Safe Haven Currencies*

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Abstract

We study high-frequency exchange rates over the period 1993–2008. Based on the recent literature on volatility and liquidity risk premia, we use a factor model to capture linear and non-linear linkages between currencies, stock and bond markets as well as proxies for market volatility and liquidity. We document that the Swiss franc and Japanese yen appreciate against the US dollar when US stock prices decrease and US bond prices and FX volatility increase. These safe haven properties materialise over different time granularities (from a few hours to several days) and non-linearly with the volatility factor and during crises. The latter effects were particularly discernible for the yen during the recent financial crisis.

Keywords: exchange rates, high-frequency data, crisis episodes, non-linear effects

JEL Classification Numbers: F31, G15

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1 Introduction

There is a remarkable disparity between the media coverage and the financial market literature on safe haven currencies. While in the financial press the debate on which currencies represent safe haven assets—and why—is burgeoning, the scientific literature has been mostly silent.

As illustrations of dramatic exchange rate movements, consider "9/11" and the "Madrid attacks" of March 2004. On the basis of five-minute data, *Figures 1* shows the appreciations of several currencies (CHF, EUR, GBP and JPY) against the dollar. For instance, the Swiss franc appreciated 3% against the dollar within two hours after the first plane crash on 9/11 and by 1% within four hours after the first bomb blast in Madrid. This paper examines whether such safe haven patterns are systematic.

We address two questions: first, which currencies can actually be considered safe haven assets and, second, how do safety effects materialise? To answer these questions, we base our empirical analysis on both traditional factor models and on the recent literature about volatility and liquidity risk premia. Our empirical specification is meant to be parsimonious but still account for 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 a more extreme nature. We find a systematic relation between risk increases, stock market downturns and the appreciation of safe haven currencies—and that some of these effects are more than proportional (non-linear patterns). By changing the time granularity of our analysis, we provide evidence that this risk-return transmission mechanism is operational from an intraday basis up to several days.

Our study contributes to three main fields of the financial literature: First, to the literature on safe haven assets. There are two main ways to define what a safe haven asset is: it may provide hedging benefits *on average* or *in times of stress*.

An asset that offers hedging benefits on average is uncorrelated or negatively correlated (unconditionally) with its reference asset.[1] For instance, Campbell, Serfaty-de Medeiros, and Viceira (2009) consider the currency allocation that minimises portfolio risks for global equity and bond investors (on monthly or longer horizons). Similar to our findings, they show that the Swiss franc and euro (US dollar) is negatively (positively) re-

[1] Upper (2000) uses a similar definition when analysing German government bonds.

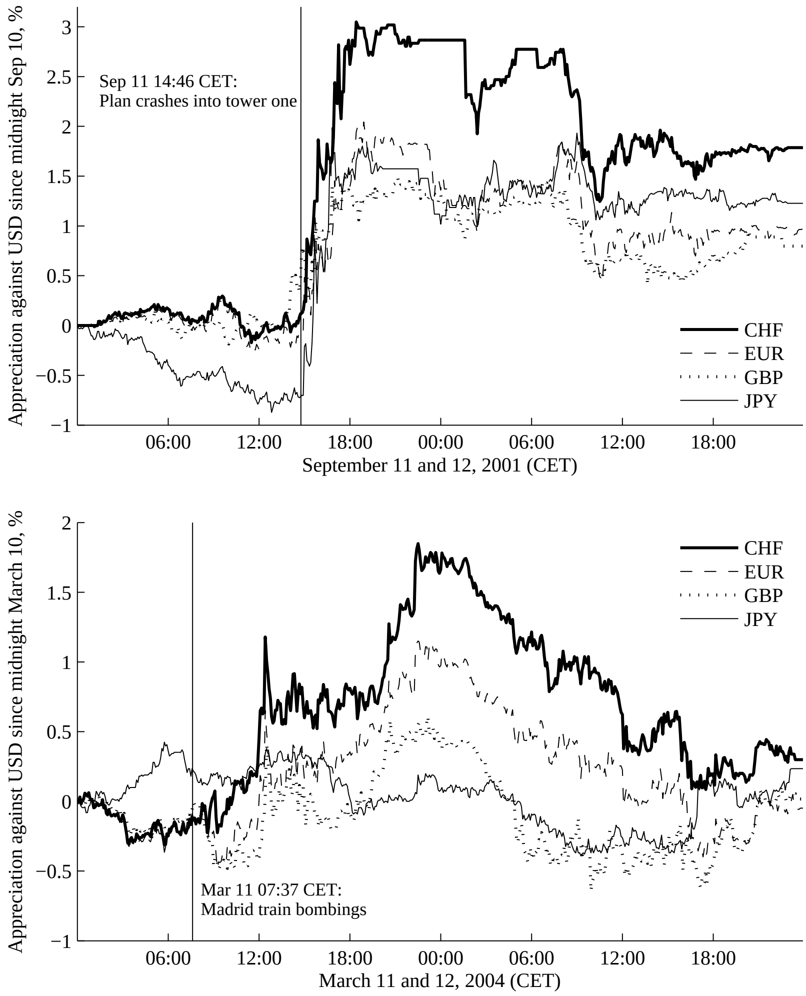

Figure 1: **Exchange rate development around 9/11 and the Madrid attacks.**

lated to equity (bond) returns. However, our contribution differs in several respects: first, our approach also incorporates liquidity and risk factors to capture more than the average hedging properties; second, we demonstrate non-linear patterns; third, we investigate the safe haven mechanism in a high frequency domain (3 hours to several days).

An asset can also be considered a safe haven if it gives hedging benefits in times of stress (conditionally). For instance, Kaul and Sapp (2006) show that the US dollar was used as a safe vehicle around the millennium change.[2] Our contribution is to analyse

[2]A similar definition is also applied by Baur and Lucey (2006) in their examination of whether gold has safe haven properties.

sixteen years of high-frequency data to document that this type of safe haven property (of some currencies) seems to be persistent over time and present both during times of geopolitical crises and whenever the FX markets become volatile.

The definition of safe haven currencies used in our paper thus encompasses both ideas. We show that some currencies provide a hedge in normal times *and* an additional shield in time of crisis (and thus on average).

The second strand of literature related to our study is the recent asset pricing analysis showing that investors require compensation for being exposed to liquidity and/or volatility risk. In particular, Acharya and Pedersen (2005) and Pastor and Stambaugh (2003) show that illiquidity is priced into US stock returns and Ang, Hodrick, Xing, and Zhang (2006) that aggregate volatility risk is another priced factor. This could, for instance, be explained in terms of the model by Brunnermeier and Pedersen (2009), where market liquidity and funding illiquidity are connected and co-move positively with volatility and negatively with returns. Our contribution is to show that this type of liquidity and volatility risk factors are relevant also for currencies (even at such short frequencies as a couple of hours), but that it is risk measures specific to exchange rates that matter—not broader measures of risk like the VIX or TED.

Third, our study contributes to a better understanding of currency movements in tumultuous markets. Since the performance of safe haven currencies mirrors the losses of carry trade speculation, our finding that safe haven currencies have non-linear appreciations with increasing FX risk is of particular interest. It supports the idea of crash risk (Brunnermeier, Nagel, and Pedersen (2009)) with dramatic performance swings (Plantin and Shin (2008)) and Peso problems (Farhi and Gabaix (2008)).[3] The flight-to-quality literature argues that an increase in perceived riskiness engenders conservatism and demand for safety (Caballero and Krishnamurthy (2008)). At the same time, the contagion literature shows that risk and market crashes spill over across international markets (Hartmann, Straetmans, and De Vries (2004)). Here, we shed new light on the role of currencies in these adverse events and we document a systematic (high-frequency) transmission among currencies, equities and bond markets.

Two main results emerge from our work. First, the fortunes of the US dollar go hand-in-hand with risk appetite pervading financial markets. In contrast, the Swiss franc,

[3]On carry trade, see also Burnside, Eichenbaum, Kleshchelski, and Rebelo (2006), Burnside, Eichenbaum, and Rebelo (2007a), Burnside, Eichenbaum, and Rebelo (2007b), Burnside, Eichenbaum, Kleshchelski, and Rebelo (2008) and Lustig, Roussanov, and Verdelhan (2008).

Japanese yen and, to a lesser extent, the euro have significant safe haven characteristics and move inversely with international equity markets and FX volatility. These results hold also after controlling for several factors such as the performance of local equity markets or allocation into investment vehicles commonly considered safe assets, as well as different proxies of risk. The effects are not only statistically but also economically significant. For instance, on 2% of the days in our sample 1993–2008 (that is, on around 67 days), the equity price drop is so large that our regression equation predicts at least a 0.26% 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 0.5% percent Swiss franc appreciation. Second, our study delivers insights into how safe haven effects materialise: the safe haven effects are evident on frequencies from a few hours to several days, and are particularly (non-proportionally) pronounced during times of market stress and/or geopolitical crises.

The paper proceeds as follows: Section 2 provides the theoretical motivation for our approach, Section 3 documents the data sources and discusses our econometric method, Section 4 presents the results and Section 5 concludes.

2 Motivation

A safe haven asset is typically perceived as performing reasonably well in difficult market situations: it should have a low exposure to traditional risk factors and not be markedly sensitive to market volatility and liquidity squeezes. This is strongly related to both traditional factor models and to recent work on volatility and liquidity risk premia.

Acharya and Pedersen (2005) and Brunnermeier and Pedersen (2009) demonstrate both theoretically and empirically that liquidity is a priced factor. Similarly, Ang, Hodrick, Xing, and Zhang (2006) use ICAPM (with the extensions in Campbell (1993,1996)) to argue that market volatility may be a priced factor since it forecasts future volatility—and find supporting empirical evidence. Most of this work has focused on equity markets, but some studies have extended the ideas to carry trade on FX markets. Among others, Brunnermeier, Nagel, and Pedersen (2009) use the TED (the spread between Libor and T-bill rates) as a measure of funding liquidity, while Lustig, Roussanov, and Verdelhan (2008) use the VIX (an index of equity market volatility derived from options) as a risk factor.

The current paper examines whether some of the major currencies (USD, EUR, JPY, CHF and GBP) possess safe haven properties—on data frequencies from a few hours up to almost a week. To do that we incorporate the key factors from both traditional finance models of exchange rates[4] as well as from the literature on market volatility and liquidity discussed above.

Our main tools are linear and non-linear factor models for the excess return from investing in a foreign money market instrument (mostly treating the US as the home market), where the factors are the US equity and Treasury note markets as well as proxies for market "risk": a measure of FX market volatility, the TED spread and the VIX. We include lags since there is some autocorrelation in many exchange rates and also because we want an agnostic way to capture both surprises and expected values of the risk factors (see, for instance, Bandi, Moise, and Russell (2008)). Our main (linear) specification of the factor model is therefore

$$\begin{aligned} R_t^e &= \beta_1 \text{S\&P}_t + \beta_2 \text{TreasNote}_t + \beta_3' \text{Risk}_t + \\ &\quad \beta_4 \text{S\&P}_{t-1} + \beta_5 \text{TreasNote}_{t-1} + \beta_6' \text{Risk}_{t-1} + \beta_7 R_{t-1}^e + \alpha + \varepsilon_t, \end{aligned} \tag{1}$$

where R_t^e is the excess return from investing in a foreign money market instrument, $\text{S\&P}_t$ is the return on a Standard and Poor's futures, TreasNote_t is the return on a Treasury note futures and Risk_t is a vector that may include FX volatility, the TED spread and the VIX. 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 measured as the realised volatility over the same 24 hours. For the x-hour frequency, substitute x for 24. (See Section 3 for details.) We also estimate non-linear versions and extend the model by including interaction dummies around dates with known financial and geopolitical events.

The factor model (1) allows us to study several aspects of safe haven properties: first, if the exchange rate is negatively related to (risky) stock returns ($\beta_1 < 0$); second, if the exchange rate is positively related to bond returns ($\beta_2 > 0$) since Treasury notes can themselves be considered safe havens; third, if it is positively related to market risk ($\beta_3 > 0$)—which would be typical patterns for a safe haven asset. When incorporating non-linear effects, we can also examine whether the exposure to the equity market depends on

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

the market return or whether the exposure to the risk factors only kicks in during extreme market stress. The event dummies add to that by investigating how the risk exposures differ between event dates and other days.

The factor model (1) and the non-linear extension also allow us to study important issues with respect to volatility and liquidity factors. It is interesting to see if the earlier findings (mostly on equities) carry over to the FX market—in particular, to the major currencies. We study two aspects. First, which risk factors are important on the FX market: those representing funding liquidity (TED), general market uncertainty/risk aversion (VIX) or FX market volatility? Second, at which data frequencies are these effects discernible: on 3-hour data or on 4-day data?

Although our focus is on the safe haven properties, the results may still have something to say about carry trade. The interest differentials between US dollar interest rates and the yen and Swiss franc interest rates were almost always positive in our sample. For instance, the interest rate differentials between US dollar and yen (franc) 3-month LIBOR rates were positive 98% (90%) of the time. On average, the differentials were 3.6% (2.1%) for the dollar-yen (dollar-franc) LIBOR rate differentials. Therefore, the JPY/USD and CHF/USD can be seen as potential carry trade positions for much of the sample.[5]

An important limitation of our study is that we focus on short-run returns. We therefore have little to say about long run movements of exchange rates, which are likely also to be influenced by macro factors.

3 Data and Methods

3.1 Data

We analyse the link between foreign exchange rates, equity and bond markets by using high-frequency data for the period 1 January 1993 to 31 December 2008. 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 (1999–2008).

A study of intraday market co-movements requires observations on synchronised and

[5]This is consistent with Galati, Heath, and McGuire (2007) who indicate that the yen and Swiss franc are indeed the main funding currencies used by carry trade speculators.

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 mid quote price (the average price between the last representative ask and bid quotes of the five-minute interval). Although indicative quotes have their shortcomings[6], the microstructure literature shows that for frequencies longer than the tick frequency, the indicative midquote 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 Merctantile Exchange and Chicago Board of Trade, respectively.[7] The data contain the time stamp to the nearest second and transaction prices of all trades that occurred during the sample period—and we organise them 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 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 of a trading day for the "round-the-clock" equity index is as follows: from midnight to 8:00 a.m. (GMT) for NIKKEI futures, from 9:00 a.m. to 16:00 p.m. for DAX futures, and from 16:00 to 22:00 p.m. for S&P futures. This leaves three hours uncovered.[8]

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

[7]We have also analysed S&P500 futures contracts 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.

[8]This corresponds to the shortest length of a regular trading day at the beginning of our sample. All the three exchanges extended their trading sessions in the late 1990s, and today electronic trading platforms allow investors to trade 24 hours. The various structures and definitions of "round-the-clock" equity indices we have tested provide us with similar and consistent findings. Here, we present the intraday findings based

We use several measures of market volatility/liquidity: the TED spread, CBOE's VIX and the realised FX volatility. The TED spread is the difference between the 3-month USD LIBOR interbanking market interest rate and the 3-month T-Bill rate. The FX volatility 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 of the factor model. For instance, when CHF/USD returns are the dependent variable, then the FX volatility is based on the log realised volatilities of EUR/USD, JPY/USD and GBP/USD.[9] The individual time series of realised volatility are computed as in Andersen and Bollerslev (1997), that is, as the sum of consecutive squared log five-minute returns.[10]

The excess return is the appreciation of the counter currency plus the interest rate differential (counter minus base currency interest rates). For instance, for the CHF/USD this is the appreciation of the CHF relative to the 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.

3.2 Methods

The linear factor model (1) is estimated with ordinary least squares—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 is not present).

To study non-linear effects (for instance, if the betas are different in dramatic down-markets) we start by estimating a sequence of partial linear models, where one of the regressors (x_{1t}) is allowed to have a non-linear effect of unknown form while the other regressors (x_{2t}) are assumed to have linear effects

$$R_t^e = g(x_{1t}) + \beta' x_{2t} + \varepsilon_t. \tag{2}$$

on the three-phase construction described above.

[9]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 currencies. Therefore, a straight average realised volatility gives very similar results. The exchange rate quotes are stale on a few days, which creates large negative outliers in the log realised volatility. For that reason, we replace observations below the 0.0025 quantile with that quantile. This puts a "floor" on the data for approximately 10 days of the sample. These days often lack other data as well (often 25 or 31 Dec), so in the end this procedure effectively relates to only 5–6 days of data.

[10]For liquid assets such those analysed here, it is reasonable to assume that the microstructure noise is negligible at a sampling frequency from five minutes or higher, as argued in Andersen and Benzoni (2008).

The estimation is done by the "double residual" method where $g(x_{1t})$ is estimated by a kernel regression technique using a Gaussian kernel and a cross-validation technique to determine the proper band width (Pagan and Ullah (1999)).

Based on the results from these estimations, we proceed by estimating a piecewise linear regression (Hastie, Tibshirani, and Friedman (2001)) where each regressor is endogenously assigned two segments—and separate slope is estimated for each segment

$$R_t^e = \gamma_0 + \gamma_1' x_t + \gamma_2' \max(x_t - \xi, 0) + \varepsilon_t, \tag{3}$$

where x_t is the vector of regressors. The estimation of the coefficients in $(\gamma_0, \gamma_1, \gamma_2)$ as well as the knot points in ξ is done by GMM (non-linear least squares) and the inference is here too based on the Newey-West estimator of the covariance matrix. (We also tried three or more segments, but found little significance.)

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 before 2004 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. To avoid losing too much data in the intraday regressions, we do two things. First, the lagged Treasury note futures is excluded for the regressions. Second, we apply the Griliches (1986) two-step approach to handle the still missing data points of the Treasury note futures.

4 Results

4.1 Results for Daily Data

Table 1 shows results from estimating the factor model (1) on daily data. Different exchange rates (against USD) are shown in the columns. All these exchange rates, except the GBP, show significant safe haven patterns: they tend to appreciate when *(a)* S&P has negative returns; *(b)* US bond prices increase; and *(c)* when currency markets become more volatile. The perhaps strongest safe haven patterns are found for the CHF and JPY 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. For the FX

	CHF/USD	EUR/USD	JPY/USD	GBP/USD
S&P	−0.08	−0.06	−0.05	−0.00
	(−4.06)	(−2.56)	(−2.49)	(−0.14)
Treasury notes	0.23	0.19	0.07	0.12
	(5.86)	(5.13)	(1.62)	(4.17)
FX volatility	0.68	0.46	0.72	0.15
	(3.50)	(2.57)	(3.88)	(1.03)
TED spread	0.02	−0.03	0.18	−0.01
	(0.07)	(−0.13)	(0.75)	(−0.03)
VIX	0.02	−0.02	0.04	0.00
	(0.85)	(−0.88)	(2.15)	(0.08)
S&P$_{t-1}$	0.06	0.07	0.02	0.04
	(4.59)	(5.63)	(1.34)	(4.13)
Treasury notes$_{t-1}$	0.08	0.05	0.16	0.01
	(2.42)	(1.72)	(4.95)	(0.34)
FX volatility$_{t-1}$	−0.60	−0.50	−0.48	−0.29
	(−3.86)	(−3.24)	(−3.03)	(−2.26)
TED spread$_{t-1}$	−0.05	−0.01	−0.14	−0.05
	(−0.19)	(−0.03)	(−0.59)	(−0.21)
VIX$_{t-1}$	−0.01	0.02	−0.04	−0.00
	(−0.80)	(0.98)	(−2.14)	(−0.08)
Own lag	−0.05	−0.05	−0.04	−0.02
	(−2.09)	(−2.58)	(−1.33)	(−0.91)
Constant	0.00	−0.00	−0.00	0.00
	(0.13)	(−0.04)	(−1.27)	(1.07)
R2	0.07	0.05	0.05	0.02
n obs	3439.00	3428.00	3443.00	3464.00

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 1993–2008. 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; the TED spread is the difference between the 3-month LIBOR and T-bill rates; VIX is CBOE's volatility index; and FX volatility is the first principal component of the realised volatilites for several exchange rate excess returns.

volatility—which has a high first-order autocorrelation—this implies that essentially only the innovation in volatility matters (similar to the finding on the equity market by Bandi, Moise, and Russell (2008)). The significance of some of the lags suggests that there is a small degree of predictability.[11]

Comparing the different proxies for market volatility/liquidity, the TED spread (used by Brunnermeier, Nagel, and Pedersen (2009), among others) is not significant for any of the exchange rates, while the VIX (used by Lustig, Roussanov, and Verdelhan (2008), among others) is significant only for the JPY (but the economic effect is small)—and overall the realised FX volatility gives strong and significant results. Therefore, the latter is used in the rest of the paper, while TED and VIX are not.[12] These results suggest two points: first, the volatility risk is a significant factor as found in Ang, Hodrick, Xing, and Zhang (2006) for the stock market; second, the risk specific to exchange rates, rather than broader measures of risk, is significant to explain excess returns of currencies.

The results presented above appear to be robust to various changes. 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. Third, proxies for bond market risk (in particular, the Merrill Lynch's Move index) also gave similar results. On the other hand, various proxies for stock market risk (for instance, realized S&P volatility and spreads on corporate bonds) turned out to be less significant. Fourth, further lags were not significant. Finally, adding stock market returns for the counter currency did not change the results significantly.[13]

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

[11]This finding is also supported by out of sample evidence. We estimated a VAR(1) of the excess return and regressors on recursive samples (using 2 years of data as the initial sample) and generated out-of-sample one-day forecasts. Comparing with the recursively estimated historical mean gives Diebold-Mariano t-stats of above 3 for CHF and EUR, but below 1 for JPY and GBP—which is very much in line with the significance of the "own lag" in Table 1.

[12]Menkhoff, Sarno, Schmeling, and Schrimpfz (2009) show that FX volatility is relevant to explain the performance of carry trade porfolios.

[13]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) GMM based test shows that the model cannot be rejected at conventional significance levels. The GMM system is set up to generate the same point estimates as the factor model and LS estimates of λ in $\mathrm{E}\,R_t^e = \beta'\lambda$ (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	−0.40	−0.33	−0.29
0.010	−0.34	−0.27	−0.24
0.020	−0.24	−0.22	−0.15
0.980	0.26	0.19	0.15
0.990	0.32	0.23	0.19
0.995	0.44	0.28	0.21

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 1993–2008. The regression coefficients are from Table 1.

of FX markets on a daily basis. What is important is that Table 1 shows distinct and (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 (1) it shows quantiles of $\beta_1 \text{S\&P}_t$ (demeaned), $\beta_2 \text{TreasNote}_t$ (demeaned) and $\beta_3 \text{FX volatility}_t$ (demeaned). For instance, the results for the 0.98 quantile show that on 2% of the days (around 67 days from our sample), the S&P returns (Treasury notes) are associated with at least a 0.26% (0.19%) return of the CHF/USD exchange rate while the FX volatility is associated with at least a 0.15% return. While these numbers are modest compared to the overall volatility (the standard deviation of the excess return is around 0.5%)—as already evident from the low R2 values—they still indicate important economic effects. Incorporating non-linear effects (see below) more than doubles some of these effects.

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 and JPY show safe haven patterns: they appreciate (significantly) against the other cross currencies in the same situations as they appreciate against the USD (negative S&P returns, US bond price increases and high currency market volatility). Also in line with the previous results, the GBP is perhaps the least safe haven, while the EUR is a mixed case. It can also be noted that both the "reversal effect" and the negative autocorrelation are typically weaker on the cross rates.

	JPY/EUR	GBP/EUR	CHF/EUR	GBP/JPY	CHF/JPY	CHF/GBP
S&P	−0.06	0.04	−0.06	0.09	−0.01	−0.09
	(−2.08)	(3.87)	(−7.58)	(3.53)	(−0.25)	(−8.59)
Treasury notes	−0.10	−0.07	0.05	0.03	0.14	0.12
	(−1.94)	(−2.65)	(2.95)	(0.57)	(3.17)	(3.77)
FX volatility	0.43	−0.33	0.25	−1.02	−0.48	0.62
	(2.12)	(−2.52)	(3.24)	(−4.42)	(−2.33)	(4.25)
S&P$_{t-1}$	−0.05	−0.02	−0.01	0.02	0.04	0.02
	(−3.16)	(−2.46)	(−1.54)	(1.51)	(2.91)	(1.53)
Treasury notes$_{t-1}$	0.11	−0.04	0.03	−0.15	−0.09	0.06
	(2.89)	(−1.56)	(1.85)	(−3.69)	(−2.49)	(2.13)
FX volatility$_{t-1}$	−0.05	0.15	−0.16	0.42	0.15	−0.35
	(−0.34)	(1.37)	(−2.41)	(2.32)	(0.99)	(−2.84)
Own lag	−0.02	−0.02	−0.07	−0.02	0.00	−0.03
	(−0.83)	(−0.86)	(−3.23)	(−0.86)	(0.19)	(−1.04)
Constant	−0.00	0.00	−0.00	0.00	0.00	−0.00
	(−0.93)	(0.52)	(−0.94)	(1.27)	(0.70)	(−0.93)
R^2	0.02	0.02	0.08	0.04	0.02	0.06
n obs	3387.00	3419.00	3395.00	3396.00	3373.00	3431.00

Table 3: **Regression results for cross rates.** The table shows regression coefficients and t-statistics (in parentheses) for daily data 1993–2008. The t-statistics are based on a Newey-West estimator with two lags. See Table 1 for details on the data.

Overall, the results seem to corroborate the traditional view that the Swiss franc provides *on average* safe haven or hedging benefits (see, in particular, Campbell, Serfaty-de Medeiros, and Viceira (2009) and Kugler and Weder (2004)). The evidence also support the idea that proxies for market volatility are important also for FX markets (see Brunnermeier and Pedersen (2009) and Ang, Hodrick, Xing, and Zhang (2006) for evidence from equity markets). However, our findings clearly show that exchange rate returns are more connected with FX risk than measures of risk referring to stock or bond markets or broadly used to gauge global risk or risk aversion (e.g. VIX and TED spread).

4.2 Results from Non-Linear Estimation and Dummy Variable Regressions

Figure 2 shows results for non-linear estimations of daily CHF/USD returns. The dots are results from the partial linear factor model (2), where only one variable at a time is allowed to have a non-linear effect. The lines are the fitted values and a 90% confidence band from the piecewise linear factor model (3), where 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. The results of the two methods could therefore differ, but it turns out here that they deliver similar pictures. Initial estimates suggest virtually linear effects of the lagged variables, so this is imposed in the results we report below.

The evidence shows that both the S&P and Treasury notes returns have almost linear effects: while the point estimates suggest some non-linear features, they are far from significant (cf. the width of the confidence bands). This means, among other things, that the effects from S&P are similar in up and down markets.

In contrast, there are 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. The economic importance of this effect is non-trivial: while the linear model showed that on 2% of the days the FX volatility is associated with at least a 0.15% return of the CHF/USD exchange rate (see Table 2), the non-linear model would instead suggest more than double this. These patterns are in line with the common wisdom that sudden increases in risk aversion fuel a flight-to-quality and to safety that, in turn, leads to unwinding carry trade.

Figure 3 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 Swiss franc, but that the pound has virtually no non-linearities.

Our results on non-linearity between excess exchange rate returns and realised volatility add to the extant literature advocating hedging benefits inherent in some currencies. Here, we show that these effects are more than proportional (non-linear patterns). These results are consistent with the model in Plantin and Shin (2008) which emphasises the dynamics of the leveraged carry trade positions. Our findings also square well with Gagnon and Chaboud (2007), Brunnermeier, Nagel, and Pedersen (2009) and Gyntelberg and Remolona (2007) who find evidence of a relationship between the skewness of exchange rate returns and the size of short-term interest rate differentials. In fact, we find that the non-linear return-volatility patterns are more marked in exchange rates with higher differ-

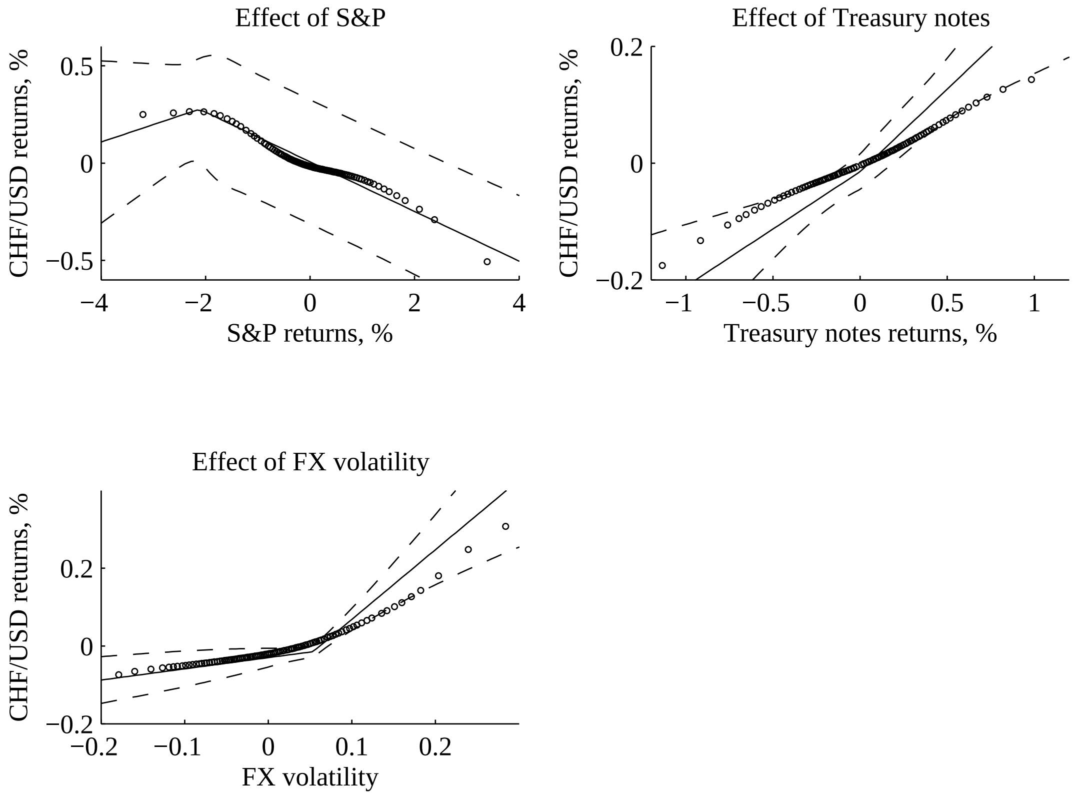

Figure 2: **Non-linear estimates, CHF/USD excess returns.** The dots are results from estimating partial linear models (see Pagan and Ullah (1999)) on daily data 1993–2008. Each circle represents the fitted value at each of the 1st to the 99th percentile of the regressor. The solid lines indicate the 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.

entials, namely CHF/USD and JPY/USD.[14] As pointed out by Gyntelberg and Remolona, this finding suggests that carry trade returns at least partially reflect compensation for large downside risks.

The results presented so far demonstrate safe haven effects, and that they are and mostly linear—except 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 linear factor models, but where all the regressors are also interacted with a

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

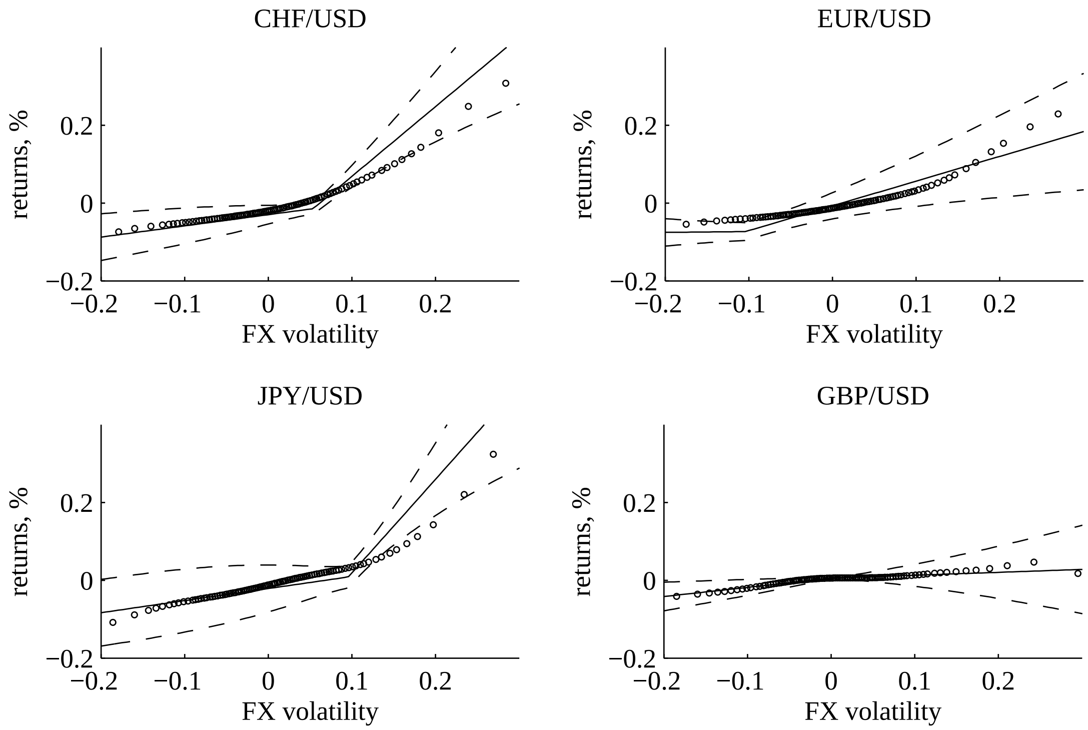

Figure 3: **Non-linear estimates of FX volatility coefficient.** This figure reports the FX volatility part of piecewise linear regressions. See Figure 2 for details on the method and Table 1 for details on the data.

dummy variable around large crisis episodes.

We aimed to define events by major media headlines and categorise them into "Nature" (disasters), "Finance" (market crashes, accounting scandals, etc.) and "Terror and war." However, it is very difficult to define distinct events since the start of the recent financial crisis—as the whole period is an extraordinary event itself: almost every day, financial markets have been rocked by one or more events that would usually be considered exceptional. As pointed out by Melvin and Taylor (2009), foreign exchange markets were hit by unprecedented phenomena such as contagion across asset classes, illiquidity and massive unwinding carry trade during this crisis. We have also seen unparalleled policy measures—in particular the central banks' swap lines to alleviate the shortage of liquidity, not least in US dollars and Swiss francs.

We therefore choose to define a set of short events for the sample period January 1993 to July 2007 by a news search—and then we let the whole period since 1 August 2007 be a separate event. For the news search, we use factiva.com.[15] The search of these news items was conducted by subject criteria and without any particular free text. We let factiva.com rank 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 set of these events is given in *Table 4*.

For the events before August 2007 we set the dummy variable to unity on the event days and the following 9 days (our "event window") and re-run the linear factor models (1), 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 somewhat—which is not surprising given the low number of data points in the events. 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

[15]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.

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

Table 4: **Event dates**

indeed seem to represent the pattern on ordinary days. Second, only the FX volatility variable shows "extra effects" during the events, so we only report this coefficient in *Table 5*. The point estimates indicate larger impacts of FX volatility around crisis events than on other days. This finding squares well with the results from the non-linear estimation (see Figure 3), since these crisis events are also characterised by high FX volatility.

For the recent financial crisis we use a dummy for all dates since 1 Aug 2007. As above, the old regressors are fairly similar to before, so *Table 6* reports only the coefficients for the regressors interacted with dummies: these coefficients therefore represent the extra effect during the recent crisis. Three results are significant. First, the coefficient on (the dummy times) S&P is negative for the yen, but positive for the other currencies. Second, the coefficient on Treasury notes is positive for JPY. Third, the coefficient on FX volatility is negative for EUR and GBP. Combined with the results in Table 1 (summing the respective coefficients), this suggest that—during the recent financial crisis—the yen

	CHF/USD	EUR/USD	JPY/USD	GBP/USD
Nature	3.46	2.72	3.28	5.78
	(2.11)	(1.69)	(2.05)	(3.03)
Finance	2.59	2.56	0.11	1.04
	(1.99)	(1.74)	(0.10)	(1.33)
Terror&War	2.63	0.42	0.40	0.90
	(1.10)	(0.22)	(0.26)	(0.54)
All	2.32	1.50	0.63	1.97
	(2.54)	(1.45)	(0.74)	(2.21)

Table 5: **Regression results for event dummies, coefficients on dummy variable $\times$ FX volatility.** The table shows regression coefficients and t-statistics (in parentheses) for daily data 1993–2008. 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.

had very strong safe haven properties, the (Swiss) franc still had some safe haven properties (no exposure to equity and positive exposure to both bonds and FX volatility) and that the pound was the opposite of a safe haven asset.

4.3 Results for other Data Frequencies

Based on the findings so far, we now examine how the safe haven effects look at different investment horizons.

Figure 4 reports results from estimating the linear factor model (1) 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 3). 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, but there are interesting differences across different horizons. At short horizons (3–12 hours), the coefficients are small but strongly significant (circles indicate that the coefficient is significant at the 5% level). At the medium horizons (1–2 days), the coefficients are considerably larger and also very significant, but the effect tends to vanish at longer horizons (4 days)

	CHF/USD	EUR/USD	JPY/USD	GBP/USD
S&P	0.14	0.22	−0.15	0.17
	(4.02)	(6.47)	(−4.67)	(6.41)
Treasury notes	0.10	0.04	0.41	−0.02
	(0.65)	(0.26)	(3.46)	(−0.19)
FX volatility	−0.46	−0.72	−0.16	−0.63
	(−1.28)	(−2.22)	(−0.43)	(−2.32)
S&P$_{t-1}$	0.02	−0.03	−0.04	−0.02
	(0.81)	(−1.02)	(−1.42)	(−0.63)
Treasury notes$_{t-1}$	−0.15	−0.28	0.20	−0.32
	(−1.32)	(−2.47)	(2.20)	(−3.29)
FX volatility$_{t-1}$	0.40	0.66	0.15	0.32
	(1.10)	(1.82)	(0.41)	(0.98)
Own lag	0.10	0.11	−0.28	0.11
	(1.23)	(1.52)	(−4.64)	(1.65)
Constant	0.00	0.00	0.00	−0.00
	(0.50)	(0.92)	(0.24)	(−0.89)
R2	0.09	0.08	0.08	0.06
n obs	3441.00	3431.00	3444.00	3466.00

Table 6: **Regression results for credit crunch dummy, coefficients on dummy variable for credit crunch × regressor.** The table shows regression coefficients and t-statistics (in parentheses) for daily data 1993–2008. The dummy variable is set to unity for all days 1 Aug 2007 to 31 Dec 2008. The t-statistics are based on a Newey-West estimator with two lags. See Table 1 for details on the data.

as the coefficients become smaller and often insignificant. The results for the other exchange rates are similar.

These results suggest two main points. First, FX, equity and bond markets are effectively inter-connected at high frequencies (several hours to a few days), but the link weakens at longer horizons. These links are significant in statistical and economic terms. For instance, on the three-hour horizon, a 1% decrease in 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 in the Treasury notes with a thirty basis points excess return. Second, FX volatility also appears to be priced into the currency values for short horizons, but perhaps not for longer horizons.

Overall, the empirical evidence reported here shed new light on the role of curren-

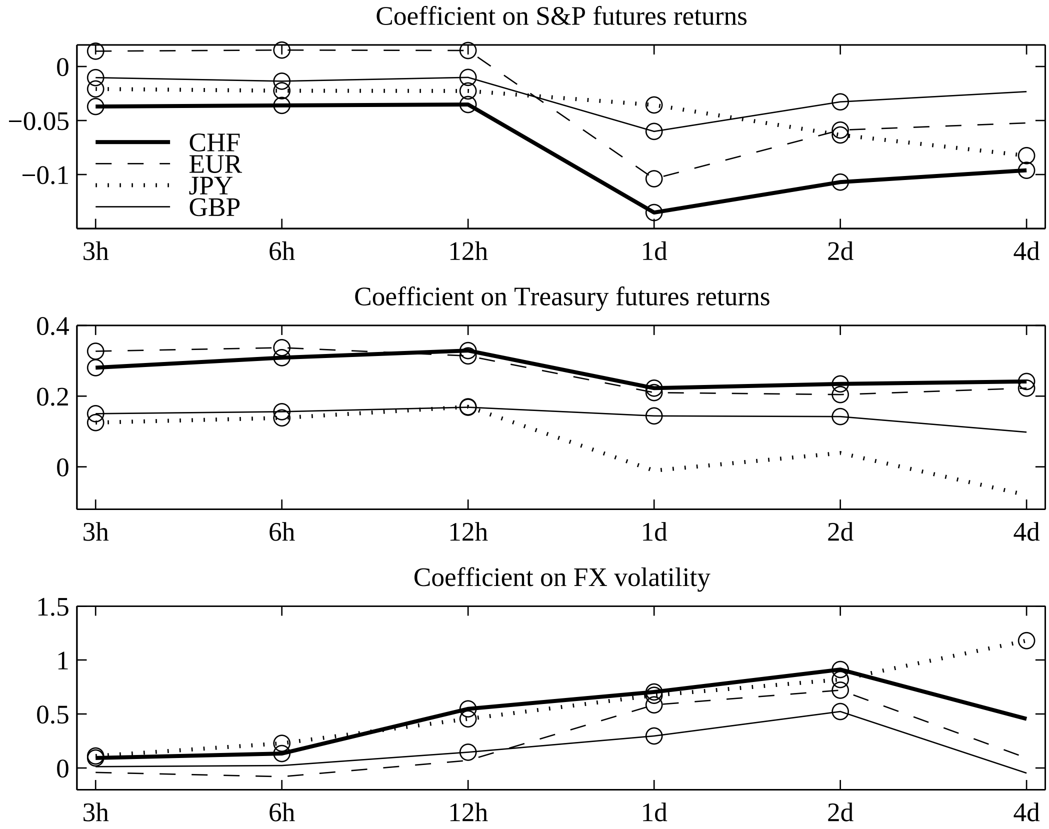

Figure 4: **Regression results for different horizons.** The figure shows regression coefficients for 1993–2007. In addition, t-statistics (based on a Newey-West estimator with two lags) with absolute values above 1.96 are indicated by circles. The regressions on intra-day data do not include the lagged 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.

cies in tumultuous markets that typically engender flight-to-quality and contagion effects. Currencies, equities and bond markets are systematically interconnected. Some currencies appreciate more-than-proportionally with increasing volatility. All these dynamics are operational already at very high frequencies.

4.4 Further Analysis

We conducted further analysis in several respects. At least two of these deserve brief comments.

First, we extended our analysis to currencies notoriously considered "investment currencies" in carry trade speculation (Australian dollar, New Zealand dollar, Icelandic krona, Polish zloty, Mexican peso, Russian rouble, Turkish lira and South African rand). The main idea was to test whether high-yielding currencies were the mirror-image of safe haven currencies. The results are very supportive in the sense that (1) all investment currencies have a positive exposure to S&P return and it is mostly significant, (2) the exposure to US bond returns is overall positive although typically not significant and (3) the exposure to realised volatility is mostly negative but with mixed significance. These currencies do indeed look like the the mirror image of the safe haven currencies.

Second, we analysed the safe haven effects at lower frequencies. More specifically, we sampled our data on a weekly basis in order to assess the significance of additional market proxies for volatility and liquidity. Four main variables were considered: the three discussed before (TED, VIX and FX volatility) and also the balance sheet growth for US financial intermediaries which can be interpreted as a further measure of funding liquidity since in case of market turmoil, financial intermediaries typically react by shrinking their balance sheets.[16] We found similar results as those reported in Table 1, namely that the excess return for the Swiss franc and yen increases with higher FX volatility, but that the significance is lower than for daily data—consistent with Figure 4. The point estimates for TED are positive but insignificant and the same is true for VIX, except that the JPY is significant. Finally, there are some weak indications that lags of balance sheet growth for US financial intermediaries predict future exchange rate movements (see Adrian, Etula, and Shin (2009)).

5 Summary

This study provides empirical support for the traditional wisdom that some currencies have safe haven attributes. We define a currency as a safe haven if it benefits from negative exposure to risky assets and if it appreciates when market risk and illiquidity increase. To study this, we propose a factor model with reference to the recent contributions in the asset pricing literature in which liquidity and risk are priced factors.

The empirical findings on data for 1993–2008 show that the excess returns of the Swiss franc and Japanese yen do indeed increase with a decrease in US stock prices and

[16]We thank Tobias Adrian for providing the data.

an increase in US bond prices as well as with an increase in FX volatility. The euro has similar, but weaker, properties—and the pound might not be regarded as a safe haven at all. These safe haven properties are visible already at intraday sampling frequencies and are still discernable at frequencies of up to several days. There are also indications of non-linear patterns such that the appreciation of the safe haven currencies are more than proportional to increases in risk and particularly strong during crisis episodes. The effects are not only statistically but also economically significant.

The results also hold after controlling for other factors such as the performance of local equity markets as well as different proxies of market risk and liquidity. Further analysis shows two other findings. First, the so-called investment currencies, i.e. those currencies having higher interest rates, are the mirror-image of safe haven currencies. Second, the current financial crisis left the safe haven currencies unscathed—and the yen even strengthened its safe haven properties.

This study contributes to the literature in three ways. First, it shows that some currencies have hedging properties not only on average but even more so in distressed markets. Second, it shows that FX volatility is a significant non-linear factor for currencies. Third, it sheds light on the interrelation among currencies, equity and bond markets which are interconnected already at very high frequencies and no matter if in regular market conditions or in time of stress.

This study attempted to empirically capture the factors at the surface of the safe haven phenomenon. A greater challenge is to understand its real drivers. How and to what extent safe haven effects originate from capital flows looking for reassuring political and economic environments, flight-to-quality/liquidity dynamics and unwinding of carry trade speculation are questions left for future research.

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