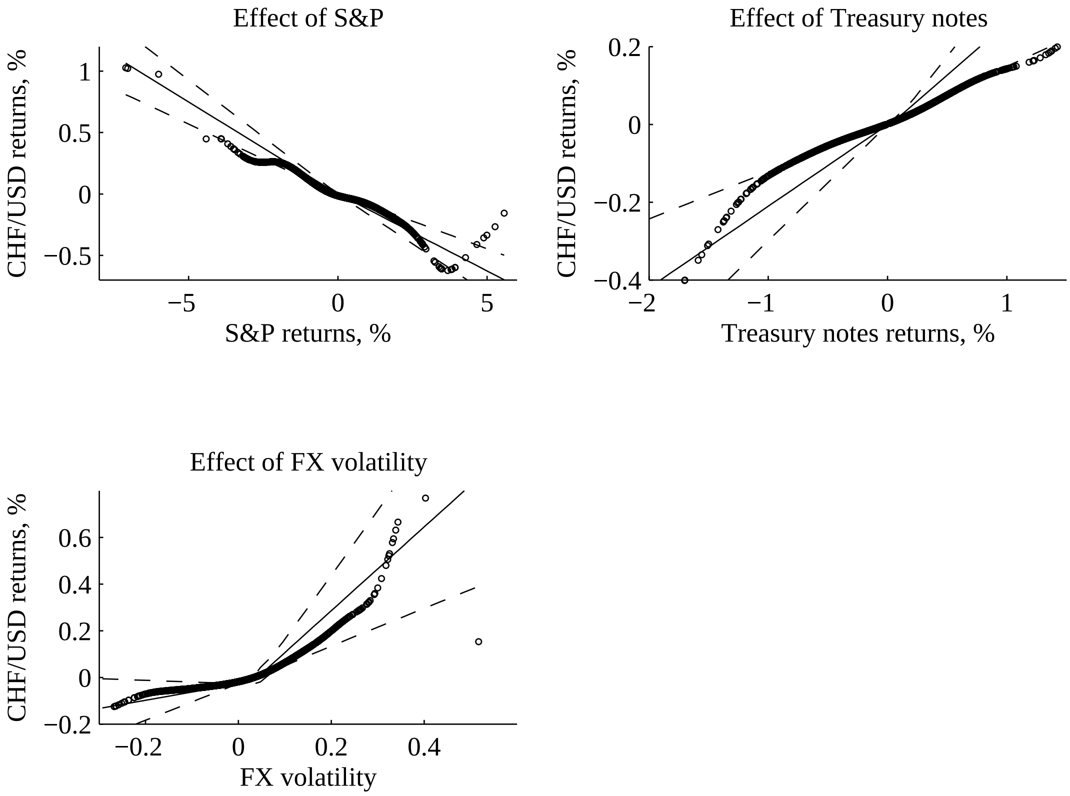

Figure 6: **Non-linear estimates, CHF/USD excess returns.** The dots are results from estimating partial linear models (see Pagan and Ullah (1999)), while the solid lines indicate the fitted curve and the dashed curves 90% confidence bands from a piecewise linear model (see Hastie, Tibshirani, and Friedman (2001)). See Table 1 for details on the data.

Figure 7 illustrates the results from non-linear estimations for all currencies. We only report the results for the FX volatility, since there is very little non-linearity in the other variables. It is clear from the figure that the Euro and yen show patterns similar to the

[18]The apparent positive FX volatility outlier does not affect the results much.

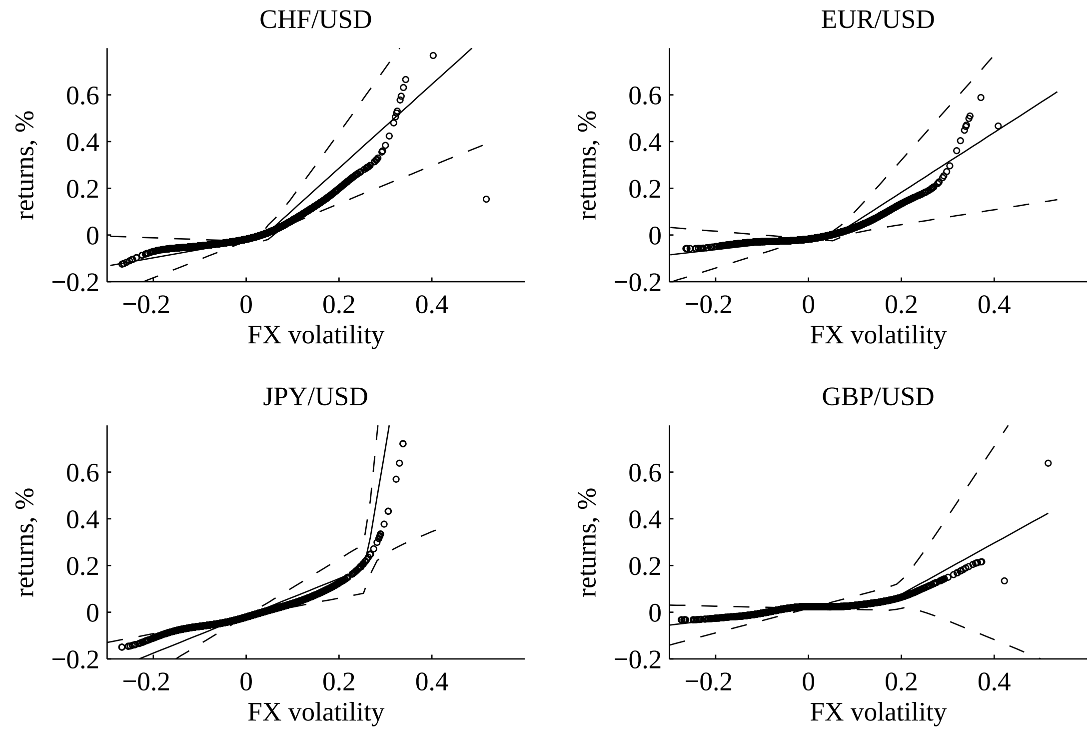

Figure 7: **Non-linear estimates, different exchange rate excess returns as dependent variables.** This figure resports the FX volatility part of piecewise linear regressions. See Figure 6 for details on the method and Table 1 for details on the data.

Swiss franc, but that the pound has virtually no non-lineartities.

The literature proposes some theoretical arguments that imply non-linearity between volatility and exchange rate returns. In particular, the model in Plantin and Shin (2008) provides two rationales for a non-linear linkage between volatility and exchange rate returns. On the one hand, the capital requirement to fund the carry trade speculation (its leverage) decreases (increases) with the value of the high rate currency. This mechanism implies a mutually reinforcing speculation that provides additional positive (funding) externalities for each other by entering carry trades. On the other hand, Plantin and Shin show that in equilibrium, uncertainty in the evolution of fundamentals leads to prolonged periods of smooth appreciation of the high-interest currency and crashes in rapid unwinding dynamics. Our results on non-linearity between excess exchange rate returns and realised volatility are consistent with these ideas. Our findings also square well with Gagnon and Chaboud (2007), Brunnermeier, Nagel, and Pedersen (2008) and Gyntelberg and Remolona (2007) who find evidence of a relationship between the skewness of exchange rate returns and the size short-term interest rate differentials. In fact, we find that the non-linear return-volatility patterns are more marked in those exchange rates with higher differentials, namely CHFUSD and JPYUSD.[19] As pointed out by Gyntelberg and Remolona, this finding suggests that carry trade returns at least partially reflects compensation for large downside risks.

The result presented so far demonstrate safe haven effects, and that they are reasonably stable over time and linear (except possibly for FX volatility). This suggests that the safe haven effects are systematic and not driven by any particular episodes. To gain further insight into this, we re-run the regression for the exchange rate excess returns (daily data), but where all the regressors are also interacted with a dummy variable around large crisis episodes.

The episodes are chosen to represent major media headlines. We try to limit the arbitrariness in the selection of episodes by using factiva.com. This is a Dow Jones' company that provides essential business news and information collected by more than 10,000 authoritative sources including the Wall Street Journal, the Financial Times, Dow Jones and Reuters newswires and the Associated Press, as well as Reuters Fundamentals, and D&B company profiles. The search of these news items was conducted by subject criteria and without any particular free text. We let this information provider order news bulletins by relevance for the following political and general news subjects: risk news including acts of terror, civil disruption, disasters/accidents and military actions. For the sake of comprehensiveness, we also included the most representative financial crises that had political origins (see "Tequila peso crisis", "East Asian Crisis", "Russian financial crisis") and/or initiated by special economic circumstances (see "Global stock market crash", "Dot-com bubble burst" and "Accounting scandals"). The selection of episodes is given in *Table 4*.

We set the dummy variable to unity on the event days and the following 9 days (our "event window") and re-run the regressions for the exchange rate excess returns (daily data), but with all the regressors also interacted with the dummy variable. The results we report below are fairly robust to changes of the event window, although the statistical significance seems to vary a bit—which is not surprising given the low number of data

[19]Leon, Sarno, and Valente (2006) show that non-linearities are also relevant to explain the forward bias puzzle.

Date	Event	Type
12/03/1993	Storm of the Century	Nature
20/12/1994	Tequila peso crisis	Finance
02/07/1997	East Asian Financial Crisis	Finance
27/10/1997	Global stock market crash	Finance
23/03/1998	Russian financial crisis	Finance
10/03/2000	Dot-com bubble burst	Finance
04/06/2001	2001 Atlantic hurricane	Nature
11/09/2001	WTC terrorist attacks	Terror&war
02/12/2001	Accounting scandals (Enron)	Finance
01/11/2002	SARS	Nature
20/03/2003	Second Gulf War	Terror&war
01/08/2003	European heat wave	Nature
11/03/2004	Madrid bombings	Terror&war
24/09/2004	Hurricane Rita	Nature
26/12/2004	Tsunami	Nature
07/07/2005	London bombings I	Terror&war
27/07/2005	London bombings II	Terror&war
23/08/2005	Hurricane Katrina	Nature
08/10/2005	Kashmir earthquake	Nature
12/07/2006	Lebanon War	Terror&war
27/02/2007	Sell-off of Chinese shares	Finance
09/08/2007	Sub-prime crisis	Finance

Table 4: **Event dates**

points in the episodes. In addition, it can always be argued that the list of events is not exhaustive or precise enough. For these reasons, the results should be interpreted as indicative rather than conclusive. Still, several interesting results emerge. First, the results for the “old” regressors are virtually the same as before, so the results reported before indeed seem to represent the pattern on ordinary days. Second, only the FX volatility variable shows “extra effects” during the episodes, so we only report this coefficient in *Table 5*.

The point estimates indicate larger impacts of FX volatility around crisis episodes than on other days. This is particular true for "financial crisis". This finding squares well with the results from the non-linear estimation (see Figure 7), since these crisis episodes are also characterised by large increases in FX volatility.

	CHF/USD	EUR/USD	JPY/USD	GBP/USD
All	2.67	1.11	1.32	2.06
	(3.15)	(1.09)	(1.64)	(2.08)
Nature	3.10	0.44	3.05	5.62
	(1.84)	(0.25)	(1.91)	(2.92)
Finance	3.74	2.71	1.46	1.59
	(3.37)	(2.58)	(1.78)	(1.24)
Terror&War	2.25	−0.89	0.18	0.69
	(0.94)	(−0.47)	(0.12)	(0.42)

Table 5: **Regression results, coefficients on dummy variable $\times$ FX volatility, different exchange rate excess returns as dependent variables.** The table shows regression coefficients and t-statistics (in parentheses) for daily data 1993–2007. The dummy variable is set to unity on the event days defined in Table 4 and the following 9 days. The t-statistics are based on a Newey-West estimator with two lags. See Table 1 for details on the data.

6 Summary

This study has addressed two key questions: first, which currencies have safe haven properties and second, how the safe haven mechanism materialises. Our findings show that the Swiss franc carries the strongest safe haven attributes. The yen and euro have similar, but weaker, properties. The opposite holds for the US dollar that has moved pro-cyclically with equity markets.

In our analysis, excess return of a safe haven currency corresponds to losses in carry trade. Thus, this study shows that the safe haven phenomenon proceeds is a dual, pass-through mechanism. On the one hand, safe haven currencies (carry trade) suffer (prospers) during bull markets. Empirically, we observe a negative correlation between the performance of safe haven currencies and international equity markets. On the other hand, safe haven currencies (carry trade) appreciate (fails) as market risk rises. These patterns are observed on data frequencies of a few hours up to almost a week. The effects are not only statistically but also economically significant. The study also shows that the safe haven phenomenon does not rely only on specific episodes—although it reinforces during episodes that increase market uncertainty.

The findings in this paper could be useful for both monetary authorities and financial investors. Since the exchange rate is an essential channel for inflation, monetary policy makers should carefully consider the state-dependent and time-varying nature of safe-haven properties. Overall, the link between exchange rate and its “fundamental value” depends on how market conditions determine currency valuation. Furthermore, how FX, equity, bond markets are interconnected and how spillovers between return and risk propagate across markets relates to financial stability. On the other hand, the safe haven property is crucial for risk management and asset allocation. In spite of the general conviction that exchange rates are disconnected with other markets, this study highlights the systematic and time-varying risk as well as hedging opportunities inherent in some currencies. It also enhances the understanding of the risk-return payoff in speculative currency strategies such as carry trade.

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