Exchange rates and financial stress

Experience has shown that exchange rates can be fairly volatile in times of heightened tension in the international financial markets. This often sends the currencies of countries with relatively high interest rates on a steep and abrupt downward trajectory. The opposite effect can be observed for low-interest currencies. In the course of the global financial crisis, currencies such as the Swiss franc, the yen or the US dollar experienced at least temporary steep increases in value whilst others such as the Australian dollar, the Canadian dollar and the currencies of many emerging market economies depreciated considerably. When the sovereign debt crisis in the euro area came to a head in the course of 2011, the Swiss franc appreciated so strongly against the euro that it almost reached parity. This even prompted the Swiss National Bank to announce in autumn 2011 that it was prepared to purchase unlimited amounts of foreign currency if need be so as to bring about a minimum exchange rate of CHF 1.20 to the euro.

This article discusses various explanatory approaches for these significant exchange rate fluctuations in times of crisis. One possible explanation is the unwinding of currency carry trades – ie speculative transactions in which investors seek to take advantage of international interest rate differentials in an effort to generate superior returns. Another explanation which is often voiced in this context is safe haven flows – movements of capital by investors who believe that a particular currency area is a relatively safe place to invest their capital in times of crisis.

As the term "safe haven currency" is not always used consistently, and different currencies are regarded as safe haven currencies in different settings, the article also suggests an empirical approach for identifying safe haven currencies. In the underlying model an explicit distinction is made between times of higher and lower tensions on the financial markets and an analysis is made of how far the exchange rate reactions in both regimes differ. Based on the empirical findings, the Swiss franc and the US dollar can be described as safe haven currencies. Taken in isolation, their rates rise whenever the global equity market returns diminish in times of heightened financial stress. The appreciation shown by the yen in times of crisis, meanwhile, appears to be mainly attributable to the unwinding of carry trades. There is no evidence of any further relationship between the rate of change in the yen's exchange rate and global stock market returns.

As for the euro, the results produced by the model do not point to any crisis-specific reaction. This outcome is consistent with the observation that, even when the sovereign debt crisis was at its most intense, the euro lost comparatively little of its value against the currencies of the euro area's most important trading partners.

Exchange rate changes and financial stress since introduction of the euro

Currencies sometimes subject to major fluctuations in times of crisis

The global financial crisis and the sovereign debt crisis in the euro area have shown – like earlier crises – that currencies are subject to stronger fluctuations in times of heightened tension on the financial markets than they are in calm periods. When, for example, the US investment bank Lehman Brothers filed for bankruptcy in September 2008, within one month the trade-weighted yen appreciated by approximately 11%, the Swiss franc by 3% and the US dollar by 5%, while the Australian dollar depreciated by 13½% and the Canadian dollar lost 8½% over the same period.[1] Generally speaking, low-interest currencies tend to depreciate in periods of calm on the financial markets, while they often appreciate abruptly in troubled times.[2] The opposite can be observed in the case of countries with relatively high interest rates. Assuming rational expectations, this observation contradicts the hypothesis of uncovered interest parity, at least in the short term. If an investor takes up funds in a low-interest currency and invests them in a higher-interest currency, the interest rate parity theory postulates that the expected profit from this transaction should be zero because an expected appreciation of the financing currency over the investment period should exactly offset the return from the interest rate advantage. If investors' expectations are correct on average, low-interest currencies should consequently appreciate and not depreciate against high-interest currencies – irrespective of the degree of uncertainty on financial markets.

In order to gain an initial rough impression of whether there exists, beyond the individual cases cited above, a general relationship between exchange rates and the level of financial stress, an illustrative analysis is made of the percentage monthly rates of change of the nominal effective exchange rates of Australia, Switzerland, the European Economic and Monetary Union (EMU), Japan, the United Kingdom and the United States against 37 important trading partners[3] together with the Chicago Board Options Exchange (CBOE) S&P 100 volatility index (VXO) since the introduction of the euro (see chart on page 17).[4] The effective exchange rates used are noted in indirect quotation, ie they state how many units of a weighted foreign currency are required to buy one unit of a given domestic currency. Consequently, an increase in the effective exchange rate in this notation implies an appreciation of the domestic currency. The VXO mirrors the expected fluctuation band of the US S&P 100 stock index for the coming month. In the analysis below it serves as an indicator of the degree of tension on the financial markets.[5]

Heightened financial stress tends to be linked to appreciations of Swiss franc, yen and US dollar

It is apparent that higher values of the VXO, which reflect a higher financial stress level, tend to be accompanied by an appreciation of the Swiss franc, the yen and the US dollar. The opposite can be observed for the Australian dollar. In the case of the euro, no clear relationship can be identified on the basis of this simple graphic analysis.

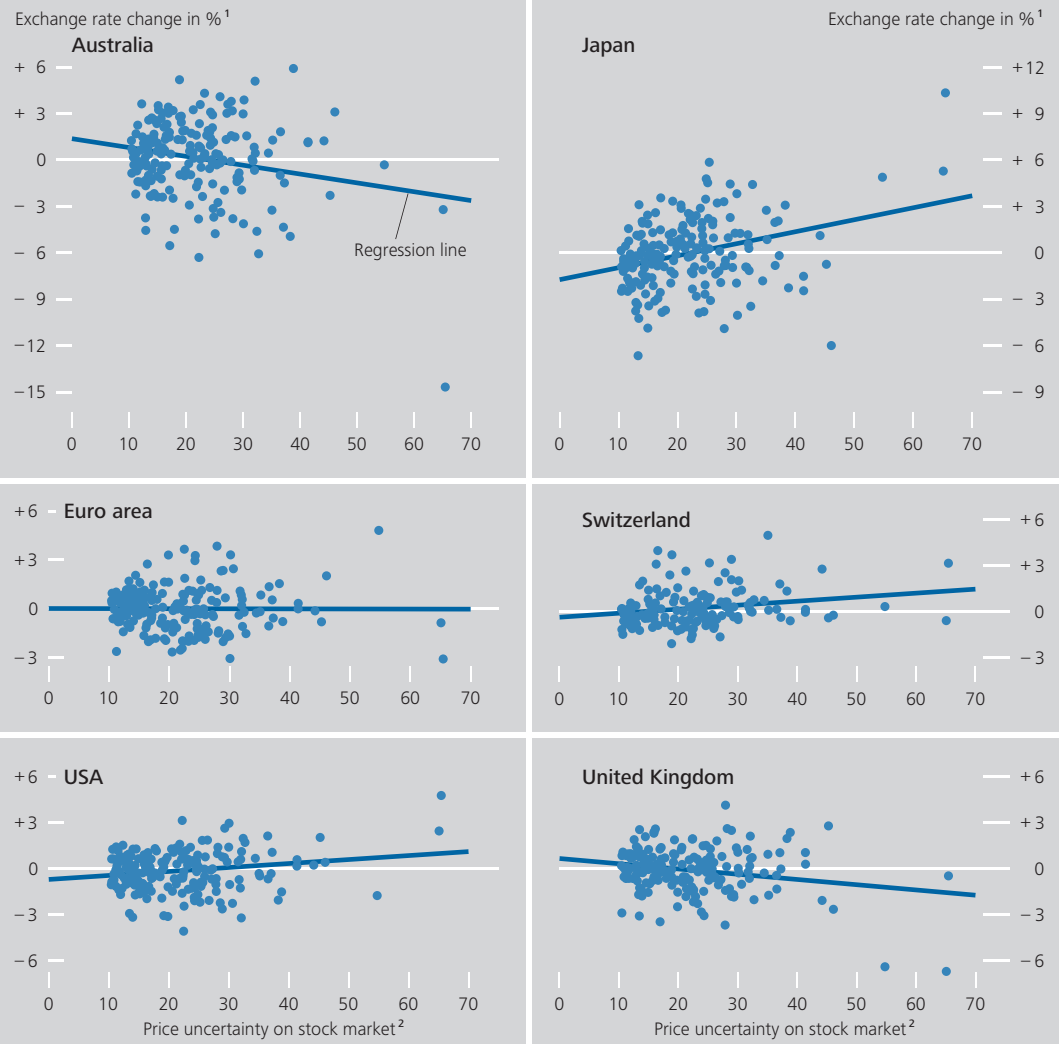
Unwinding of carry trades and safe haven flows as possible causes

Two things are often cited as the reason for the marked swing of exchange rates in times of heightened financial stress – first, the unwinding of currency carry trades and, second, safe

1 Based on the rates of change of the nominal effective exchange rates of the currencies under consideration against 37 major trading partners. By contrast, before the bankruptcy of Lehman Brothers, the average absolute monthly rates of change of these currencies in 2008 were only around 1% to 2%.
2 Studies which investigate this observation in more detail include, for example, M Brunnermeier, S Nagel and L H Pedersen (2008), Carry trades and currency crashes, NBER Working Paper No 14473; and C Burnside, M Eichenbaum und S Rebelo (2011), Carry trade and momentum in currency markets, Annual Review of Financial Economics 3, pp 511-535.
3 In the case of the euro area, against 20 countries.
4 Owing to the announcement of the Swiss franc's minimum exchange rate against the euro in autumn 2011, only data up to and including August 2011 are used for Switzerland.
5 The VXO is highly correlated with the CBOE S&P 500 volatility index (VIX), which is often used as a measure of uncertainty or as a financial stress indicator in the economic literature. The VXO is applied instead of the VIX, as data, which will be used in the econometric analysis presented later, are available for a longer period.

Exchange rate changes and price uncertainty on the stock market

Review period January 1999 to May 2014, Switzerland only up to and including August 2011



1 Month-on-month change in the nominal effective exchange rate. An increase corresponds to an appreciation of the currency under consideration. **2** Measured by the volatility index for the S&P 100 (VXO).

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haven flows. On the other hand, the financial press also often points to carry trades and safe haven flows as the cause of exchange rate fluctuations in the absence of any obvious explanation based on classical exchange rate determinants. However, not every currency fluctuation in times of crisis is necessarily attributable to one of these two causes. A changing influence of other exchange rate determinants might also be responsible. It is therefore prudent to examine carry trades and safe haven flows as causes of significant exchange rate fluctuations in times of crisis in greater detail and more precisely. The resulting implications for the affected countries will also be discussed.

Causes of strong exchange rate fluctuations in times of heightened financial stress

Unwinding of currency carry trades

In currency carry trade strategies, investors raise money in a low-interest currency (financing or debt currency) and invest it in a high-interest currency (target currency), without hedging the

In carry trades, money is raised in a low-interest currency and invested in a high-interest currency

resulting exchange rate risk.[6] According to the theory of uncovered interest parity, which assumes risk neutrality, the expected return on such a transaction should be zero, since, over the investment period, the expected appreciation of the financing currency should exactly offset the gain from the interest rate differential. Nevertheless, a large number of empirical analyses examining the uncovered interest parity come to the conclusion that the condition is not met on average *ex post*, at least for short-term money market paper.[7] Often, it is possible to observe the opposite, namely that the target currency appreciates over the investment period and the carry trade transaction thus becomes even more lucrative; in addition to the interest rate differential, the investor also obtains a capital gain on the foreign exchange market.

Carry trade strategies profitable on average, but very risky

With low interest rates prevailing over a long period of time, the yen, along with the US dollar, was in particular demand as a financing currency for carry trades over the past two decades. Even if, from a historical perspective, this strategy delivered positive excess returns on average for many pairs of currencies, it is fraught with major risks in specific cases. There is the danger of considerable losses if, contrary to speculators' hopes, the financing currency appreciates significantly. The investment is exposed to what is described in the literature as a crash risk.[8]

Unwinding of carry trades causes appreciation of financing currency

If uncertainty on the financial markets and, more particularly, on the foreign exchange market suddenly increases and market participants' risk appetite fades, investors active in carry trades cancel their investment in the high-interest currency – in some cases abruptly – and go back to the low-interest currency. The unwinding of carry trades thus weakens the high-interest currency and strengthens the low-interest currency. This can, in turn, prompt other investors to unwind their investment, thus reinforcing the described exchange rate effect.[9] As a large fraction of carry trades are debt-financed and thus dependent on financing through banks, restricted lending for very risky investments – which also include carry trades – may also play a part in the unwinding of carry trades during a crisis.[10]

Implications of low-interest-rate policy for carry trade volumes

In view of the very loose monetary policy, the return on short-term government bonds has slipped into negative territory in many industrial countries in real terms. This is why investors are increasingly seeking alternative investment opportunities, which are possibly more risky but offer a higher expected yield (known as the search for yield). The build-up of currency carry trade positions is such an investment opportunity. The upward trends of various high-interest currencies in the wake of easing tensions on the international financial markets up to spring 2013 were the result of stronger capital inflows, which were also associated with an increase in carry trade flows into these countries.[11]

Carry trades may contribute to the build-up of asset price bubbles and lead to problems in the banking sector

Generally speaking, there is a danger that the capital flows associated with carry trades may lead to an excessive price increase and, ultimately, to exaggerations in the case of various asset classes in the target countries if additional demand meets a supply which is normally limited in the short term.[12] In addition, there

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6 See Deutsche Bundesbank, Exchange rates and interest rate differentials: recent developments since the introduction of the euro, Monthly Report, July 2005, pp 27-42.
7 See, for example, M D Chinn and G Meredith (2005), Testing uncovered interest parity at short and long horizons during the post-Bretton Woods era, NBER Working Paper No 11077; R Clarida, J Davis and N Pedersen (2009), Currency carry trade regimes: beyond the Fama regression, Journal of International Money and Finance 28, pp 1375-1389, also show that the results of econometric estimations for examining uncovered interest parity differ greatly according to level of stress on the financial markets.
8 See M Brunnermeier, S Nagel and L H Pedersen (2008), loc cit, p 313.
9 For more information on the impact of carry trade reversals on exchange rate fluctuations in times of crisis, see M Kohler, Exchange rates during financial crises, BIS Quarterly Review, March 2010.
10 See R McKinnon (2013), Hot money flows, commodity price cycles, and financial repression in the USA and China: the consequences of near-zero US interest rates, China & World Economy 21, pp 1-13.
11 The Australian dollar, for example, appreciated by around 27% in effective terms against 37 major trading partners from mid-2009 to April 2013.
12 See also R McKinnon (2013), loc cit.

often occurs a marked appreciation of the target currency over time, which reduces the competitiveness of the affected country. Conversely, in the case of an unwinding associated with an abrupt and marked appreciation of a financing currency, there is a risk of credit defaults because the majority of carry trades – as mentioned above – are debt-financed. The potential negative repercussions of carry trades through the banking sector might therefore also affect the economies of other countries. Furthermore, assuming unchanged relative price developments at home and abroad, the international price competitiveness of countries whose currencies are used to finance carry trades might abruptly deteriorate due to their unwinding. However, it should not be ignored in this context that price competitiveness is also likely to have shown a steady improvement beforehand owing to the depreciation of the domestic currency.

Clear losses for typical carry trade target currencies during the tapering discussion in the USA

One indication of how sensitively carry trades react to changing underlying conditions was the sometimes marked depreciation of a number of high-interest currencies over the course of last year, for which the unwinding of carry trades and other short-term-oriented capital flows provide an explanation.[13] Discussions about an earlier gradual tapering of the loose US monetary policy and associated expectations of higher interest rates along with an expected appreciation of the US dollar were enough to cause this; as a result, the profitability of carry trades using the US dollar as financing currency are said to have decreased.[14]

Safe haven flows

Currencies can also appreciate in times of crisis because they are offered as safe investment instruments by the countries issuing them. The currencies of such countries are commonly referred to as safe haven currencies. Safe haven inflows into a currency area – just like the unwinding of carry trades – lead *per se* to the currency of these capital flows' target country becoming more expensive.

Literature defines safe haven currency in a variety of ways

There are nevertheless some differences in the literature concerning the precise definition of safe haven currencies (or assets in general). They are viewed as hedge assets, which tend to appreciate when a certain reference portfolio simultaneously falls in value, as "rainy day" assets which appreciate whenever a reference portfolio loses value in times of high uncertainty or generally as assets whose prices rise if uncertainty is high.[15] Apart from the fact that the definitions differ in terms of their substance, the classification as a safe haven asset in the first two definitions is determined by the selection of a suitable reference portfolio. The development of the Swiss franc and the yen during the sovereign debt crisis exemplifies the difficulties in identifying safe haven currencies.

Massive appreciation of the Swiss franc during the sovereign debt crisis in the euro area

The media and the literature are unanimous in ascribing the strength of the Swiss franc to its status as a safe haven currency. When in mid-2011, the franc appreciated so strongly against the euro that it almost attained parity, the Swiss National Bank announced that it would defend a minimum exchange rate of CHF 1.20 against the euro. The aim, as explained in its press release, was to counteract the massive overvaluation of the Swiss franc.[16]

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13 From April to December 2013, the Australian dollar depreciated by around 14½%, the Brazilian real by 16½% and the Indonesian rupiah by as much as 19% against the 37 major trading partners.

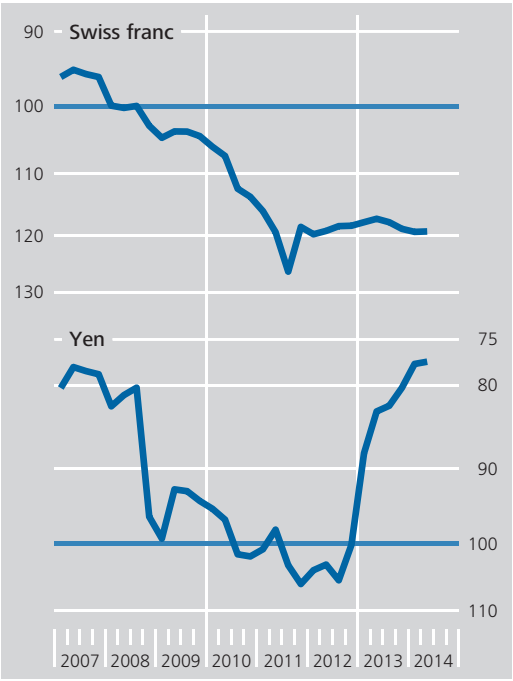
14 For an in-depth analysis of the impact of tapering news on emerging market economies see J Aizenman, M Binici und M M Hutchison (2014), The transmission of Federal Reserve tapering news to emerging financial markets, NBER Working Paper No 19980; and F Nechio, Fed tapering and emerging markets, Federal Reserve Bank of San Francisco, FRBSF Economic Letter, 3 March 2014.

15 See R N McCauley and P McGuire, Dollar appreciation in 2008: safe haven, carry trades, dollar shortage and overhedging, BIS Quarterly Review December 2009; D G Baur and T K McDermott (2012), Is gold a safe haven? International evidence, Journal of Banking & Finance 34, pp 1886-1898; and A Ranaldo and P. Söderlind (2010), Safe haven currencies, Review of Finance 14, pp 385-407.

16 The Swiss National Bank's press release of 6 September 2011 may be found at http://www.snb.ch/en/mmr/reference/pre_20110906/source/pre_ 20110906.en.pdf.

Real effective exchange rate of the yen and Swiss franc*

Average since 1975 = 100, quarterly, log scale[1]



* Against 19 major trading partners based on the deflators of total sales. **1** Inverted scale: rising curve (decline in values) denotes a real depreciation/increase in competitiveness.

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Safe haven inflows hamper international price competitiveness

The significant nominal appreciation of the franc which preceded this step had a negative impact on the international competitiveness of the Swiss economy. This is shown clearly by the development of the real effective exchange rate of the Swiss franc (see the chart above). For the third quarter 2011, ie when the Swiss National Bank announced its exchange rate target, this indicator points to competitiveness which is roughly 26½% less favourable than on the long-term average normalised to 100. This was thus an all-time low.[17]

In principle, appreciations caused by reversal of carry trades "correct" earlier depreciation

Although the yen also appreciated noticeably during this period, thus weakening Japan's price competitiveness, it was, at the same time, only around 3% below its long-term average (see chart above). The overvaluation of the yen, which was no more than moderate measured by this criterion, was also due to the fact that its clear appreciation – unlike the Swiss franc – was preceded by a long period of continuous nominal depreciations. This may be seen as an indication that the appreciation of the yen was due primarily to the unwinding of carry trades, while safe haven inflows are likely to have played a key role in the appreciation of the Swiss franc. The empirical study below will support this hypothesis (see box on pages 21 to 23).

Financing currency not automatically also a safe haven currency

Although both the Swiss franc and the yen are typical low-interest currencies, a currency that is attractive as a financing currency for carry trades due to low interest rates is not necessarily also a safe haven currency. While low interest rates are of major importance when choosing a financing currency for carry trades, other (structural) factors play a part in safe haven flows. In Switzerland's case, for example, factors cited include political and institutional stability, a low rate of inflation, confidence in the central bank and a positive net external position.[18] Empirical findings, too, suggest that there is a positive relationship between the status of a currency as a safe haven and the net external position of the country that issues it.[19] However, even this does not always help to distinguish between carry trade and safe haven currencies.

Preliminary conclusion and next steps

Difficult to make an empirical distinction between unwinding of carry trades and safe haven flows

At this intermediate stage, we can conclude that the unwinding of carry trades as well as safe haven flows can trigger the observed international capital flows and exchange rate changes. Nevertheless, it is very difficult to make a clear-cut empirical distinction between

17 Measured by the real effective exchange rate of the Swiss franc based on the deflators of total sales compared with 19 industrial countries. Observations since the beginning of 1975 are included in the calculation of the long-term average.
18 See T Jordan, Der Schweizer Franken und die Finanzmarktkrise, Kapitalmarktforum 2009 der WGZ-Bank Luxembourg SA in Luxembourg, 24 to 25 September 2009. This source is cited in R N McCauley and P McGuire, loc cit.
19 See M M Habib and L Stracca (2012), Getting beyond carry trade: what makes a safe haven currency?, Journal of International Economics 87, pp 50-64.

Empirical method of identifying safe haven currencies

An econometric method of identifying safe haven currencies is presented below. To do this, a threshold model is estimated. This allows the estimated coefficients to be dependent on the degree of tension in the financial markets[1] with a distinction being made between two "regimes" of financial stress.

For simplicity of presentation, the model is initially described for the case where the coefficients are identical in both regimes. The econometric model is then written as

$$\begin{aligned}\Delta e_t = {} & \beta_0 + \beta_1(i^*_{t-1} - i_{t-1}) \\ & + \beta_2(i^*_{t-1} - i_{t-1}) \cdot VXO_t \\ & + \beta_3(\pi^*_{t-1} - \pi_{t-1}) + \beta_4 u_{t-1} \\ & + \beta_5 \Delta msciw_t + \varepsilon_t\end{aligned}$$

where Δe_t denotes the rate of change of the nominal effective exchange rate,[2] $(i^*_{t-1} - i_{t-1})$ is the difference between the weighted foreign and domestic one-month money market rate in the preceding period, $(\pi^*_{t-1} - \pi_{t-1})$ the difference between the weighted foreign and domestic inflation rate in the preceding period, VXO_t the contemporary CBOE S&P 100 Volatility Index, u_{t-1} the deviation from a separately estimated equilibrium real exchange rate in the preceding period and $\Delta msciw_t$ the contemporary return of the global MSCI World stock market index.

The analysis considers the effective exchange rates of the currencies of Australia, Canada, Switzerland, the euro area, Japan, Norway, New Zealand, Sweden, the United Kingdom and the United States. Each of these is calculated against the other nine currencies. The official trade weights are used, which are also used by the European Central Bank to calculate effective exchange rates.[3]

The long-term equilibrium exchange rate is estimated on the basis of the purchasing power parity theory, additionally allowing a deterministic trend, ie $q_t = \alpha_0 + \alpha_1 trend + \upsilon_t$; q_t describes the real effective exchange rate calculated on the basis of the consumer price indices and υ_t an iid error term. The contemporary deviation from the estimated equilibrium real exchange rate $\hat{q}_t$ is calculated as $u_t = q_t - \hat{q}_t$.

The theory of uncovered interest rate parity would be fulfilled *ex post* only if it is not possible to reject the null hypothesis that β_1 is equal to 1 and, at the same time, all other coefficients are equal to zero.

If the coefficients are permitted to differ as a function of the financial stress regime, the model is written as

$$\begin{aligned}\Delta e_t = {} & \beta_{s,0} + \beta_{s,1}(i^*_{t-1} - i_{t-1}) \\ & + \beta_{s,2}(i^*_{t-1} - i_{t-1}) \cdot VXO_t \\ & + \beta_{s,3}(\pi^*_{t-1} - \pi_{t-1}) + \beta_{s,4} u_{t-1} \\ & + \beta_{s,5} \Delta msciw_t + \varepsilon_t,\end{aligned}$$

$$s = \begin{cases} l \; if \; VXO_t \leq \gamma \\ h \; if \; VXO_t > \gamma \end{cases}$$

It differs from that shown above by the s index characterising the regime, with l (= low) denoting the regime with comparatively low financial stress, h (= high) the regime with comparatively high financial stress. The VXO, which may be interpreted as an indicator of the level of financial stress, serves as the threshold variable. The model is estimated separately for each currency. Consequently, the threshold values that separate the two regimes from each other are currency-specific.[4] Put simply, the

1 In terms of methodology, the econometric approach applied here originates with B Hansen (2000), Sample splitting and threshold estimation, Econometrica 68, pp 575-603.
2 An increase in the nominal effective exchange rate equates to an appreciation of the currency under observation.
3 As the effective exchange rates calculated here include the currencies of only some of the countries considered in the official group, the weighting factors are rescaled accordingly.
4 For the sake of clarity, the presentation of the models does not include an index of countries.

Estimation results and currency classifications*

Currency	2 regimes: Financial stress regime: Low: Sign of $\hat{\beta}_{l,5}$	2 regimes: Financial stress regime: High: Sign of $\hat{\beta}_{h,5}$	1 regime: Sign of $\hat{\beta}_5$	Classification
AUD	+	+	+	Speculative
CAD			+	Speculative
CHF	–	–	–	Hedge/safe haven
EUR			–	Hedge
JPY	0	0	0	Carry trade financing[1]
NOK			+	Speculative
NZD			+	Speculative
SEK			+	Speculative
GBP	0	0	0	Unclear
USD	0	–	0	Carry trade financing[1]/ safe haven

* "–" ("+") denotes coefficients which are negative (positive) and significantly different from zero. "0" denotes coefficients which are statistically not significantly different from zero. **1** In both cases, the estimated coefficient $\hat{\beta}_{h,2}$ is positive and significantly different from zero.

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threshold value is set so that the explanatory power of the regression is as high as possible over both regimes. If the determined threshold value is statistically significant, the coefficients of the model are then estimated using regime-specific linear least squares regressions. However, the regression for the low-stress regime incorporates only observations at such points in time when the value of the VXO is not higher than the determined threshold value. All other observations are assigned to the high-stress regime. If the determined threshold value is not statistically significant, only one regression is performed for all observations. In this case, the model parameters are therefore not regime-dependent.

Two conditions have to be fulfilled for a currency to be classified as a safe haven currency. First, the statistical evidence has to indicate the existence of two regimes. Second, the estimated coefficient $\hat{\beta}_{h,5}$ must be negative and be significantly different from zero. By contrast, in the case of a hedge currency, $\hat{\beta}_5$ must be negative and statistically significantly different from zero, ie there must be a negative relationship between the rate of change in the exchange rate and global stock market returns on average across all observations. If these conditions are fulfilled, the currency is fundamentally suitable for hedging equity positions.[5]

Currencies are classified as speculative where $\hat{\beta}_5$ (if there is a single regime) or $\hat{\beta}_{h,5}$ (if there are two regimes) is positive and is significantly different from zero. In this case, there would be (on average across all observations and/or in the high-stress regime) a positive relationship between the rate of change in the respective exchange rate and global stock market returns.

Currencies are classified as carry trade financing currencies where the sign of the estimated coefficient of the interaction term $(i^*_{t-1} - i_{t-1})\, VXO_t$ is positive, and the coefficient is significantly different from zero (ie $\hat{\beta}_{h,2}$ if there are two regimes and $\hat{\beta}_2$ if there is a single regime). Under these conditions, the currency which is remunerated at a low rate depreciates (appreciates) if there is low (high) tension in the financial markets. Classification as a safe haven currency and as a carry trade financing currency is therefore not mutually exclusive.

The econometric model is estimated for the period from March 1986 to September 2012. In the case of the Swiss franc, only observations up to the end of August 2011 are included. The currency classifications derived from the estimates and based on the definitions above are shown in the table above.

The results indicate stress regime-dependent behaviour for five of the currencies: the Australian dollar, the Swiss franc, the yen, the pound sterling and the US dollar.

5 However, this interpretation – like the interpretation of the other parameters – holds only ceteris paribus, ie if it is controlled for the influence of the other explanatory variables.

Two currencies, the US dollar and the Swiss franc, are classified as safe haven currencies. First, two different regimes exist for these currencies. Second, the sign of $\hat{\beta}_{h,5}$ is negative for both currencies. As the results in the case of the Swiss franc also suggest a negative relationship between its rate of change and global stock market returns on average across all observations, it can – unlike the US dollar – also be termed a hedge currency.

In the case of the yen, the results also point to the existence of two different regimes. Nevertheless, for the yen it is not possible to find any statistically significant relationship between currency yields and global stock market returns – either in periods of high financial stress or on average across all observations – if it is controlled for the other determinants considered in the model. Owing to the positive sign of $\hat{\beta}_{h,2}$, the yen is therefore classified as a carry trade financing currency. This interpretation is also supported by the fact that the estimated coefficient of the interest differential in the low-stress regime $\hat{\beta}_{l,1}$ – counter to the theory of uncovered interest rate parity – is negative and statistically significant. Moreover, it is only in times of high financial stress that the nominal effective exchange rate of the yen adjusts to such a degree that deviations from the long-term real equilibrium rate are corrected.

In the case of the pound sterling, the results do not allow a clear-cut classification. The Australian dollar, the Canadian dollar, the Norwegian krone, the New Zealand dollar and the Swedish krona are classified as speculative currencies.

The results do not point to any crisis-specific behaviour for the euro. As its rate of change, according to the results, is also negatively related to global stock market returns, it is classified as a hedge currency.

these two determinants since they share the same trigger – a high level of financial stress accompanied by reduced risk appetite. Furthermore, the carry trade volume cannot be quantified reliably. It is difficult to distinguish capital flows associated with carry trades from capital flows motivated by other factors.[20] A higher interest rate in a given country may also reflect a better growth outlook and lead to long-term capital imports which, in turn, cause the national currency to appreciate. Unlike capital inflows based on carry trades, however, these investments would not be expected to unwind abruptly during sudden periods of tension on the financial markets.

Even so, changes in the exchange rate depending on financial stress can be used as an indicator for identifying safe haven currencies if a distinction is made between the different degrees of tension and, at the same time, the protective function of secure assets is taken into consideration. Unlike a carry trade currency, a safe haven currency would be characterised by the fact that, during periods of especially heightened financial stress and assuming that the other exchange rate determinants remain constant, it offers protection against asset losses. This is largely consistent with the "rainy day" definition of safe haven currencies. A broad, global share price index can be used as an indicator of (potential) asset losses. In times of major uncertainty, it may be assumed that investors avoid risk and that share prices tend to fall.

Below, we present a corresponding analysis which specifically uses monthly returns on the MSCI World Index at times of varying levels of financial stress. This global equity price index, calculated by Morgan Stanley Capital International, captures more than 1,600 market

20 An overview of various measures and their limitations may be found in S Curcuru, C Vega and J Hoeck (2010), Measuring carry trade activity, Board of Governors of the Federal Reserve System.

prices from 23 countries[21] and can therefore provide a picture of global developments in the equity markets.[22] This index was chosen as the reference portfolio because it is more broadly based than national indices and offers a global perspective.

It is evident that some currencies are linked positively to global equity price developments and that others have a negative connection (see chart on pages 25 and 26). It is also apparent that, in many cases, there appears to be a higher degree of dependency between exchange rate developments and equity price developments in periods of great uncertainty in the financial markets (right-hand column of the chart). At this point, the chosen threshold value is the value of the VXO which is not exceeded by 80% of the observations (the lower 80% quantile).

Procedure allows distinctions to be made between different stress regimes

These descriptive findings will be investigated econometrically below in terms of their significance, taking due account of other determinants. To this end, an empirical approach to identifying safe haven currencies will be presented.[23] The objective is first to define the term "safe haven currency" as precisely as possible and, second, to make a distinction as far as possible between safe haven currencies and carry trade financing currencies. Moreover, the underlying analysis provides insights into the extent to which the influence of classical exchange rate determinants, such as relative price developments, differs in periods of high and low financial stress.

An empirical method of identifying safe haven currencies

The downside of the graphical evidence portraying the relationship between financial stress, global stock market returns and exchange rates presented in the preceding section is that it does not allow us to control for the influence of other determinants. The method presented here, however, also takes into account standard exchange rate determinants.

The analysis also considers classical exchange rate determinants

The rate of change of the relevant nominal effective exchange rate is used as a dependent variable in this study. In addition to the lagged interest rate differential between home and abroad (referred to below as the effective interest rate differential), explanatory variables are the relative price developments of the previous month as well as the deviation from a long-term real equilibrium rate of the currency in question, estimated in a separate regression based on the theory of purchasing power parity. Furthermore, the econometric model contains an interaction term between the effective interest rate differential and the level of financial stress measured by the VXO. Using this term, the influence of the unwinding of carry trades on exchange rate developments can be controlled for, at least approximately.[24] The impact of global stock market returns, which are also incorporated into the model as a potential determinant, is of key interest. If the estimated coefficient is negative, this implies, *per se*, a negative relationship between the rate of change of the currency under consideration and global stock market returns. Provided that the other determinants of the currency do not change, it thus offers a certain degree of protection against price losses in the equity market.

Earlier analyses of safe haven currencies almost exclusively used bilateral exchange rates. The

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21 The index calculation in "local currency" is used, which means that, unlike the US dollar-based MSCI World Index, the performance of the currencies relative to the US dollar has no impact on the index.
22 Details of the index construction may be found at www.msci.com.
23 This section is based on the research paper "Carry funding and safe haven currencies: a threshold regression approach" by O Hossfeld and R MacDonald, shortly to be published by the Deutsche Bundesbank as a discussion paper.
24 See M Hattori and H S Shin (2009), Yen carry trade and the subprime crisis, IMF Staff Papers No 56, pp 384-409 on the underlying motivation of this specification, and M M Habib and L Stracca, loc cit, who also include an interaction term of this type in their model.

Exchange rate changes and global stock market returns in periods of low and high tension on the financial markets

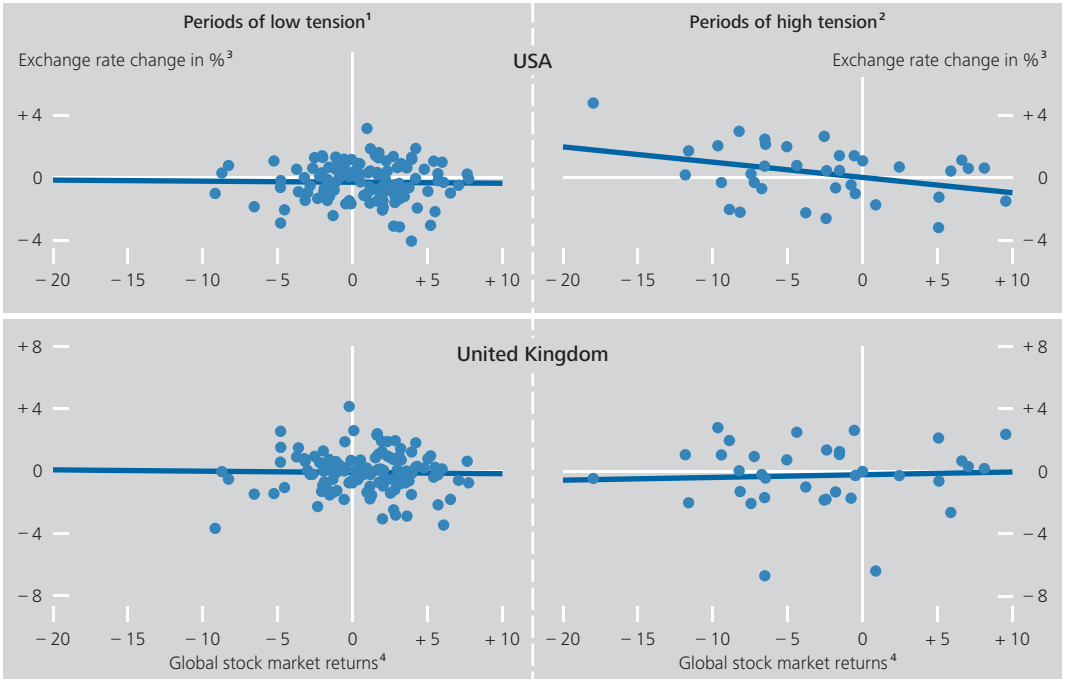
Observation period January 1999 to May 2014, for Switzerland only up to and including August 2011

1 Value of the volatility index for the S&P 100 (VXO) does not exceed the lower 80% quantile. **2** Value of the volatility index for the S&P 100 (VXO) exceeds the lower 80% quantile. **3** Month-on-month change in the nominal effective exchange rate. **4** Measured by the MSCI World Index. Month-on-month change.

Deutsche Bundesbank

Exchange rate changes and global stock market returns in periods of low and high tension on the financial markets (continued)

Observation period January 1999 to May 2014



1 Value of the volatility index for the S&P 100 (VXO) does not exceed the lower 80% quantile. **2** Value of the volatility index for the S&P 100 (VXO) exceeds the lower 80% quantile. **3** Month-on-month change in the nominal effective exchange rate. **4** Measured by the MSCI World Index. Month-on-month change.

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Estimation based on effective instead of bilateral exchange rates

problem with this is that this method can only express whether a particular currency can be seen as a safe haven currency in relation to another currency, and not in the wider sense that the term "safe haven currency" actually implies. For this reason, this study analyses effective exchange rates – ie trade-weighted exchange rates – rather than simple bilateral exchange rates. A significant advantage of using effective exchange rates is that there is a smaller risk that two safe haven currencies will not be identified because they "neutralise" each other due to the fact that one of the currencies is notated in the numerator and the other in the denominator of a bilateral exchange rate. Furthermore, using effective exchange rates makes it easier to analyse the impact of high levels of financial stress and the resulting capital flows on international price competitiveness.

Description of data

Because the time series presented above are available only for a relatively short period and more reliable analyses can be performed using longer time series, effective exchange rates against a smaller group of countries than previously are used. These data are available for a longer period. A total of ten currencies are observed:[25] The effective exchange rates of these ten currencies are calculated against each of the other nine currencies. In doing this, the applied weightings are those which are also used by the European Central Bank to calculate the official effective exchange rates, albeit with the difference that the calculation here does not incorporate all the countries included in the ECB's calculations and that the weightings therefore have to be rescaled accordingly. The analysis period is from March 1986 to September 2012.[26] In the case of Switzerland, how-

25 The currencies considered are the Australian dollar (AUD), the Canadian dollar (CAD), the Swiss franc (CHF), the euro (EUR), the yen (JPY), the Norwegian krone (NOK), the New Zealand dollar (NZD), the Swedish krona (SEK), the pound sterling (GBP) and the US dollar (USD).
26 In the case of the euro area, for the period prior to the introduction of the euro, back-calculations are performed using German data.

ever, only observations up to and including August 2011 are taken into account.

To investigate which currency is a safe haven currency – in empirical terms and based on the definition provided above – a threshold regression analysis is performed.[27] This method makes it possible to perform a regression analysis for various regimes which differ over the range of financial stress covered by the study. In this approach, the coefficients estimated on the basis of the econometric model may therefore differ from one another depending on the stress regime. The threshold value is not determined on an *ad hoc* basis as in the previous descriptive analysis, but such that the explanatory power of the models is as great as possible across both regimes. We then test whether the identified threshold value is statistically significant.

Precise definition of a safe haven currency

The classification of a currency as a safe haven depends on the estimation results for the regime with high financial stress. A currency is referred to as a safe haven currency if there is a negative relationship between its return and global stock market returns (measured by the MSCI World Index) in periods of heightened financial stress, ie the estimated coefficient of global stock market returns should be negative and statistically significant even when controlling for the influence of the other exchange rate determinants mentioned above.

This largely corresponds to the "rainy day" interpretation of a safe haven asset. However, taking into account other exchange rate determinants also helps to ensure that any appreciation in times of crisis is not due to fluctuations in other fundamental determinants.

Swiss franc and US dollar classified as safe haven currencies …

In the case of the Swiss franc, the results indicate that, in times of low financial stress, exchange rate developments depend primarily on classical fundamental determinants such as relative price inflation. By contrast, in a high-stress regime, changes in global stock market returns are the only determinant that exerts a significant – negative – influence on the rate of change of the Swiss franc. This analysis therefore classifies the Swiss franc as a safe haven currency. It is also striking that the percentage of explained variation of exchange rate changes in the high-stress regime is nearly three times as high as in the low-stress regime.

… appreciations of the yen in periods of heightened uncertainty probably due to its role as a financing currency in carry trades

The US dollar is also classified as a safe haven currency according to the definition and the estimation results. Unlike the Swiss franc, however, it is not simultaneously a hedge currency because the negative relationship to global stock market returns is limited to periods of high financial stress and does not apply on average for all observations, ie independently of the level of financial stress. In the case of the yen, the results tend to indicate that, in periods of calm, it is used as a financing currency for carry trades, which weakens the yen, and built-up positions are unwound during periods of heightened financial stress, causing the yen to appreciate again suddenly.[28] The empirical study does not confirm any additional relationship between the rate of change for the yen and global stock market returns, meaning that the yen cannot be described as a safe haven currency on the basis of the selected definition and the estimation results.

The euro as a regime-independent hedge currency

The evidence suggests that the results for the euro are not regime-dependent. The euro is classified as a hedge currency since there is, *per se*, a negative relationship between its rate of change and global stock market returns. Estimating the model using bilateral euro-based rather than effective exchange rates shows that only the Swiss franc can be considered a safe haven currency in relation to the euro. There is, meanwhile, no significant relationship between the rate of change of the euro-US dollar exchange rate and global stock market returns.

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27 For more detailed information about the estimation methodology, see the box on pp 21-23.
28 This interpretation is also supported by the fact that the nominal effective exchange rate only changes in periods of heightened financial stress to such a degree that deviations from the real effective equilibrium rate are corrected.

Conclusion

In times of heightened financial stress, exchange rates, like other asset prices, are subject to larger fluctuations than during periods of calm. This is often attributed to two key factors: first, carry trades, which are unwound abruptly in a crisis, raising the price of the original financing currency, and second, flight on the part of investors into what are considered to be safe havens for investments. This article provides points of reference for a clear conceptual separation of these phenomena, which are otherwise often bracketed together. According to the estimation results, the Swiss franc and the US dollar can be considered to be safe haven currencies. By comparison, the appreciation of the yen during periods of heightened uncertainty in the financial markets is more likely to be due to its role as a financing currency for carry trades. The results for the euro do not point to a response that depends on the stress regime. This outcome is in keeping with the observation that, even at the height of the sovereign debt crisis in the euro area, the euro lost comparatively little of its value against the currencies of the main trading partners.