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Looking at the other side of carry trades:
Are there any safe haven currencies?

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Résumé court

Nous définissons les monnaies refuges comme celles capables de fournir des excès de rendements positifs durant les crises et nous montrons qu'elles ont des primes de risque négatives à long terme. Nous tentons de les identifier empiriquement en considérant un échantillon de 26 monnaies émises par des pays avancés ou émergents sur une période allant de 1999 à 2013. Premièrement, nous identifions les monnaies ayant des excès de rendements moyens ex post négatifs sur longue période et positifs durant les crises ; seuls le yen et le dollar remplissent ces conditions. Deuxièmement, nous estimons par une régression à transition douce (STR) l'équation de Fama dans laquelle nous ajoutons le VIX comme variable explicative et variable de transition de façon à saisir la réponse des taux de change au cours du cycle financier. Les résultats montrent que le dollar et le yen sont aussi les seuls candidats pour être des monnaies refuges. En dépit de son appréciation tendancielle sur le long terme, le franc suisse ne remplit pas ce rôle car il a tendance à suivre le mouvement baissier de l'euro pendant les crises récentes.

Abstract

We define "safe haven currencies" as those able to yield positive excess returns during crises and show that they are likely to have negative risk premia on the long-run. We try to identify them empirically by considering a sample of 26 currencies from advanced and emerging countries over a period spanning from 1999 to 2013. We first spot the currencies yielding negative mean excess returns over the long run and positive ones during crises; only the Japanese yen (JPY) and the US dollar (USD) meet these conditions. Second, we run a smooth transition regression (STR) of the Fama equation, in which we add the VIX as an explanatory and a transition variable, in order to capture the response of exchange rates over the global financial cycle. The results also point out to the USD and the JPY as the only candidates for a safe haven role; despite its long-run appreciation trend, the Swiss franc does not qualify for this role, as it tends to follow the downward movement of the euro during the recent financial turmoil.

JEL Classification: C32, G11, G15.

Keywords: Carry trades; safe haven currencies; financial cycle.

1. Introduction

According to the uncovered interest rate parity (UIP), a positive interest rate differential on a currency is meant to exactly compensate investors for the expected depreciation of this currency. Hence, if the UIP held, uncovered positions in foreign currencies would yield no expected excess return, as the gains on interest rates would exactly cancel the expected depreciation in the exchange rate. In reality, a large number of papers have long evidenced the existence of persistent ex-post excess returns on the forex markets (Engel, 1995; Chaboud and Wright, 2005; Sarno, 2005) even if others argue that this may vary according to the maturity (Chinn, 2006; Bernoth et al., 2010).

More recently, major advances have been made in understanding the pro-cyclical nature of excess returns in the forex market (Burnside et al., 2008; Clarida et al., 2009; Lustig and Verdelhan, 2012). These returns appear to be linked to the financial cycle just as all the other returns on risky assets. The financial cycle itself can be viewed as a succession of “booms” and “busts”, characterized by the co-movements between credit and asset prices (Borio, 2012; Drehmann et al., 2012). It is global because of the increasing financial integration, spanning across advanced and emerging economies (Rey, 2013). Typically, during the “boom” period, the prices of all risky assets tend to surge as investors having a high risk appetite take on more credit to buy them. The “bust” period is triggered the day risk aversion begins to rise, that is when investors start to deleverage and sell off all their risky assets across the board.

The global financial cycle also deeply affects the forex returns through the carry-trade operations that have become a leading factor on this market (Galati, 2010). In the boom period, market participants typically invest in high-yield currencies by shorting the low-yield ones, which amounts to buying forward the high-yield currencies with a discount. During busts, they abruptly unwind their positions by selling them off. These carry-trade strategies implemented on a huge scale bring about two effects closely linked to the global financial cycle: (i) a strong demand for high-yield currencies during booms that strengthens their exchange rates, resulting in positive excess returns; (ii) an abrupt sell-off of these currencies during the times of crises when risk aversion rises, which causes a sharp depreciation and a reversal of the excess returns to negative territories.

The low-yield currencies are just the other leg of the carry trades. Hence, their exchange rates are also linked to the financial cycle: (i) they tend to appreciate only slightly or even to depreciate during boom periods; (ii) whereas they are suddenly bidden up during busts, providing then positive returns for investors. This ability to provide positive returns in bad times is a typical feature of a “safe haven” asset. The “safe haven” is indeed an asset that investors would turn to when the prices of all other assets fall. Gold or US Treasury bills are cases in point (Baur and Lucey, 2010; Coudert and Raymond, 2011; Connolly et al., 2005;

Kontonikas et al., 2013). Some currencies, such as the US dollar (USD), the Japanese yen (JPY) or the Swiss franc (CHF) may also qualify for the role (Kaul and Sapp, 2006; Rinaldo and Söderlind, 2010; Habib and Stracca, 2012), though the issue is disputed (McCauley and McGuire, 2009; Hoffmann and Suter, 2010; Grisse and Nitschka, 2013).

In this paper, following previous work by Clarida et al. (2009) we take the view that the exchange rates depend on the global financial cycle through carry trades built up during the boom phase and undertake to characterize safe haven currencies in this framework. First, using asset pricing theory, we show that safe haven currencies should have a negative expected excess returns over long periods, whereas yielding positive mean excess returns during busts. Second, we compare the mean excess returns of a sample of 26 currencies from advanced and emerging countries, both over the whole 1999-2013 period and over the busts. This allows us to identify the currencies yielding positive excess returns in times of financial turmoil and to assess the respective parts played by currency appreciation and interest rate differentials. To do that, we use the VIX as a proxy of the financial cycle as for example Rey (2013), and spot busts (or “crises”) by the VIX overcoming a given threshold. As no emerging currencies stand out as a safe haven, we thereafter focus on those of the advanced countries. Third, we incorporate the financial cycle proxied by the VIX into the traditional Fama equation - linking the exchange rate change to the interest rate differential of the previous period - and also extend it to a non-linear framework with smooth-transition regressions (STR). The VIX is used as an explanatory variable as well as a transition variable driving the change in coefficients in the regression. These regressions throw light on the changing dynamics of safe haven currencies according to the phases of the financial cycle.

The rest of the paper is organized as follows. Section 2 reviews the literature on safe havens. Section 3 shows that the exchange-rate risk premium is linked to investors' behavior along the financial cycle; it also states the conditions that a currency should fulfill to be a safe haven. Section 4 presents the data on excess returns and identifies the currencies that meet the safe haven conditions. Section 5 presents the econometric method and discusses the results. Section 6 concludes.

2. Literature survey

The concept of safe haven currencies may seem relatively straightforward, but its actual definition varies from study to study. Despite a relatively scarce literature some interesting results emerge, that point to nonlinearities in the dynamics of currencies during crises.

2.1. Definitions of safe haven currencies

During financial crises, market participants typically tend to liquidate all their risky assets across the board, which results in a simultaneous fall in their prices. At the same time, they

turn to liquid assets whose value is not affected by crises, such as cash, gold or US Treasury bills. These latter assets can be seen as “safe havens” as they are able to hedge investors against losses during periods of financial stress. A safe haven asset may thus be broadly defined as an investment that protects the wealth of investors in times of financial stress, when the prices of risky assets plummet; therefore its price should be disconnected from those of the other assets during crises. Indeed, Baur and Lucey (2010) characterize a safe haven as an asset whose correlation with other risky assets like stock indices is negative or null during crises, whereas a hedge is characterized by a negative or null correlation, on average over good as well as bad times. Although this characterization of a safe haven has been largely adopted for gold, it is less true for the literature on safe haven currencies. As remarked by McCauley and McGuire (2009) and Kohler (2010) the characteristics of safe haven currencies vary across studies, though relying more or less to the broad definition given above.

Until recently, safe haven currencies were little dealt with in the academic literature, which sharply contrasted with the great interest of the subject for investors and its frequent coverage by the financial press (Ranaldo and Söderlind, 2010). However, since Kaul and Sapp (2006) and the recent crisis, an increasing number of studies have tackled the subject (Kohler, 2010; Hoffmann and Suter, 2010; Habib and Stracca, 2012; De Bock and de Carvalho Filho, 2013; Wong and Fong, 2013; Grisse and Nitschka, 2013). With the exception of Kaul and Sapp (2006) and Wong and Fong (2013), all these studies acknowledge significant deviations from uncovered interest parity (UIP), as they evidence the existence of positive (or negative) excess returns on currencies over long periods. In this context, safe haven currencies may be characterized as currencies that yield positive excess returns during times of financial stress or as currencies whose excess returns increase with indicators of global risk. This approach is taken by Ranaldo and Söderlind (2010), Hoffmann and Suter (2010) and Habib and Stracca (2012). Though interesting, it does not reveal whether the excess return is due to a change in the exchange rate or to the interest rate differential. Following a slightly different approach Kohler (2010), De Bock and de Carvalho Filho (2013) as well as Grisse and Nitschka (2013) try to assess which currencies appreciate in times of financial stress. As options prices can be used to gauge for risk aversion as well as market expectations, Kohler (2010) and Wong and Fong (2013) explore this avenue by using risk reversals¹ to identify safe haven currencies.

2.2. Definition of crisis periods

One of the difficulties faced when studying safe havens is to precisely define the periods of financial crises, as the results may depend on these dates. Several options have been explored in the academic literature. For instance, Gorton and Rouwenhorst (2006) use the

¹ A risk reversal consists in buying a call and selling a put on the same currency, both out of the money. Its price is positive when investors are ready to pay a higher price to bet on an appreciation, rather than on a depreciation. The risk reversal of safe haven currencies is therefore expected to increase with global risk.

US recessions determined by the NBER; Coudert and Raymond (2011) consider the bear markets for US stocks that they identify as downward phases in the S&P500 stock index by the methodology of Pagan and Sossounov (2003).

The bulk of the other studies rely on the VIX, the implied volatility on the S&P500 stock index (Habib and Stracca, 2012; De Bock and de Carvalho Filho, 2013;² Grisse and Nitschka, 2013). Indeed the VIX is generally considered as a good proxy for risk aversion as well as a gauge for the financial cycle not only in the US, but also worldwide (Rey, 2013). Some authors like Rinaldo and Söderlind (2010) follow a slightly different track by estimating financial stress both through a measure of forex volatility and a set of dummies. Wong and Fong (2013) construct their own risk aversion index as the first principal component of nine stock market volatility indices. Interestingly, their results on safe haven currencies are broadly consistent with those obtained by Grisse and Nitschka (2013) who only use the VIX.

2.3. Main results on safe haven currencies

The JPY has often been considered as a safe haven in the economic literature, whereas results are mixed for the CHF. Both JPY and CHF exchange rates against the USD are negatively correlated with the S&P500 stock index and tend to appreciate in times of high volatility on the forex markets, while this is less true for the EUR (Rinaldo and Söderlind, 2010, Habib and Stracca, 2012). Moreover both currencies gain ground against the USD at the beginning of financial stress periods, though the appreciation of the Swiss franc is less persistent (De Bock and de Carvalho Filho, 2013).

The performance of the CHF is mixed, for it is a safe haven against some currencies and not against others (Hoffmann and Suter, 2010). Grisse and Nitschka (2013) confirm this feature, showing that, in times of turmoil, the Swiss franc tends to appreciate against the EUR and most carry-trade currencies, but depreciates against the USD, the JPY, the British pound (GBP). Using data on currency option prices, Wong and Fong (2013) also conclude that the CHF is a safe haven against the EUR but not against the USD; especially, they show that investors increasingly bet on the CHF against the EUR from the start of the European debt crisis in late 2009 up to the adoption of a CHF/EUR peg on September 6, 2011.

Although the USD role as a safe haven could be justified by its international status of reserve currency, it is debated in the empirical literature. For example, Habib and Stracca (2012) deny the dollar having this property but recognize that it could have played this role over the 2007-2009 period, when abruptly lifted in times of rising risk aversion. This episode may seem puzzling as the United States was at the epicenter of the global crisis at that time (Kohler, 2010). Behaviors typically involved in safe havens, such as flight to quality (towards US T-bills) and unwinding of carry trades, explain the USD appreciation; while other factors

² They define crises as episodes where the “VIX is 10% points higher than its 60-day backward-looking moving average”.

such as dollar shortage could also have pushed up the exchange rate (McCauley and McGuire, 2009). Another episode also evidenced safe-haven flows to the USD, at the time when markets feared the Y2K problem (Kaul and Sapp, 2006).

More generally, what are the characteristics of safe haven currencies? Several studies try to answer the question. Habib and Stracca (2012) and Kohler (2010) identify a few factors, such as the net foreign asset position of the issuing country, the past record of the currency as a hedge and the interest spread with the US (but only during the last crisis). Interestingly, they also find some evidence of non-linearity, as the impact of these factors increases in times of crisis. Two other papers indirectly confirm these conclusions by studying the links between exchange rates and fundamentals (De Bock and de Carvalho Filho, 2013; Fratzscher, 2009). They both find that the currencies incurring the largest losses during episodes of financial stress are characterized by low current accounts. Other factors include high interest rates and weak net foreign asset positions (De Bock and de Carvalho Filho, 2013), as well as low foreign exchange reserves and a high financial exposure to the US during the global crisis of 2007-2009 (Fratzcher, 2009). By transposing these conclusions, we can infer that low interest rates, strong current account and high net foreign asset positions (or foreign exchange reserves) should characterize safe haven currencies.

3. Currency excess returns and safe havens

In this section, we define carry trade returns, link them to the financial cycle and infer conditions for characterizing safe haven currencies.

3.1. The returns on carry trades

Let us consider an investor that invests in a given currency (the investment currency) by borrowing another currency (the funding currency) over one year. This operation called “carry trade” will give the following excess return r_{t+1} at maturity:

$$(1 + r_{t+1}) = \frac{(1 + i_t) S_t}{(1 + i_t^*) S_{t+1}} \quad (1)$$

where i_t is the interest rate on the investment currency, i_t^* the interest rate on the funding currency and S_t is the exchange rate between the two currencies, measured as the number of units of the investment currency for one unit of the funding currency.

In practice, the carry trade can be made through the forward market because buying forward the investment currency against the funding currency normally yields the same return.

Indeed, the pay off at maturity yields $\frac{F_t}{S_{t+1}}$, with the forward rate F_t being calculated as $S_t \frac{(1+i_t)}{(1+i_t^*)}$ because of riskless arbitrage.

After linearizing Equation (1), we take its expected value and get the expected excess return ρ_t as the interest rate differential less the expected depreciation:

$$\rho_t = E_t [r_{t+1}] = (i_t - i_t^*) - E_t [\Delta S_{t+1}] \quad (2)$$

Where ΔS_{t+1} is the logarithm change in the exchange rate from t to $t+1$ and $E_t [X_{t+1}]$ stands for the agents' expectation on X_{t+1} at time t . This expected excess return ρ_t is also called the "risk premium".

In a typical carry trade, the investment currency has a higher interest rate than the funding currency, or the basket of funding currencies. Most of the time, during tranquil periods, its exchange rate does not depreciate as much as the interest rate differential or even appreciates. Therefore the expected excess return of a carry trade expressed in Equation (2) is positive, as well as the risk premia on high-yield currencies.

3.2. Risk-aversion and exchange risk premium

If investors were risk-neutral, they would be indifferent to holding assets with the same expected returns, regardless for their risk; there would be no excess return or risk premia and the UIP would hold. In such a world, the expected returns on all assets discounted at the risk free rate are equalized by arbitrage.

In reality, risk-averse investors require a risk premium to hold risky assets. The magnitude of this risk premium depends both on investors' risk aversion and the covariance of returns with investors' marginal utility (Cochrane, 2001). Risk-averse investors also equalize the expected discounted returns of their assets by arbitrage, but instead of using the same risk-free rate for discounting all returns, they use a stochastic discounting factor (SDF) that accounts for their preference to returns occurring in the different states of nature. In this framework, the returns that are gathered at the wrong moment (ie, when other sources of incomes are already high) are valued less than those arriving in the right timing (ie when they are most needed, because other incomes plummet, like in financial crises). Consequently, risky assets that leave high yields most of the times but negative ones during crises have their price bid down, which results in an excess expected return and a positive risk premia. By arbitrage,

the expected excess return discounted by the SDF should be null. In the simplifying case of only two periods t and $t+1$, this implies:

$$E_t(m_{t+1}r_{t+1}) = 0 \quad (3)$$

where m_{t+1} is the SDF.

A straightforward calculation shows that Equation (3) implies that the expected excess return is proportional to minus its covariance with the SDF:

$$E_t[r_{t+1}] = -Cov_t[m_{t+1}, r_{t+1}] / E_t[m_{t+1}] \quad (4)$$

According to Equation (4), expected excess returns are positive for assets whose returns are negatively correlated with the SDF. Indeed, risky assets tend to generate positive returns in the favorable states of nature weighted by low values of the SDF—typically during periods of booming financial markets—and conversely, poor returns during bad times, that are heavily weighted by the SDF—ie during financial crises when income is most needed as all asset prices plummet. A case-in-point is a SDF proportional to market returns (with a minus sign) like in the capital asset pricing model (CAPM).

$$E_t[r_{t+1}] = \lambda_t Cov_t[r_{t+1}^M, r_{t+1}] \quad (5)$$

where r_{t+1}^M is the return of the world market portfolio.

3.3. Characterization of safe haven currencies

As the exchange rate is a relative price between two currencies, the risk premium is symmetrical. Hence, if some currencies have positive risk premia, others necessarily have negative ones. This means that those latter currencies yield expected returns that are positively correlated to the SDF or negatively with market returns.

A negative risk premium is an untypical situation for a financial asset. According to Equation (4), this type of asset must provide returns that are positively correlated to the SDF, ie high during bad times and low otherwise. Hence they can be viewed as a sort of insurance that investors are willing to pay for in order to hedge losses during crises. Indeed assets like an insurance contract are rational for risk-averse agents, despite their expected negative returns. Safe haven currencies also enter this category of assets yielding a negative risk premium.

Consequently, for a currency to be a safe haven against a given numeraire, we can state two necessary conditions:

- (C1): a safe haven currency has a negative risk premium, ie a negative expected excess return in the long run.
- (C2): a safe haven currency yields positive excess returns in times of crisis, its return being positively correlated to the SDF.

To go beyond the excess returns and split them into exchange rate changes and interest rate differentials, we have to consider the behavior of investors on the forex market through carry trades. Let us first consider their effects on high yield currencies. In normal times, or in the upward phase of the financial cycle, carry trades sustain the demand for these currencies that either appreciate or depreciate less than predicted by the UIP; consequently, they generate positive excess returns. But during crises, as risk aversion surges, investors abruptly unwind their positions, which sparks a sharp depreciation of all these high-yield currencies, much higher than their interest differential; their excess returns then turn negative (Burnside et al., 2008; Brunnermeier et al., 2008; Clarida et al., 2009). The low interest rate currencies used to fund the carry trades follow the exact opposite pattern: in normal times, their excess returns are negative, their appreciation being insufficient to compensate for the differential of interest rates; during crises, they suddenly appreciate, their excess returns turning positive, which make them good candidates for safe havens.

We can therefore be more specific on the excess returns characterized by the two aforementioned conditions and add the two complementary conditions: (C1') a safe haven currency should have a low interest rate; consequently, (C2') its positive excess returns during crises should stem from its appreciation.

4. Statistical characterization of safe havens

In this section we describe our dataset and check the conditions defined in section 3 to identify the safe haven currencies empirically.

4.1. Data

We consider three groups of currencies: (i) the first one is made of five international key currencies which are among the most traded in the forex market: the USD, the EUR, the JPY, the GBP and the CHF; they are the most likely candidates for safe havens due to their international status; (ii) the second one includes several other advanced countries' currencies that are often involved in carry-trades: the Australian dollar (AUD), the New Zealand dollar (NZD), the Canadian dollar (CAD), the Norwegian krone (NOK), the Icelandic krona (ISK); we have put the AUD in this group although it is the fifth most traded currency just before the CHF according to the BIS (2013) survey, because it is often used in the long leg of carry trades; (iii) the third one is composed by the main convertible currencies from emerging countries: in Latin America -the Argentine peso (ARS), the Brazilian real (BRL), the Chilean peso (CLP), the Colombian peso (COP), the Mexican peso (MXN) , in Asia the Thai

bath (THB), the Indonesian rupiah (IDR), the Malaysian ringgit (MYR), the Philippine peso (PHP), the Korean won (KRW), as well as the Russian ruble (RUB), the Romanian Leu (RON), the Czech koruna (CZK), the Hungarian forint (HUF), the Polish zloty (PLN), Israeli new shekel (ILS). In the whole, the sample contains 26 currencies from advanced and emerging countries.

Their exchange rates against USD as well as their 1-month interest rates are extracted from Bloomberg. All data are daily. The sample starts from 01/01/1999 except (i) for currencies whose 1-month interest rate is not available at this date; in this case, we take the earliest possible date³; (ii) for the main currencies : USD, the JPY, the GBP and the CHF we start on the 1st January 1990 because series are longer. All series end on the 23rd April 2013.

In order not to choose any specific currency as a numeraire, we consider all exchange rates against the special drawing right (SDR) (whose parity is also taken from Bloomberg). The choice of the numeraire is a sensitive one, as by nature the property of safe haven currencies is relative. For instance, all the currencies under review would appear as safe havens against the Polish zloty, because it is the currency that depreciated most on average during crises. Obviously it makes more sense to choose the numeraire amongst the key international currencies that are widely used in international trade and international investments. But any specific choice would be arbitrary. Besides forex investors have a taste for diversity and use a variety of funding currencies, which amounts to baskets of currencies, such as the SDR. The choice of the SDR as a numeraire is in line with, for example, Frankel and Wei (1995, 2008)⁴ when they study the *de facto* anchors of currencies.

We calculate the interest rates on the SDR by the weighted average interest rate on the four currencies in the basket (USD, EUR, JPY, GBP). We then compute the 1-month ex post excess returns of carry trades long in each of the 26 currencies under review, using Equation (1) with the SDR as funding currency. For the sake of comparison, all returns are annualized.

4.2. Empirical results on the currency risk premia

We now check which of our currencies have negative risk premia as well as low interest rates, therefore meeting conditions (C1) and (C1') for being a safe haven. To do that, we calculate the mean *ex post* excess returns of the 26 currencies along with their interest rate differential and exchange rate appreciation. Results are displayed in Columns (a) of Table 1. Means are computed from 1999 for all currencies; in addition, we also calculate them from 1990 on for the group of the key currencies.

³ From December 1999 for Mexico, January 2000 for Iceland, October 2000 for Russia, July 2002 for Thailand and Israel, November 2002 for Peru, September 2004 for Korea.

⁴ See, for example, Bracke and Bunda (2011) for a literature review.

Means calculated over long time periods are unbiased estimators for expected values if series are stationary. Augmented Dickey-Fuller and Phillips-Perron tests show that the null hypothesis of a unit root is rejected at a conventional 95% confidence level for all the series of excess returns⁵. As a consequence, the excess returns are considered stationary. Hence, if the mean excess return reported in Column (a3) is negative, the currency meets the first condition for being a safe haven. Only the dollar and the yen fulfill this condition; it also happens to be the case for the Chilean peso, but for wrong reasons linked to the country's exchange controls. Moreover, two types of currencies clearly stand out from Table 1.

The first group gathers together the five international key currencies that share strong common features. (i) Their interest rate differentials are the lowest of the sample, which make them meet condition (C1') of low interest rates; they are even negative for the USD, the JPY and the CHF for the longest period and stay so for the two latter since 1999; (ii) their ex post excess returns are also by far the lowest of the sample, being smaller than 1% for the longest period (from 1990) and 1.2% from 1999. Two of these currencies, the USD and the JPY have negative mean excess returns over the two periods (-0.3 and -0.7% respectively over 1990-2013; -0.2 and -1.2% on the 1999-2013 period). Hence, both the dollar and the yen meet condition (C1) for being a safe haven currency. This is not the case for the CHF, the GBP and the EUR, whose mean excess returns are slightly positive in the long run.

⁵ For ADF test, maximum lag length is chosen using AIC criteria. For Phillips-Perron test, following Newey and West (1987), the truncation parameter, noted l , is 10.

Table 1: Interest rate differentials, exchange rate appreciation and excess returns for 1-month carry trades funded in SDR, annualized means in percentage.

	(a) over the whole period			(b) During crises			(c) During "severe crises"		
	(a1)	(a2)	(a3)	(b1)	(b2)	(b3)	(c1)	(c2)	(c3)
	Interest rate diff	Exchange rate change	Excess returns	Interest rate diff	Exchange rate change	Excess returns	Interest rate diff	Exchange rate change	Excess returns
5 main currencies since 1990									
USD	-0,1	-0,4	-0,6	-0,3	-0,8	-1,1	-0,5	5,7	4,8
EUR	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
JPY	-2,4	1,6	-0,9	-1,9	15,3	13,3	-1,8	28,5	27,2
CHF	-1,3	1,8	0,5	-1,3	3,8	2,5	-1,3	2,9	1,6
GBP	1,5	-0,7	0,9	1,4	-4,4	-2,9	1,2	-26,6	-26,4
5 main currencies since 1999									
USD	0,2	-0,4	-0,1	-0,4	3,2	2,8	-0,6	9,4	8,5
EUR	0,1	0,5	0,6	0,7	-4,1	-3,3	0,9	-9,4	-8,5
JPY	-2,1	1,1	-1,1	-1,6	12,0	10,3	-1,6	27,0	25,3
CHF	-1,3	2,6	1,2	-1,0	0,2	-0,9	-1,1	-0,3	-1,5
GBP	1,2	-0,8	0,4	1,0	-6,0	-5,0	1,1	-28,4	-28,5
Other advanced countries currencies since 1999									
AUSD	2,6	3,7	6,3	2,8	-11,6	-8,8	2,9	-32,0	-30,5
NZD	2,9	3,4	6,3	3,0	-11,8	-8,8	3,4	-33,7	-31,6
CAD	0,4	2,7	3,1	0,2	-7,5	-7,3	-0,1	-26,0	-28,0
NOK	1,6	1,7	3,3	2,8	-13,1	-10,2	2,5	-21,8	-20,1
ISK	6,9	-3,6	3,5	9,4	-19,2	-19,5	13,1	-28,4	-13,6
Emerging countries currencies since 1999, or since availability									
ARS	12,7	-10,4	1,9	20,5	-6,8	13,9	16,1	-21,1	-5,3
BRL	12,7	-1,2	11,9	12,9	-40,8	-28,1	11,2	-48,4	-38,5
CLP	-2,0	0,2	-1,9	-1,5	-17,0	-18,6	-1,6	-15,0	-17,3
COP	3,0	-0,9	2,2	3,3	-17,1	-13,8	3,9	-28,3	-24,6
MXN	5,0	-2,1	3,0	5,0	-25,7	-21,0	5,0	-47,9	-43,1
THB	0,8	2,2	3,0	0,8	-1,5	-0,6	0,9	0,1	0,4
IDR	8,1	-0,4	7,9	9,2	-19,5	-10,3	8,4	-35,8	-27,1
MYR	0,6	1,2	1,8	0,9	-3,1	-2,2	0,9	-5,3	-4,6
PHP	4,2	-0,7	3,6	3,8	-6,6	-2,8	2,8	-0,1	2,2
KRW	1,6	0,6	2,2	2,0	-19,5	-17,6	1,8	-36,9	-34,3
RUB	4,8	-1,9	3,0	10,7	-19,3	-8,6	17,3	-44,2	-27,2
ROL	18,1	-7,8	10,5	15,4	-19,9	-4,4	12,9	-36,6	-23,2
CZK	0,5	3,1	3,6	0,9	-11,6	-10,6	1,0	-25,2	-24,5
HUF	6,3	-0,3	6,2	6,7	-23,2	-16,5	7,1	-48,5	-41,2
PLN	4,9	1,0	6,0	4,9	-29,1	-24,1	3,7	-62,0	-58,1
ILS	2,0	1,7	3,7	2,8	-4,9	-2,0	1,5	-20,1	-18,9

Notes. Currency codes are given in the first paragraph of Section 4.1. (a) The whole period begins on 02/02/1990 for the five first rows, on 02/02/1999 for the others, except for Mexico (since Dec. 1999), Iceland (Jan. 2000), Russia (Oct. 2000), Thailand and Israel (July 2002), Peru (Nov. 2002), Korea (Sept 2004). All data ends on 04/13/2013. (b) Crises are defined by periods with the VIX over 30 level; (c) severe crises as periods with the VIX over 40. Results in bold and grey meet the conditions (C1), (C2) for safe haven currencies.

Second, all the other currencies, be them from advanced or emerging countries, have a positive interest rate differential (except the Chilean peso). They are therefore likely to be used as investment currencies in carry trades. For each of them, the exchange rate depreciation is smaller than the interest differential on average, which results in a positive mean excess return of the carry trade, going from 1.9% for the Argentinean peso to as much as 11.9% a year for the Brazilian real. Hence, the risk premia are positive for these countries, corroborating the break in the UIP and the presence of risk aversion. The only exception is the Chilean peso, as the Chilean monetary authorities had to struggle against capital inflows and currency appreciation for years through lowering the interest rate and implementing exchange rate controls.

4.3. Identifying global financial crises

To assess currency returns during crises, we need to define crisis periods beforehand. As global financial crises always go with increasing volatility on stock markets, the implied volatility index on the S&P500, the VIX, has been shown to be a good gauge of stress on the financial markets (Clarida et al., 2009, Brunnermeier et al., 2008). It is a relevant indicator of the financial cycle, not only in the US, but also on global markets, since its level is correlated to international capital flows (Rey, 2013).

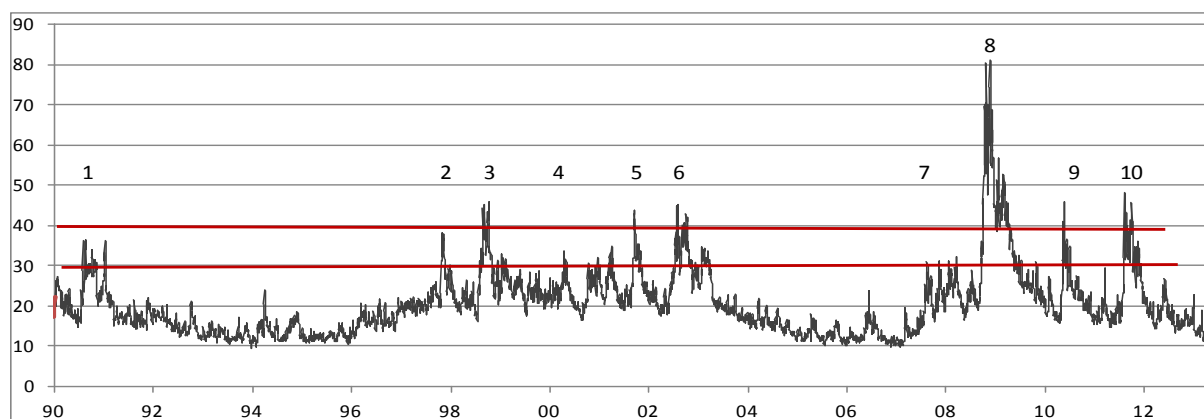
More precisely, we define financial “crises” as periods when the VIX rises above the 30 level and “severe crises” when it overcomes 40 points. We set these thresholds following Coudert et al. (2011) who estimate them through a panel smooth transition regression (PSTR) aimed at assessing the effect of crises on emerging countries’ exchange rates. Note that these 30 and 40 thresholds will only be used in this section to calculate the mean returns of currencies over crises, but will be estimated econometrically in Section 5.

We verify that these thresholds are appropriate to identify the main financial crises since 1990. This amounts to check that the dates identified in this way do match a major event that is widely known to have sparked a financial downswing. Table 2 reports all episodes found along with their corresponding events. We identify 10 crises: the first Gulf war in 1990, the Asian crisis in 1997, the Russian and LTCM crisis in 1998, the two successive crashes of the dot-com bubble in 2000-2002, the 11/09/2001 terrorist attack, the banking crisis in 2007 following the collapse of Northern Rock, the aftermath of Lehman Brothers bankruptcy in 2008-2009, the burst of Greek sovereign debt crisis in 2010 and the European banks crisis in 2011.

Table 2: Global financial crises since 1990 matching the VIX hitting the 30 and 40 thresholds

		Start	Crises Periods when VIX is > 30	Severe crises Periods when VIX is >40
1	First Gulf war	August 90	06-07/08/1990; 22-24/08/1990; 06/09/1990; 09-17/10/1990; 26/10-08/11/1990; 08-16/01/1991.	
2	Asian crisis (after the Korean won was attacked)	Nov. 97	27/10/1997-18/11/1997; 24-25/12/1997	
3	Russian crisis and LTCM bankruptcy,	August 98	04/08/1998; 11/08-28/10/1998; 14/12/1998; 13-14/01/1999; 21-25/01/1999; 08-10/02/1999; 17-18/02/1999	31/08/1998; 03-07/09/1998; 10-11/09/1998; 30/09/1998-13/10/1998
4	First crash of the dot-com bubble	March 00	14/04/2000; 03-04/05/2000; 12/10/2000; 20/12/2000; 13/03/2001; 20-23/03/2001; 02-09/04/2001	
5	11 September 2001		07/09/2001-05/11/2001	17-21/09/2001
6	Crash of the dot-com bubble	July 02	09/07/2002-14/08/2002; 27/08/2002-13/11/2002; 05/12/2002; 09/12/2002; 19/12/2002; 24/01/2003-24/03/2003	22-23/07/2002; 02-06/08/2002; 19/09/2002; 07-09/10/2002
7	Beginnings of the subprime crisis with the collapse of Northern Rock	Fall 07	12/11/2007; 21/01/2008; 14-17/03/2008	
8	Lehman Brothers collapse	Sept. 08	15/09/2008-04/06/2009; 15-23/06/2009; 07-08/2009	29/08/2008; 02/10/2008-01/01/2009; 07/01/2009-07/04/2009
9	Greek sovereign crisis,	May 10	06-07/05/2010; 14/05/2010-10/06/2010; 29/06/2010-05/07/2010	07/05/2010; 20-21/05/2010
10	European banks crisis,	Summer 11	04/08/2011-29/11/2011; 08/12/2011.	08/08/2011; 10/08/2011; 18-22/08/2011

Figure 1: The VIX, implied volatility on the S&P500 and the events matching the thresholds of 30 and 40(*).



(*) Numbers 1 to 10 refer to the 10 episodes described in Table 2.

As these crises differ in intensity, we also define “severe crises” as periods when the VIX hits the 40 level. It happened during six episodes over our sample: the Russian and LTCM crisis in 1998, the 11/09/2001 attack, the high-tech crash in 2002, the 2007-2008 crisis and the sovereign and banking crises in Europe in 2010 and 2011 (Table 2).

These episodes also differ in terms of duration, some of them standing for mere spikes of volatility over a few days - like the first backlashes of the subprime crisis after the collapse of Northern Rock - whereas others last several weeks or even months, like the Lehman Brothers collapse, the sovereign crisis in Greece that durably affected market volatility over this period (Figure 1).

4.4. Currency excess returns during crises

We now search which currencies provide positive excess returns during crises through appreciation, therefore meeting our conditions (C2) and (C2') for being a safe haven. To do so, we compare the returns of currencies over periods restricted to the crises and “severe crises” defined above (Columns (b3) and (c3) of Table 1). Several features stand out from the results.

First, the USD, the JPY and the CHF are the only currencies to keep negative interest rate differentials during crises (again except the Chilean peso but because of exchange controls). All the other currencies have positive interest rate differentials, that are often increased during crises to stem capital outflows and sustain the exchange rate. For example, the mean interest rate differential in Russia is 4.8% over the whole period; it jumps to 10.7% during crises, and reaches 17.3% during severe crises.

Second, the dollar and the yen stand out as the only currencies prone to appreciate during crises when we consider the 1999-2013 period, then meeting condition (C2'). Moreover, when the crisis gets more severe, their appreciation is boosted, rising from 2.8% to 8.5% for the dollar and from 10.3% to 25.3% for the yen. The Swiss franc also strengthens during crises, if we consider the long period 1990-2013. However, this property has been wiped off in the more recent period by the CHF/EUR peg implemented since fall 2011, that has efficiently prevented upward market pressures on the Swiss Franc (Guillaumin and Vallet, 2013). All the other currencies sharply depreciate during crises, be them issued by advanced or emerging countries. The euro falls 3.4% (8.5% during severe crises); this is quite understandable as the euro area was at the epicenter of the financial turmoil in 2010 and 2011, with the Greek sovereign crisis, the growing sovereign risk on peripheral members and the resulting systemic risk on the European banks. The British pound also plummets during severe crises, losing 28% of its value. In the group of the five other advanced countries, all currencies drop more than 10% a year (except for Canada, 7.5%); their downward movement is amplified during severe crises, as the fall then exceeds 20% for four of them,

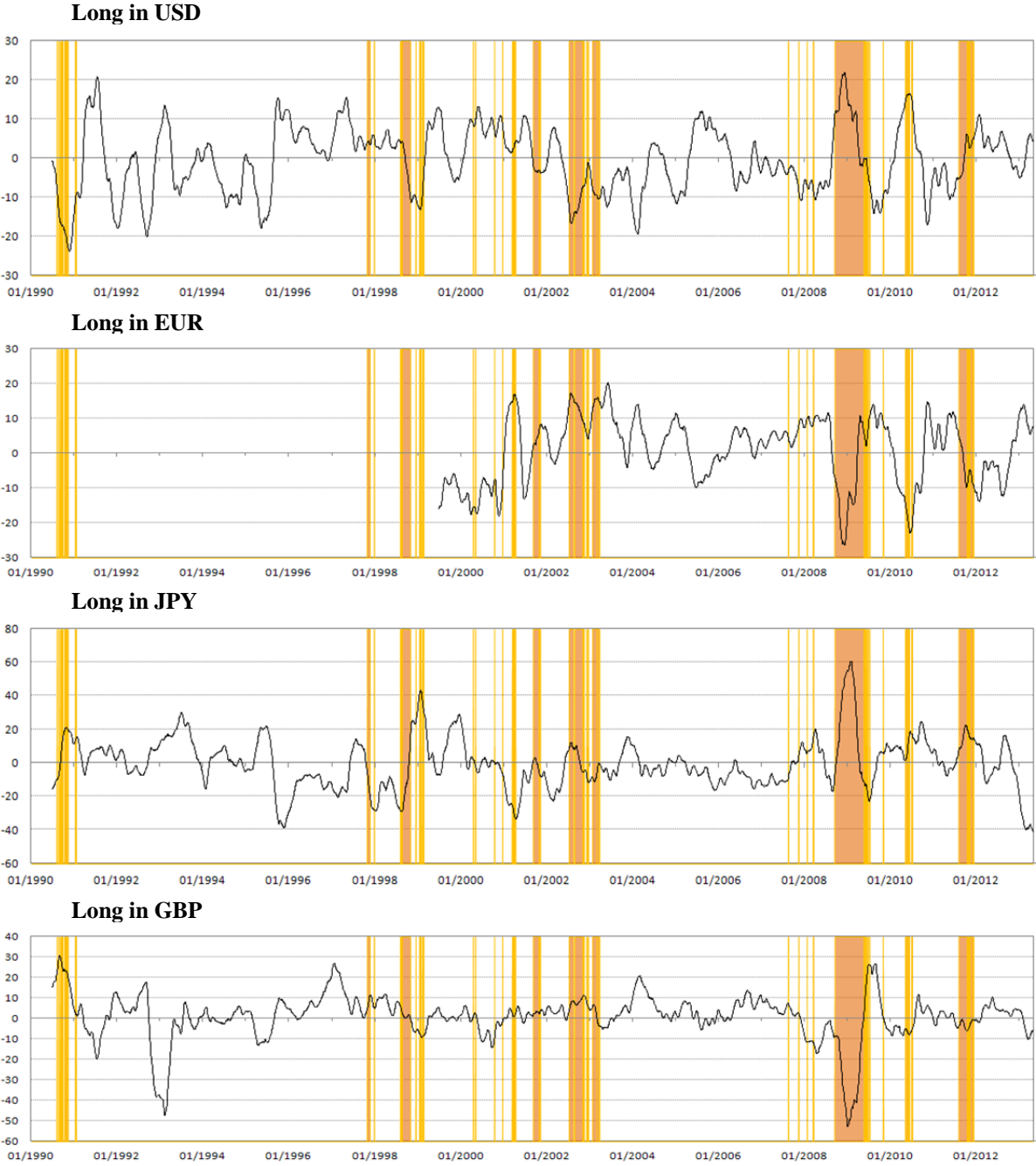
and overcomes 30% for the Australian dollar and the New Zealand dollar. The depreciation is even more pronounced in emerging countries, exceeding 20% for Brazil, Mexico and Poland, and more than 38 % during severe crises for the same three countries, as well as for Hungary.

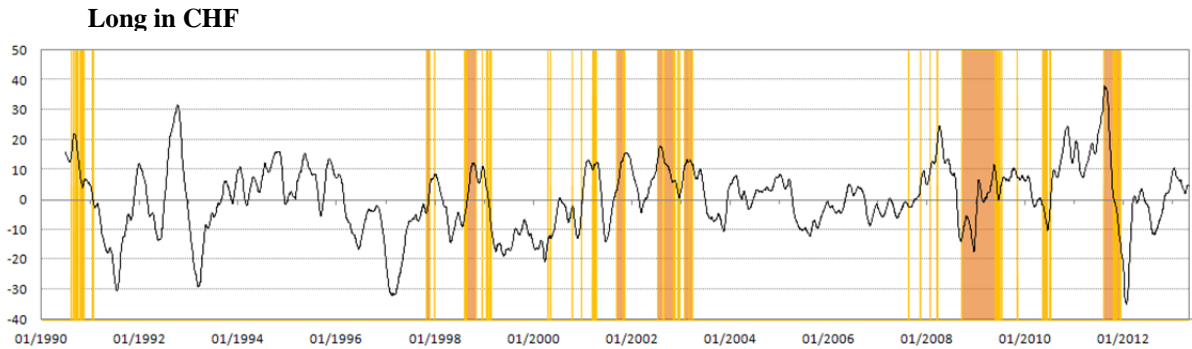
Third, the excess returns closely follow the exchange rate movements, as the interest rates differentials are much more stable than currencies most of the time. They are completely reversed during crises and even more during “severe crises”. Currencies that yield positive excess returns in normal times depreciate during crises, causing losses for carry-trade investors. Vice-versa, the dollar and the yen that provide negative excess returns in normal times turn to be lucrative during crises, hence meeting condition (C2) for safe havens. The Swiss franc also provides positive returns over the long run (1990-2013), but this does not hold any more when considering a shorter period since 1999 especially because of the peg to the euro mentioned above.

There are a few small oddities in the results for emerging countries: (i) the Argentinean peso yields positive excess returns during crises, because of a very high interest rate differential in those periods (20.5%), exceeding the observed depreciation. This atypical situation can be attributed to the peso having already lost 74% of its value in the first half of 2002 in the aftermath of the currency board collapse, a period that is not earmarked as a crisis by our global risk indicator. Indeed, it sank by 10.4% on average over the whole period, which is the worst performance of the sample. Having been submitted to such a drastic fall outside the reported periods of crisis, it is not surprising that the Argentinean peso had little room to depreciate further when the global crises burst. However, when it comes to severe crises, excess returns do turn negative for the Argentinean peso as for most other emerging currencies. (ii) The Thai baht and the Philippi peso happen to have slightly positive excess returns during severe crises, due to a positive interest rate differential and a stable currency. However, their excess returns are negative over all the crises, whether severe or not; besides, their positive risk premia being positive over the whole period, neither of these two currencies could qualify for safe havens.

The former calculations show the behavior of currencies on average during financial crises. Another interesting matter is to consider their evolution during each specific crisis. Figure 2 addresses the issue by displaying the evolution of the excess returns for the five key currencies over the whole period, while exhibiting the episodes of crisis. In particular, the USD and the JPY, that are the two currencies that we have identified as safe havens by our conditions (C1) and (C2), are also the only ones to yield positive excess returns during the 2008 crisis following the Lehman Brothers’ bankruptcy as well as during the 2010 Greek crisis. The three others, the EUR, the GBP and the CHF are deeply hit by these episodes.

Figure 2: Excess returns on 1-month carry trades short in SDR and long in one of the 5 key currencies,
 annualized 6-months moving-average in %, periods of VIX hitting the 30 level in orange





5. Econometric estimation of the exchange rate changes over the financial cycle

The stylized facts found in the previous section show that two currencies, the USD and the JPY, have a tendency to appreciate when global financial markets are under stress, while all the other currencies tend to plummet. These results were obtained by defining financial stress by a VIX over two thresholds of 30 and 40. We now want to test those results econometrically and gain a more precise insight as to the mechanisms through which a currency may appreciate during crises. More precisely, we aim at evidencing a relationship between currency movements and the global financial cycle, represented by the VIX. We expect this relationship to be non-linear, as section 4 has shown that currency changes are reversed when the VIX exceeds a certain threshold. We also aim at estimating this threshold econometrically. Smooth transition regression (STR) models are typically designed for such purposes. As emerging countries' currencies clearly do not qualify for safe havens in the previous section, we remove them from the sample and therefore focus on the currencies of advanced countries.

5.1. The equation to estimate

We start from the Fama equation linking the interest rate differential to the exchange rate change of the next period (Fama, 1984):

$$\Delta s_{t+1} = \alpha + \beta(i_t - i_t^*) + u_{t+1} \quad (6)$$

where Δs_{t+1} is the annualized one-month currency depreciation against the SDR between t and $t+1$; α and β , coefficients to estimate, i_t , the one-month interest rate on the currency, i_t^* , the one-month interest rate on the SDR, and u_t , the error term.

The β coefficient would be equal to unity if UIP held. In reality, $\beta < 1$ and even < 0 , as currencies with high (low) interest rates tend to depreciate (appreciate) less on average than

the UIP would have predicted (see for example: Engel, 1995; Chaboud and Wright, 2005; Sarno, 2005). Clarida et al. (2009) find these β coefficients negative only during periods of low volatility and positive otherwise, as also Coudert and Mignon (2013). These latter results incite us to think that exchange movements depend on the financial cycle.

To incorporate the financial cycle into the Fama equation, we proceed in two ways. First, we add the VIX as an explanatory variable in the equation, with a ϕ coefficient. Second, we allow the β and ϕ coefficients to vary over the financial cycle by using a non-linear estimation. To do that, we use a smooth transition regression (STR) model - following Teräsvirta (1994, 1998) - in which the VIX is the transition variable:

$$\Delta s_{t+1} = \alpha_0 + \beta_0(i_t - i_t^*) + \phi_0 v_t + g(v_t, \gamma, c) [\beta_1(i_t - i_t^*) + \phi_1 v_t] + u_{t+1} \quad (7)$$

where v_t is the VIX and $g(v_t, \gamma, c)$, a transition function whose values fluctuate between 0 and 1 depending on the VIX level as described below; $\alpha_0, \beta_0, \phi_0, \beta_1, \phi$ are parameters to estimate; γ and c are also parameters to estimate standing for, respectively, the speed of adjustment and the threshold of function g .

Our main parameters of interest in Equation (7) are the coefficients ϕ_0 and ϕ_1 on the VIX that capture the behavior of the exchange rates along the financial cycle, as well as the c threshold that sparks non-linearities. Interest rate differentials are seen as control variables in the equation.

5.2. The specification of the transition function

The transition function g may take two shapes: either logistic or exponential. In the logistic STR (LSTR), the transition function is defined as:

$$g(v_t; \gamma, c) = \frac{1}{1 + e^{-\gamma(v_t - c)}} \quad (8)$$

Following Jansen and Teräsvirta (1996)⁶, in the exponential STR (ESTR), the exponential transition function may be written as:

$$g(v_t; \gamma, c) = \frac{1}{1 + e^{-\gamma(v_t - c_1)(v_t - c_2)}} \quad \text{with } c_2 \geq c_1 \quad (9)$$

In both transition functions (8) and (9), the lower the slope parameter γ , the smoother the transition. In the extreme case where $\gamma = 0$, g is constant and Equation (7) becomes linear.

⁶ This specification nests the LSTR model as a special case (when $c_1 = c_2$) of the ESTR one and allows a straightforward interpretation of the slope parameter γ in both models.

The choice between the two specifications is made by applying the tests introduced by Teräsvirta (1994, 1998). Nevertheless, the retained specification affects the interpretation of results. Indeed, the LSTR model is more straightforward to interpret in our case. The logistic function is a monotonous function of the VIX, increasing from 0, when v_t is far below the c threshold, to 1, when the VIX is much greater than c . Hence the LSTR model can be interpreted as having two regimes: (i) a linear one when the VIX is low, the explanatory variables being multiplied by coefficients β_0, ϕ_0 ; (ii) a non-linear one when it overcomes the c threshold, the coefficients then being equal to $\beta_0+g\beta_1$ and $\phi_0+g\phi_1$ respectively.

On the contrary, the ESTR model seems less appropriate, as the exponential g function is then U shaped, getting closer to 1 when the VIX moves far below c_1 or above c_2 and reaching its minimum when the VIX is comprised between c_1 and c_2 . However, the interpretation of the ESTR model varies with the values found for c_1 and c_2 ; if there are very few occurrences of $v_t < c_1$ or $v_t > c_2$, the ESTR model also results in two regimes, as it will be the case for our results.

5.3. Specification tests

We first test the null hypothesis of linearity against the alternative of an STR model. This amounts to test if $\gamma = 0$ in Equation (7). However, as Equation (7) is not identified under the null hypothesis (Luukkonen et al., 1988), we resort to another version of Equation (7), where the transition function g is replaced by its Taylor approximation at the third order. We therefore run the following auxiliary regression:

$$\Delta s_{t+1} = \theta_{00} + \theta'_0 z_t + \theta'_1 z_t v_t + \theta'_2 v_t^2 + \theta'_3 z_t v_t^3 + \eta_{t+1} \quad (10)$$

where $z'_t = (i_t - i_t^*, v_t)$ denotes the vector of our explanatory variables and $\theta'_i = (\theta_{i1}, \theta_{i2})$ is the vector of coefficients associated with $z_t v_t^i$ for $i = 0$ to 3.

We test for linearity in Equation (10) by testing the null hypothesis:

$$(H_0) \theta_{11} = \theta_{12} = \theta_{21} = \theta_{22} = \theta_{31} = \theta_{32} = 0$$

against its alternative: at least one of the θ_{ik} is different from 0, for $i = 1$ to 3 and $k = 1, 2$.

Second, once (and if) linearity is rejected, we turn to the choice of the transition function in Equation (7) and test whether g is logistic (LSTR, Equation (8)) or exponential (ESTR, Equation (9)). To this purpose, we consider the powers of the polynomial in Equation (10). Intuitively the logistic function being monotonous can only be approximated by an odd-degree polynomial - 1 or 3 - whereas the U shape of the exponential function can only be approximated by an even-degree polynomial: 2 or 4. We therefore test sequentially, beginning with H_{04} , the following set of hypotheses (Teräsvirta, 1994):

$$H_{04}: \theta_{31} = \theta_{32} = 0$$

$$H_{03}: \theta_{21} = \theta_{22} = 0 \mid \theta_{31} = \theta_{32} = 0$$

$$H_{02}: \theta_{11} = \theta_{12} = 0 \mid \theta_{21} = \theta_{22} = \theta_{31} = \theta_{32} = 0$$

The rejection of H_{04} leads to an LSTR model and thereby ends the sequence of tests, whereas if H_{04} cannot be rejected, the next step is to test for H_{03} . If H_{03} is rejected we select an ESTR model, if it is not, we proceed to the test of H_{02} . If H_{02} is eventually rejected we retain the LSTR model.

5.4. Empirical results of the tests

We estimate Equation (10) and then (7) over a sample of 10 advanced countries' currencies over the period spanning from 01/02/1999 up to 23/04/2013. Note that the exchange rate changes are calculated over one month while the estimation is run on daily data. As this implies overlapping data and auto-correlated error terms, we use the Newey and West (1987) correction to obtain a consistent covariance estimator.

The null hypothesis of linearity is rejected for all the considered currencies, with at a level of confidence over 99%. This shows that the behavior of all the currencies varies along the financial cycle, comforting our approach in terms of non-linearities and justifying the use of a STR model. The LSTR model is nearly always selected as evidenced by the results of the sequence of tests (Table A1 in the appendix). The only exceptions are the Australian and New Zealand dollars for which the ESTR model is retained. This means that in eight cases out of ten, the exchange rates follow two regimes depending on the value of the VIX: (i) a linear regime, characterized by coefficients β_0 and ϕ_0 when the VIX is below the c threshold, (ii) a non-linear regime characterized by coefficients $\beta_0 + g\beta_1$ and $\phi_0 + g\phi_1$ when it is above its threshold.

We then estimate the STR model of Equation (7) and apply three misspecification tests: a test of no error autocorrelation (Teräsvirta, 1998), the LM-test of remaining nonlinearity of Eitrheim and Teräsvirta (1996), the ARCH-LM test of heteroskedasticity (Engle, 1982). Results globally confirm the nonlinear specifications retained (Table A2 in the Appendix); the hypothesis of error autocorrelation is always rejected except for New Zealand; there is no remaining nonlinearity except for Norway and the hypothesis of heteroskedasticity is rejected in all cases but Australia and New Zealand.

5.5. Econometric results and implications for safe haven currencies

The estimated parameters are displayed in Table 3 with their Student-statistics corrected for overlapping data. As expected, the β_0 coefficients reported in the first column are well below unity for all currencies (except for the Icelandic krona) and even negative for six currencies out of ten, evidencing significant deviations from the UIP in times of low volatility.

Coefficients φ_0 and φ_1 are of particular interest for they capture the response of the exchange rate to the financial cycle. In the case of the LSTR models⁷, we can use these coefficients to identify safe haven currencies. A negative φ_0 refers to a currency that appreciates when the VIX rises; a negative $\varphi_0 + \varphi_1$ means that a surge in the VIX above its threshold still strengthens the currency. As specified in condition (C2'), safe haven currencies are characterized by their appreciation during crises. Therefore, we will spot the safe haven currencies by their negative sign on both φ_0 and $\varphi_0 + \varphi_1$.

Three interesting results emerge from Table 3: the first two ones deal with the different responses of currencies to financial strains, which allow us to characterize the safe haven currencies, the third one concerns the form of the transition function.

First, most exchange rates are directly impacted by the global financial cycle, but with different signs across countries. To see that, we consider the sign of the φ_0 coefficient for the LSTR models. Two groups of currencies stand out by this criterion. The USD and the JPY appreciate when the VIX increases, their coefficient φ_0 being significantly negative. On contrary the EUR, the GBP and the CAD lose value when the VIX rises.

Second, when the VIX overcomes its estimated threshold, only two currencies still significantly strengthen as financial volatility continues to soar: the US dollar and the Japanese yen. This is evidenced by $\varphi_0 + \varphi_1$ being significantly negative for these two currencies. Hence, both meet the condition that we have stated above for safe haven currencies. All other currencies tend to drop during these crisis periods. The fall is significant for the Sterling, the Canadian dollar, the Norwegian krone and the Icelandic krona.

Third, the levels of the VIX triggering non-linear effects are different across countries, as indicated by the threshold values reported in Table 3. They are comprised between 25 and 35 for six currencies in 10, above 40 for 3 others. The slope parameters γ are also very different, the transition from the linear to the non-linear regime being more or less smooth across countries. A high value of γ such as the one observed for the US dollar indicates a very rapid regime switch, once the VIX hits the threshold (of 29 for the US). Figure 2 depicts the transition function according to the realized values of the VIX over the period under study. The transition is quite abrupt for the USD and smoother for the JPY.

⁷ In the following comments, we will focus on the LSTR models, the ESTR will be dealt with below.

Table 3: Estimation of Equation (7). February 1999-April 2013

$$\Delta s_{t+1} = \alpha_0 + \beta_0(i_t - i_t^*) + \phi_0 v_t + g(v_t, \gamma, c) [\beta_1(i_t - i_t^*) + \phi_1 v_t] + u_{t+1}$$

Currency	Model	Interest rate differential		Effects of the financial cycle (VIX)			Threshold		Slope
		β_0	β_1	ϕ_0	ϕ_1	$\phi_0 + \phi_1$	c/c_1	c_2	g
5 key currencies									
USD	LSTR	-3,19	-4,86	-0,06	-0,14	-0,20	28,9		183,8
		<i>-12,22</i>	<i>-4,54</i>	<i>-1,58</i>	<i>-5,60</i>	<i>4,46</i>	<i>288,8</i>		
EUR	LSTR	-6,81	-0,80	1,03	-0,45	0,58	21,9		6,1
		<i>-9,13</i>	<i>-0,70</i>	<i>7,80</i>	<i>-5,17</i>	<i>3,66</i>	<i>43,7</i>		
JPY	LSTR	0,26	-7,98	-1,37	0,37	-1,00	26,6		3,6
		<i>0,66</i>	<i>-7,88</i>	<i>-6,42</i>	<i>2,65</i>	<i>-3,89</i>	<i>64,1</i>		
GBP	LSTR	-0,24	-12,48	0,27	0,50	0,77	39,5		3,3
		<i>-0,51</i>	<i>-3,20</i>	<i>4,48</i>	<i>3,94</i>	<i>3,94</i>	<i>16,7</i>		
CHF	LSTR	-4,60	3,70	0,14	-0,04	0,10	25,6		18,8
		<i>-12,21</i>	<i>4,24</i>	<i>1,78</i>	<i>-0,68</i>	<i>1,04</i>	<i>63,5</i>		
Other advanced countries' currencies									
AUD	ESTR	-10,27	7,61	1,01	-1,08	-0,08	32,6	81,0	1,6
		<i>-8,60</i>	<i>-6,18</i>	<i>11,11</i>	<i>-10,90</i>	<i>-0,57</i>	<i>60,1</i>	<i>73,1</i>	
NZD	ESTR	-2,23	4,62	0,1	0,27	0,32	10,4	35,4	2,7
		<i>-5,35</i>	<i>1,91</i>	<i>-0,5</i>	<i>1,5</i>	<i>1,6</i>	<i>10,3</i>	<i>47,0</i>	
CAD	LSTR	-44,59	63,77	0,73	-0,05	0,67	35,4		0,3
		<i>-5,73</i>	<i>4,27</i>	<i>7,0</i>	<i>-0,3</i>	<i>3,4</i>	<i>0,6</i>		
NOK	LSTR	-0,11	-0,11	0,04	0,09	0,13	51,2		71,0
		<i>-3,46</i>	<i>-0,22</i>	<i>6,2</i>	<i>3,8</i>	<i>5,4</i>	<i>81,2</i>		
ISK	LSTR	1,14	4,65	0,21	0,18	0,39	49,6		0,6
		<i>1,80</i>	<i>1,91</i>	<i>0,9</i>	<i>0,5</i>	<i>0,9</i>	<i>5,7</i>		

Note. Figures in italics below coefficients are the t-Student.
Currency codes are given in the first paragraph of Section 4.1.

Figure 3 represents the response of the USD and the JPY to a change of one percentage point for the VIX, ie the sum of coefficients $\phi_0 + g\phi_1$ over the estimation period. The USD appreciates by 0.06% on an annual basis when the VIX increases by 1 percentage point; this appreciation jumps to 0.2% when the VIX overcomes the threshold of 29. The response of the Japanese yen is more pronounced, as it appreciates by 1.4% for each percentage point increase in the VIX outside crisis times, and by 1% when the VIX exceeds 27.

The ESTR model found for the Australian dollar leads to a truncated exponential function, because there is no observation with the VIX above the estimated value of the threshold $c_2=81$. Hence this particular ESTR model has only two regimes as the LSTR commented above. One notable difference however is that the exponential function is decreasing with the VIX over this segment, instead of increasing for the logistic. It goes from 1 when the VIX is far below $c_1= 32.6$ to 0 when above. Hence in the tranquil phase of the financial cycle, when

the VIX is smaller than 32, the sum of coefficients $\phi_0 + \phi_1$ applies and it is found to be non significantly different from zero; therefore there is no influence of the financial cycle on the Australian dollar. On the contrary during crises, when the VIX hits the 32.6 threshold, the coefficient ϕ_0 applies and is significantly positive, which means that the AUD tends to depreciate with financial strains. This result fits the commonly reported view in the financial press of the Australian dollar as the long leg of carry trades. Although this property is also frequently mentioned for the New Zealand dollar, it is not corroborated in our estimations, the coefficients on the VIX being non-significant for this country, whatever the phase of the financial cycle.

Figure 2: Value of transition function depending on the level of the VIX, for the US dollar and the Japanese yen

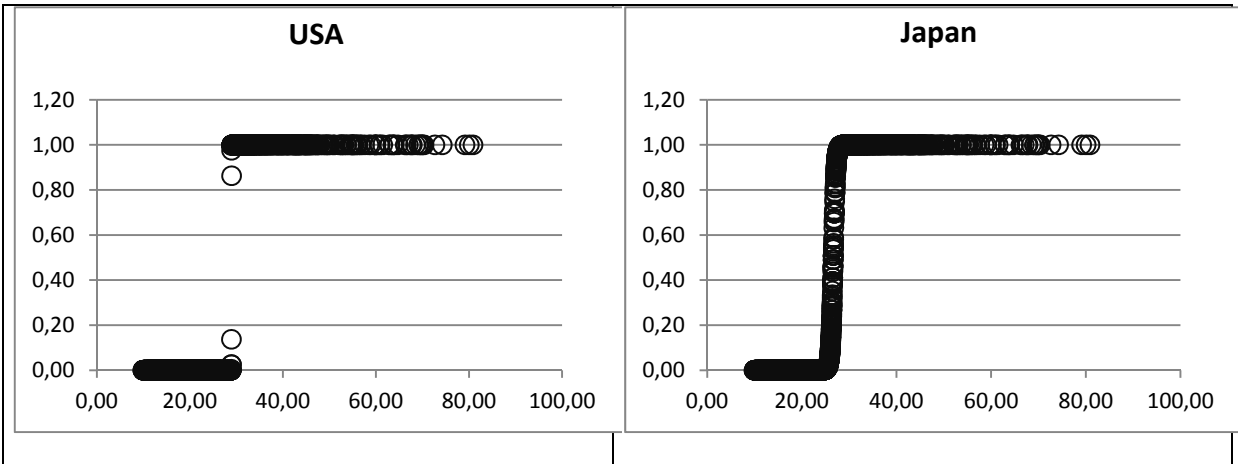
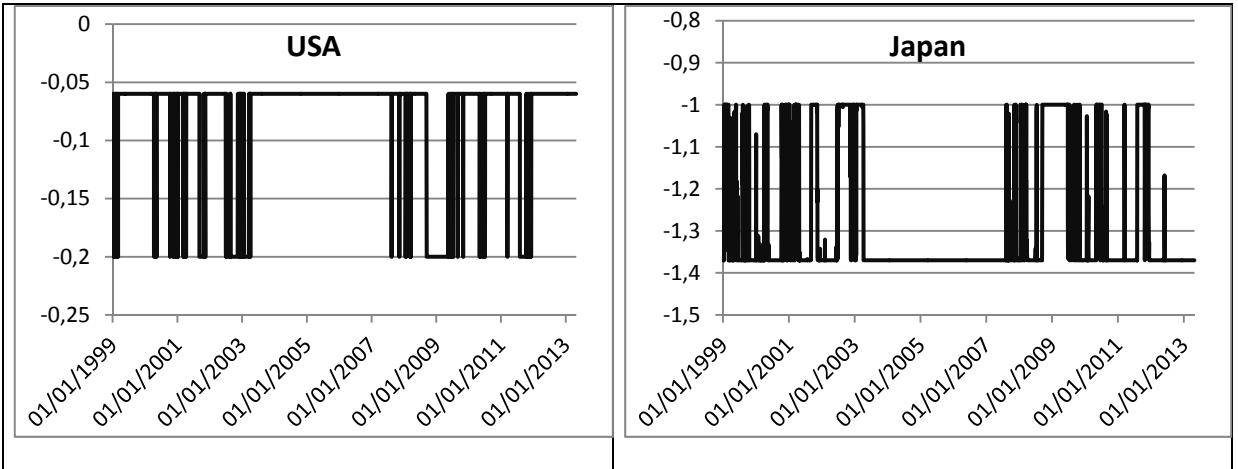


Figure 3: One-day change in the exchange rate in response to a 1 point change in the VIX; ie sum of the coefficients $\phi_0 + g\phi_1$ over the period of estimation, for the US dollar and the Japanese yen (a negative value indicates an appreciation).



6. CONCLUSION

Financial asset returns are known to vary over the financial cycle. The forex market is no exception: some currencies typically plummet during crises while others tend to appreciate, a phenomenon that is clearly corroborated by our results. The huge amounts of carry trades - long in high-yield currencies and shorting the low-yield ones - that investors build up in the upward phase of the cycle tend to exacerbate these fluctuations, as they are abruptly unwound during financial crises. Hence the funding currencies of these carry trades which are bidden up during crises are likely to play the part of safe havens. The last crisis, the ensuing “currency war”, as well as the quest of investors for safe havens may also have amplified the phenomenon.

In this paper, we have first characterized the safe haven currencies by their negative risk premia in the long run, as well as by their positive excess returns during financial downturns. The empirical calculations of ex post excess returns over a sample of 26 currencies from 1999 to 2013 point to the JPY and the USD as the only currencies to meet these conditions. The mean excess returns of both currencies are negative over the long run, whereas turning positive during financial crises.

Second, the financial cycle – proxied by the VIX – drives the exchange rate changes in different directions across currencies, as evidenced by the econometric results. This influence is two-fold: direct as an explanatory variable and also indirect as a factor of nonlinearity in a smooth-transition regression (STR) model. According to these estimations, typical carry trade currencies such as the Australian dollar tend to plunge in response to a volatility rise during financial turmoil, while the JPY and the USD react the opposite way by an appreciation, once again qualifying for a safe haven role. However, the interventions of the Japanese monetary authorities selling the JPY against USD to fight deflation through quantitative easing might prevent the yen from playing this part in the future. As regards to the Swiss franc that is often considered as a safe haven, our results do not support this view; actually its long-run appreciation is more a continuous trend than a specific reaction to global financial turmoil.

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Appendix

Table A1: Specification test for the transition function (p-values of F-statistic)

Currency	$p(F)$	$p(F_{04}) - H_{04}$	$p(F_{03}) - H_{03}$	$p(F_{02}) - H_{02}$
USD	0.0410	0.5737	0.1637	0.0150
EUR	0.0000	0.0000	0.0003	0.2317
JPY	0.0000	0.0000	0.0000	0.0000
CHF	0.0000	0.0002	0.0005	0.1103
GBP	0.0000	0.0000	0.0006	0.0170
AUD	0.0000	0.0000	0.0000	0.0000
NZD	0.0000	0.4649	0.0000	0.0000
CAD	0.0000	0.0000	0.0001	0.0000
NOK	0.0000	0.0959	0.0194	0.0000
ISK	0.0000	0.0000	0.4266	0.0000

Notes: The VIX is the transition variable. This table indicates the results of the choice of the transition function (p-value are given). We follow the procedure of Teräsvirta (1994). Hypothesis H_0 is the general null hypothesis based on the third-order Taylor expansion of the transition function. The rejection of H_{04} leads to an LSTR model and thereby ends the sequence of tests, whereas if H_{04} cannot be rejected, the next step is to test for H_{03} . If H_{03} is rejected we select an ESTR model, if it is not, we proceed to the test of H_{02} . If H_{02} is eventually rejected we retain the LSTR model. For currencies codes, see Section 4.1.

Table A2. Misspecification tests (p-values)

Currency	No autocorrelation [*]	No remaining nonlinearity ^{**}	ARCH ^{***}
USD	0.81	0.45	0.25
EUR	0.52	0.06	0.41
JPY	0.95	0.49	0.95
CHF	0.66	0.16	0.93
GBP	0.79	0.33	0.40
AUD	0.64	0.28	0.05
NZD	0.04	0.34	0.03
CAD	0.48	0.16	0.78
NOK	0.96	0.00	0.25
ISK	0.84	0.37	0.38

Notes: This table indicates the results of residual tests (*p-values* are given): ^{*} test of no residual autocorrelation (Teräsvirta, 1998), ^{**} LM test of no remaining nonlinearity (Eitrheim and Teräsvirta, 1996) and ^{***} ARCH-LM test (Engle, 1982). For currencies codes, see Section 4.1.