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V. Dobrynskaya

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Centre for Advanced Studies
Russia, Moscow
http://www.cas.hse.ru
E-mail: cas@hse.ru

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Downside risk of carry trades

Victoria Dobrynskaya*

London School of Economics,
Houghton St. London WC2A 2AE,
and Center for Advanced Studies of
Higher School of Economics,
11, Pokrovsky Boulevard. Moscow
E-mail: v.v.dobrynskaya@lse.ac.uk
Tel: +44(0)7765595504

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Abstract

Carry trades consistently generate high excess returns with high Sharp ratios, but are subject to crash risk. I take a closer look at the link between the carry trade returns and the stock market to understand the risks involved and to determine when and why currency crashes happen. Every period, I sort currencies of developed and emerging economies by their interest rates and form portfolios to diversify the idiosyncratic risk. First, I find a strong negative relationship between portfolio returns and skewness of exchange rate changes. In fact, skewness and coskewness with the stock market have a much greater explanatory power in the cross-section of excess returns than consumption and stock market betas. But separating the market beta into upside and downside betas improves the validity of the CAPM significantly. Downside beta has a much greater explanatory power than upside beta, and it correlates with coskewness almost perfectly. This means that carry trades crash exactly in the worst states of the world, when the stock market goes down. After controlling for country risk, the downside beta premium in the currency market is comparable to that in the stock market and equals 2-4 percentage points p.a. I also find that country risk proxies well for the downside beta and skewness. This suggests that there is unwinding of carry trades and a "flight to quality" when the stock market plunges, and that lower interest rate currencies serve as a "safe haven". Finally, I estimate even higher downside betas of the top portfolios and I find an even greater explanatory power of the downside beta in the early 2000s. The growing volume of carry activities might have contributed to the closer link between the currency and the stock markets.

JEL classification: G12, G15, F31

Keywords: carry trades, currency risk, downside beta, coskewness, crash risk

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1. Introduction

There are several puzzles in international finance, which challenge the traditional theory. Among them is the forward premium puzzle, or the violation of the Uncovered Interest Parity (UIP). According to the UIP, free capital mobility ensures that investments in different currencies with different levels of the local interest rates do not consistently generate excess returns, because a negative interest rate differential is compensated by the expected exchange rate appreciation of the target currency, or the forward premium. In reality, though, this does not happen. Furthermore, the opposite is observed quite often: high-interest currencies tend to appreciate while low-interest currencies tend to depreciate, on average (Fama, 1984). Then, investment in high-interest currencies consistently yields higher returns than investment in low-interest currencies. This empirical 'anomaly' has led to the popularity of carry trades – an investment strategy where an investor borrows in low-interest currencies and invests into high-interest currencies and, thus, enjoys the positive interest rate differential together with a positive exchange rate return.

The UIP assumes risk-neutrality of investors. But if investors are risk-averse, investments in high-interest currencies should yield higher returns than investments in low-interest currencies, if the former are more risky than the latter. Thus, if a carry trade is a sufficiently risky strategy, then the high returns to carry trades, observed empirically, are not an anomaly at all. But carry trades also have high Sharp ratios, so the volatility of returns is not an adequate risk measure. Therefore, there is a quickly emerging literature which tries to understand and measure the risks involved in carry trades.

Lustig and Verdelhan (2007) look at carry trades through the Consumption CAPM lenses, and claim that returns of high-interest currencies co-move with US non-durable and durable consumption growth, while returns of low-interest currencies serve as hedge against local consumption risk. Hence, they conclude, the average high returns of carry trades are a mere compensation for the consumption risk because carry trades yield low returns when consumption growth is low and the marginal utility of wealth is high. The relevance of the Consumption CAPM framework for explaining currency returns was also confirmed by De Santis and Fornari (2008) for several European countries.

Also, carry trades seem to perform poorly in high-volatility regimes. Menkhoff et. al (2009) find that returns to carry trades correlate negatively with the volatility in the currency market. Furthermore, their volatility proxy explains the returns of five currency portfolios, sorted by the interest rate, well. Ronaldo et al. (2009) distinguish between regimes of high and low volatility in the currency and stock markets, using different volatility proxies (e.g. implied volatility in the currency market, VIX, TED, bid-ask spread, etc.), and find that their carry trade strategy has a much higher exposure to the stock market in high-volatility regimes. Clarida et al. (2009) estimate that the coefficient in the 'Fama regression' is greater than unity[2] in high FX volatility regimes, and carry trades generate losses in such periods, despite their average high profitability. A similar conclusion was drawn in Brunnermeier et al. (2008) for seven major single currencies, rather than for portfolios of currencies. The authors find that there is a negative relationship between currency interest rates and skewness of returns, so that high-interest currencies (i.e. the investment currencies) are subject to crash risk, with the crashes happening in periods of high volatility, as measured by VIX.

This paper contributes to the above literature by studying the performance of currency portfolios, sorted by the interest rate. In particular, I take a closer look at the link between the currency and stock markets and study the stock market risk of carry trades. This type of risk is also explored in Campbell et al. (2010) and Ronaldo and Söderlind (2009) for several single currencies of developed countries. Campbell et al. (2010) find a positive correlation of the Australian dollar and the Canadian dollar with the global equity markets and a negative correlation of the euro and the Swiss franc (the Japanese yen, the British pound and the US dollar fall in the middle of the two extremes). A high-frequency analysis in Ronaldo and Söderlind (2009) uncovers a similar pattern: the Swiss franc and the Japanese yen (and to a lesser extent the euro) appreciate when the US stock market goes down, while the opposite is observed for the British pound. The "safe haven" properties of the Swiss franc and the Japanese yen are confirmed in periods of political, natural or financial disasters, using a disaster dummy. Although these two studies do not look at carry trades explicitly, their findings suggest that there is a particular relationship between local interest rates and the hedging properties of the currencies. In both papers, the currencies which go against the stock market are the ones which are the most common funding currencies for carry trades (the Japanese yen and the Swiss franc), while the currencies with the highest exposure to the stock market are the usual target currencies. Hence, carry trades may be prone to high stock market risk, and this idea is explored thoroughly in this paper.

Instead of looking at single currencies, I form portfolios of currencies sorted by the interest rate. This allows me to diversify away the idiosyncratic risk and to concentrate on those properties which are attributable to currencies with different levels of interest rates. I include 47 developed and emerging economies in the sample, and hence I provide evidence for a much wider spectrum of currencies than in the papers cited above, which concentrate on several currencies of developed countries.

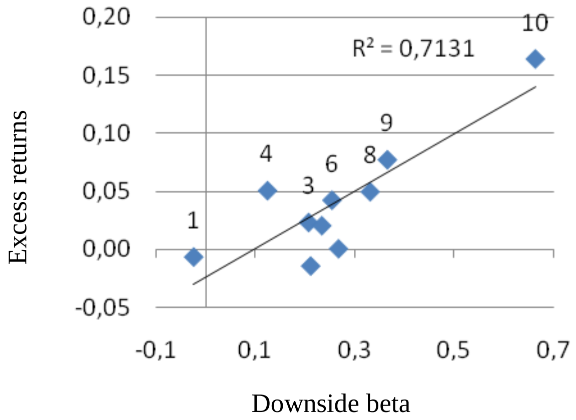
[2] According to the UIP, this coefficient should equal to 1, but empirically it was estimated to be close to zero or even negative (Burnside et al., 2006).

First, I confirm the finding of Brunnermeier et al. (2008) that there is a strong negative relationship between portfolio returns and skewness of returns. Thus, carry trades are subject to occasional crashes. Having more countries in the sample and forming portfolios shows that the range of skewness, as well as returns, is much greater than in Brunnermeier et al. (2008), and the relationship between the two is more pronounced. But this relationship disappears if portfolios are sorted once by the average interest rate, instead of the monthly rebalancing. Therefore, I conclude that low skewness is a property of currencies with high contemporary interest rates and, as the interest rate in a country decreases, the exchange rate skewness approaches zero.

Second, I find a positive relationship between portfolio returns and consumption and stock market betas of exchange rate returns. Higher-interest currencies have relatively higher consumption and stock market exposure, while low-interest currencies can hedge against these risks. This is in line with the findings of Lustig and Verdelhan (2007) and Campbell et al. (2010). But, in the cross-section of currency portfolio returns, the explanatory power of consumption and stock market betas is much lower than that of skewness and coskewness with the stock market. Therefore, the asymmetry of currency returns should be taken into account, and the three-moment CAPM explains the cross-section of currency portfolio returns well.

If carry trades are subject to crash risk, measured by skewness, a natural question arises when these crashes happen. This paper contributes along this dimension by studying coskewness with the stock market and the downside risk of carry trades. Low negative coskewness of high-interest portfolios suggests that these portfolios have negative returns when stock market volatility is high. This finding goes in line with the papers on the performance of carry trades in different volatility regimes, discussed above. But high stock market volatility is usually observed in periods of crashes. Then the downside beta, which conditions on negative stock market returns, should be a relevant measure of the riskiness of currency portfolios. Indeed, there is a very strong relationship between portfolio returns and the downside betas (Figure 1). The downside betas of the high-interest portfolios are much higher than their 'standard' betas, which suggests that high-interest portfolios crash in the worst states of the world when the stock market plunges. The lowest-interest portfolio, the funding portfolio, on the contrary, has a negative downside beta. Therefore, these currencies appreciate when the stock market goes down, and, hence, can serve as a hedging instrument. But there is no significant relationship between portfolio returns and their upside betas. This is a predictable result because when the stock market return is high the marginal utility of wealth is low and performance of assets in these states is not so important for an investor. The appropriateness of the downside beta and not of the upside beta as a risk measure was also confirmed in the cross-section of stock returns (Ang et al., 2006).

Figure 1. Downside risk of 10 currency portfolios



Note: The sample period is 1999-2009

In the cross-section of currency portfolio returns, separating the stock market beta into upside and downside betas improves the validity of the CAPM significantly. The two-beta CAPM explains about 70 percent of the variation of portfolio excess returns, and the explanatory power of the three-moment two-beta CAPM is even higher. Hence, I conclude that the high returns of carry trades is not a free lunch, but rather a compensation for the high downside market risk, which is so important for an investor and cannot be diversified away.

Next, I look at the country risk of the currency portfolios, measured by Fitch country rating. Although there are occasional periods when countries with low (high) rating turn out to be in low(high)-interest portfolios, on average, there is a strong negative relationship between a portfolio interest rate and its country rating. High-interest currencies have high risk of default and need to be compensated for this risk, while low-interest currencies are almost riskless. Country risk proxies well for the market risk of the currency portfolios, i.e. risky currencies have high downside betas and negative skewness and coskewness. This suggests that there is a "flight to quality" when the stock market plunges, and the lowest-interest lowest-country risk portfolio serves as a "safe haven". Ronaldo and Söderlind (2009) also find "safe haven" properties of the Swiss franc and the Japanese yen, but I confirm this in a more general setting for diversified portfolios of currencies.

This finding suggests a reason why carry trades crash. When the stock market return is low, increased risk aversion of investors (e.g. due to narrow framing as in Barberis, Huang and Santos, 2001, or due to habits, as in Campbell and Cochrane, 1999, and Verdelhan, 2010) may lead to "flight to quality", which is, among others, a flight from risky high-interest currencies to relatively riskless low-interest currencies. Since carry trades are long in the former and short in the latter, they crash.

The main claim of this paper is that high returns of carry trades are a compensation for their high downside market risk, which is non-diversifiable. Is this compensation fair relative to other asset markets? To answer this question I compare downside risk premiums in the currency and stock markets. I estimate the downside risk premium in the cross-section of stock portfolios, sorted by their individual downside betas. Such sorting allows concentrating on the downside risk in the stock market, while diversifying away other risks. The downside risk premium in the currency market appears to be much higher than in the stock market due to higher range of returns and lower range of downside betas. But, after controlling for the country risk of the currency portfolios, the downside beta premium shrinks and becomes comparable to that in the stock market (about 2-4 percent per annum). Therefore, the high returns of carry trades are a compensation for both the downside risk and the country default risk, which actually go hand-in-hand. The country default risk is unobservable in the sample (a "peso" event problem) and cannot be estimated directly in the same way as the downside risk is estimated[3]. Therefore, the country rating is used to measure it. But investors may still demand a compensation for it. Indeed, many papers find that a significant part of unhedged carry trade returns is a compensation for such "peso" events (e.g. Burnside et al, 2008; Jurek, 2008; Fahri et al., 2009).

The findings of this paper are robust in a more recent period – the first decade of the 21st century. The downside market risk of carry trades has even increased, and the explanatory power of the two-beta CAPM in the cross-section of currency returns is now even higher. Currency crashes have become less significant, but more systematic. The rising volume of carry trade activity (Galati et al., 2007) might have contributed to the closer link between the currency and stock markets.

The rest of the paper is organized as follows. In section 2, I lay out the three-moment CAPM to motivate why asymmetry of return distribution should be priced in equilibrium. Section 3 is devoted to the description of data, portfolio formation and portfolio statistics. Section 4 looks at the explanatory power of consumption and stock market betas, skewness and coskewness of exchange rate returns with the stock market returns in the cross-section of the currency portfolio returns, while section 5 analyses the downside risk in detail. In section 6, I look at the country risk of portfolios. Section 7 is devoted to comparison of the downside risk premia in the currency and stock markets. In section 8, I provide the most recent evidence and perform various robustness tests. Section 9 concludes.

2. Three-moment CAPM

Since currency returns are distributed asymmetrically (Brunnermeier at al., 2008), we should call for a model where the third moment is priced – the three-moment CAPM. The three-moment CAPM goes back to Kraus and Litzenberger (1976), where there is preference for systematic

[3] Although non-systematic skewness of exchange rate returns partially reflect this risk in long enough samples.

skewness. But for a diversifying investor, it is coskewness with the market which is important. Intuitively, adding an asset with high coskewness to a market portfolio increases the skewness of the portfolio, and, hence, such an asset is valuable and its expected return should be lower.

To show how coskewness enters the asset pricing equation I lay out the 3-moment CAPM, developed by Harvey and Siddique (2000). The first-order condition for a utility-maximizing representative investor is the following standard pricing equation:

$$E_t[(1+R_{i,t+1})m_{t+1}]=1 \tag{1}$$

where $R_{i,t+1}$ is the total return on asset i and m_{t+1} is the stochastic discount factor, which is equal to the marginal rate of substitution between periods t and $t+1$.

To produce the three-moment CAPM, the authors assume that the marginal rate of substitution is quadratic in the market return:

$$m_{t+1}=a_t+b_t R_{M,t+1}+c_t R^2_{M,t+1} \tag{2}$$

Here, the market return serves as a proxy for the growth in the marginal utility, e.g. when the market return is positive, the investor's wealth increases and the marginal utility falls.

The above expression can be derived by expanding the marginal rate of substitution to the second order:

$$m_{t+1}=1+\frac{W_t U''(W_t)}{U'(W_t)}R_{M,t+1}+\frac{W_t^2 U'''(W_t)}{2U'(W_t)}R^2_{M,t+1}+o(W_t) \tag{3}$$

where the utility function of wealth $U(W_t)$ has the following properties: $U'(W_t)>0$, $U''(W_t)<0$ and $U'''(W_t)>0$. The third property is implied by non-increasing absolute risk aversion, which is an important property of the utility function of a risk-averse investor (Arrow, 1964). Then $a_t=1+o(W_t)$, $b_t<0$ and $c_t>0$ in equation (2).

Expanding the expectation in equation (1), we obtain the following expression for asset i:

$$E_t[1+R_{i,t+1}]=\frac{1}{E_t[m_{t+1}]}-\frac{Cov_t[m_{t+1},(1+R_{i,t+1})]}{E_t[m_{t+1}]} \tag{4}$$

Substituting the expression for the stochastic discount factor (2) into equation (4) and assuming the existence of a conditionally risk-free asset, the authors obtain the following asset-pricing equation:

$$E_t[r_{i,t+1}]=\lambda_{1,t}Cov_t[r_{i,t+1},r_{M,t+1}]+\lambda_{2,t}Cov_t[r_{i,t+1},r^2_{M,t+1}] \tag{5}$$

where $r_{i,t+1}$ is the excess return on asset i, $r_{M,t+1}$ is the market risk premium, and $\lambda_{1,t}$ and $\lambda_{2,t}$ are functions of the expected market excess return, variance and skewness and expectation and variance of the squared market excess return. What is important is that $\lambda_{1,t}$ and $\lambda_{2,t}$ are the same across all assets, $\lambda_{1,t} > 0$ and $\lambda_{2,t} < 0$.

According to equation (5), an asset with higher covariance with the market return (higher beta) should have a higher expected return while an asset with higher covariance with the squared market return (higher coskewness) should have a lower expected return. While a higher beta makes an asset more risky and less attractive, a higher coskewness increases the attractiveness of an asset since adding such an asset to a portfolio increases the skewness of the portfolio return.

It should be pointed out, that if c_t in equation (2) is zero, $\lambda_{2,t}$ is also zero, and we are back to the standard CAPM, where only the market beta is priced.

3. Data and descriptive statistics

The rest of the paper is devoted to the empirical analysis. The data covers the period from January 1990 until April 2009 at a monthly frequency. Earlier years are not analyzed due to the predominance of fixed exchange rate regimes in many countries in the sample. The sample of countries consists of 47 developed and emerging economies with significant volume of currency turnover, according to BIS (2007). The full list of countries and the respective periods of available data is provided in the appendix.

For each country, I collect the beginning-of-period three-month Treasury bill rate (or the return of a comparable instrument) and the end-of-the-month exchange rate against the US dollar. An increase in the exchange rate means appreciation of the respective currency against the US dollar. The exchange rate data is corrected for denominations (see the appendix for details). Since the analysis is performed from the viewpoint of a US investor, I also collect time series of the US stock market returns, US non-durable consumption and US non-durable CPI. The data is taken from the Global Financial Database. MSCI index serves as a proxy for the US stock market index. Individual stock returns are taken from CRSP.

Since the period of available data for some countries is shorter than the period of the study, and since the periods of fixed exchange rate regimes are dropped out, the number of cross-sectional observations varies from month to month between 27 and 43.

Following Lustig and Verdelhan (2007), I sort the countries by the local interest rate every month, and form three sets of equally weighted portfolios: 5, 10 and 25 portfolios. For instance, in the 5-portfolio set, portfolio 1 consists of 20 percent of countries with the lowest interest rates, portfolio 2 consists of the next 20 percent of countries in the ranking, and so on. So, in each set, portfolio 1 always contains the countries with the lowest interest rates, while portfolios 5, 10 and 25 always contain the countries with the highest interest rates. Obviously, 5 portfolios are mostly diversified while 25 portfolios, each consisting of 1.4 countries on average, are rather noisy. The monthly rebalancing ensures that the portfolios resemble carry trade portfolios, the composition of which changes over time as relative interest rates change. It should be noted that countries do move across portfolios quite often.

Table 1 presents descriptive statistics of 10 currency portfolios[4]. The first row shows the difference between the average monthly portfolio interest rate and the US interest rate. The interest rate differential is monotonically increasing with the portfolio rank due to the sorting procedure. Portfolios 1 and 2 consist of the usual funding currencies while portfolios of higher rank consist of investment currencies. The second row shows average monthly exchange rate returns. Portfolios of higher rank do seem to depreciate more than the bottom portfolios, but the exchange rate depreciation does not offset the gain from the interest rate differential, as predicted by the UIP, so that the total portfolio return (rows three and four) is almost monotonically increasing with the portfolio rank. This confirms the profitability of carry trades. For example, a zero-investment strategy of borrowing portfolio 1 and investing the proceeds in portfolio 10 generated an average return of about 24 percent per annum in the studied period[5].

Table 1. Descriptive statistics of 10 currency portfolios

		Pfl 1	2	3	4	5	6	7	8	9	Pfl 10
1	Interest rate differential (p.m.)	-0.18	-0.03	0.05	0.11	0.17	0.27	0.40	0.59	1.02	3.77
2	ER returns (p.m.)	0.13	-0.08	0.06	0.24	0.02	0.01	-0.21	-0.24	-0.34	-1.85
3	Total excess returns (p.m.)	-0.05	-0.11	0.10	0.34	0.19	0.27	0.19	0.36	0.68	1.92
4	Total excess returns (p.a.)	-0.63	-1.38	1.22	4.11	2.23	3.29	2.25	4.30	8.12	23.08
5	Standard deviation	1.77	2.00	2.26	2.01	2.38	2.42	2.43	2.79	2.69	4.09
6	Market beta of ER returns	-0.01	0.06	0.06	0.04	0.10	0.11	0.11	0.16	0.14	0.17
		[-0.39]	[1.37]	[1.06]	[0.90]	[1.65]	[2.04]	[1.51]	[2.11]	[2.07]	[1.90]
7	Skewness of ER returns	0.76	-0.15	-0.34	-0.22	-0.69	-0.47	-0.82	-0.54	-2.38	-2.61
8	Coskewness of ER returns	0.59	-0.87	-1.47	-0.53	-0.99	-0.72	-1.14	-1.50	-1.55	-2.56
		[1.89]	[-1.43]	[-1.76]	[-0.91]	[-0.93]	[-0.68]	[-1.11]	[-0.95]	[-1.37]	[-2.39]
9	Average # of currencies	3.68	3.73	3.68	3.60	3.65	3.56	3.40	3.25	3.28	3.34

Note: All returns are in percentage points. The sample period is 1990-2009.
'p.m.' denotes 'per month', 'p.a.' – 'per annum'
t-statistics are in brackets, t-statistics are calculated
using Newey-West heteroskedasticity consistent standard errors.

Rows five to eight show various risk characteristics of the currency portfolios. Portfolios of higher rank have higher standard deviation of returns and stock market betas of exchange rate returns[6] and, hence, are more risky. But, even for the top portfolios, the market betas of 0.14-0.17 are very low in comparison with betas of individual stocks and are hard to rationalize the high

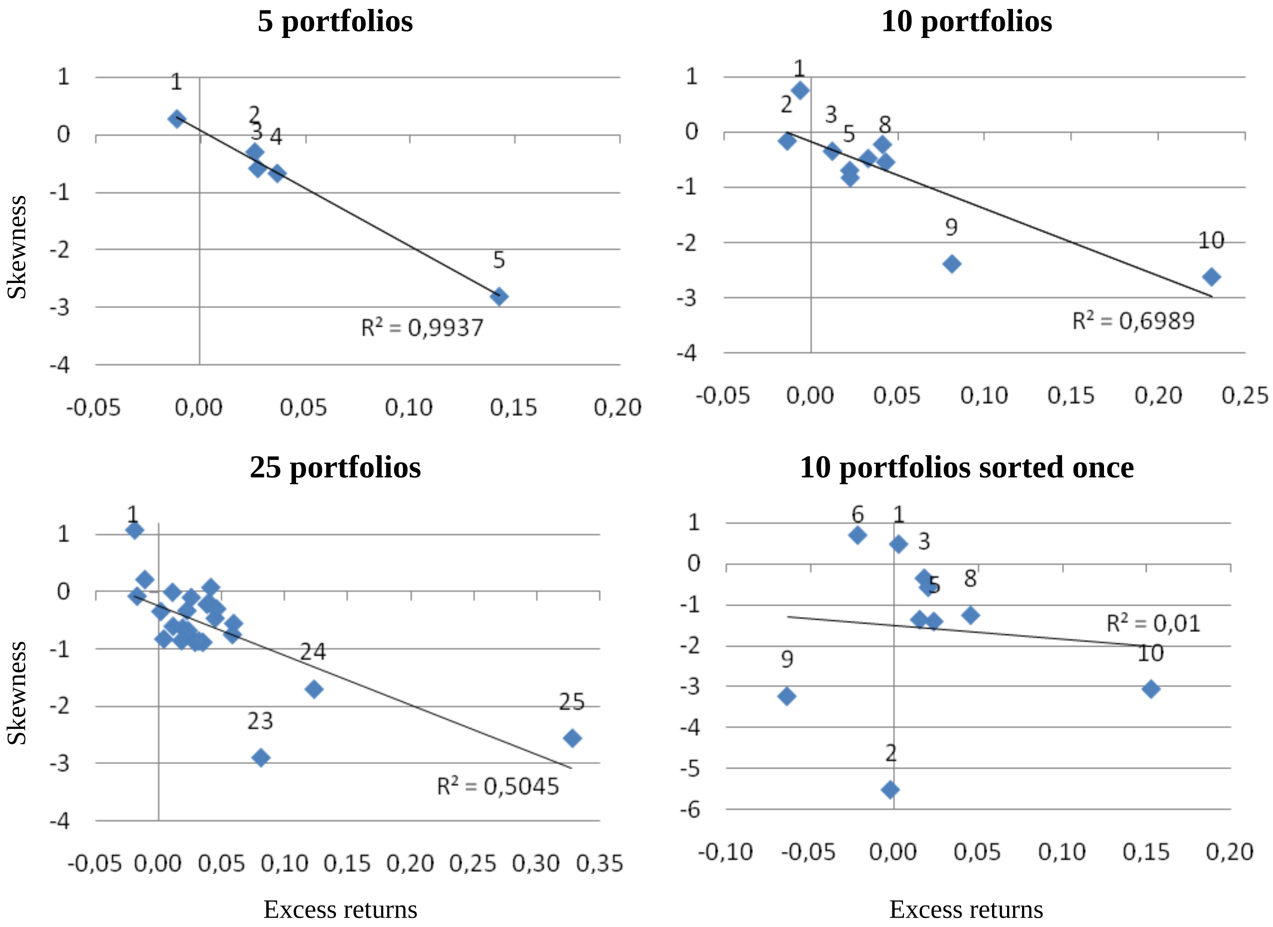
[4] Descriptive statistics of 5 and 25 portfolios looks similarly.
[5] Returns do not take into account transaction costs.
[6] I also estimate stock market betas of portfolio total returns. The estimates are almost the same since interest rates are very persistent and the variation in the total returns comes primarily from variation in exchange rates. More details are available in section 7.

portfolio returns and high Sharp ratios. This suggests that the stock market beta is not an adequate single measure of currency risk.

Indeed, rows seven and eight show that currency return distributions are very asymmetric. Returns of portfolio 1 are positively skewed, which means that the probability of a significant appreciation is higher in comparison with a symmetric distribution. Skewness is decreasing with the portfolio rank, reaching high negative levels for portfolios 9 and 10. Therefore, currencies of high interest rate countries are subject to occasional significant depreciations. This confirms the finding of Brunnermeier et al. (2008) that carry trades are subject to crashes, and extends it for a much greater number of countries and for diversified portfolios of currencies. The seven major currencies studied in Brunnermeier et al. (2008) are in portfolios 1-5 (of the 10-portfolio set), and the skewness of these individual currencies, estimated by the authors, is comparable to my estimates of skewness of portfolios 1-5. But I show that the relationship between interest rates and skewness is far more general and far more significant in a bigger sample of developed and emerging economies.

Figure 2 (except the bottom-right panel) shows the relationship between currency portfolio returns and skewness for the three sets of portfolios. Portfolio 1 always has a negative return and a positive skewness, while the high-interest portfolios have high returns and high negative skewness. The five portfolios, which are well diversified, lie on a straight line almost perfectly. In general, there is a pronounced negative linear relationship for all portfolio sets, with high R^2. Therefore, the higher the interest rate in an economy, the higher the crash risk of the domestic currency, measured by unconditional skewness. But the crash risk of carry trades, which go long in the top portfolios and short the bottom portfolio, is even more significant, since a positive skewness of the short portfolio means a negative skewness of the strategy of an investor.

Figure 2. Skewness and excess returns of currency portfolios



The bottom-right panel of Figure 2 shows the relationship between returns and skewness for ten currency portfolios which are sorted once by the average interest rate during the whole period. Hence, the set of countries in each portfolio is fixed in the whole period. We see that the relationship between portfolio returns and skewness disappears. Therefore, high negative skewness is indeed a characteristic of currencies with high interest rates, and as the interest rate in a country falls, skewness of the currency returns increases (approaches zero).

Coskewness, estimated in a time series regression of exchange rate returns on squared stock market returns and reported in row 8 of Table 1, shows the asymmetry of the currency return distribution against the distribution of the stock market returns. Like skewness, it is positive for portfolio 1 and significantly negative for high-interest portfolios. High negative coskewness indicates that a portfolio has low returns in periods of high stock market volatility, and investing in such a portfolio increases the crash risk for an investor. According to the three-moment CAPM, it is the coskewness which is important for a diversifying investor, rather than skewness. There is a very close relationship between skewness and coskewness of the ten currency portfolios, which suggests that if a portfolio crashes, it crashes in periods of high stock market volatility, and this crash risk is far more significant for high-interest currencies. The same conclusion has been drawn in Menkhoff et. al (2009), Ronaldo et al. (2009) and Clarida et al. (2009) using different proxies for volatility.

4. Beta, skewness and coskewness

It follows from the descriptive statistics of the currency portfolios that there is a specific relationship between interest rates and exchange rate risks: high-interest currencies have higher stock market beta and lower skewness and coskewness with the stock market. A question arises as to which risk measure best explains the cross-section of returns. In other words, which asset pricing model is more relevant for explaining carry trade returns: CAPM, consumption CAPM, three-moment CAPM or another one, if any?

Table 2 presents the results of Fama-MacBeth (1973) cross-sectional estimations for the sets of 10 and 25 currency portfolios[7]. I run horse races between alternative asset pricing models with different risk measures (beta, skewness or coskewness of exchange rate changes) as explanatory variables. The dependent variable is the total annualized excess return of a portfolio, which equals the sum of the interest rate differential and the exchange rate return.

Specifications (1) and (2) are Consumption CAPM and Sharpe-Lintner CAPM, respectively. Both non-durable consumption beta and stock market beta are statistically significant and have coefficients of the right sign, although their explanatory power, measured by R^2, is quite low (34 and 42 percent, respectively, for 10 portfolios, and 4 percent each for 25 portfolios). Consumption CAPM was first proposed as a relevant model of carry trade returns by Lustig and Verdelhan (2007). The authors suggest that returns of high-interest portfolios correlate with the real consumption growth significantly while low interest portfolios serve as a hedge against consumption risk. Therefore, the high returns of carry trades are a compensation for bearing consumption risk. It should be noted that the validity of Consumption CAPM was justified by the authors only after inclusion of durable consumption beta, while non-durable consumption beta alone did not have much of explanatory power. There is still a debate between Burnside (2010) and Lustig and Verdelhan (2010) on whether currency portfolios are subject to consumption risk.

Specifications (3) and (4) test the validity of skewness and coskewness for explaining the cross-section of returns. Both measures of asymmetry have negative, statistically significant coefficients: as skewness of a portfolio falls by 1, the portfolio expected excess return rises by 6 percentage points. Since skewness of the most risky currency portfolio is approximately -3, we would expect its return to be 18 percentage points higher than an expected return of an asset with

[7] Estimation results for 5 portfolios are very similar and are not reported due to the low number of cross-sectional observations.

perfectly symmetric returns. Skewness and coskewness have much greater explanatory power than consumption and stock market betas. For example, skewness alone explains 70 percent of the variation in returns of 10 currency portfolios, while market beta explains only 42 percent of it and consumption beta explains even less (34 percent). Unconditional skewness also has a higher explanatory power than coskewness, which suggests that carry trade returns compensate an investor for bearing the risk of non-systematic currency crashes, which is particularly high for high-interest currencies.

Specification (5) is the three-moment CAPM. Adding coskewness to market beta increases R^2 from 42 to 55 percent or from 4 to 23 percent, depending on the portfolio set. But after controlling for coskewness, stock market beta becomes insignificant, and only coskewness is priced. The estimate of the premium of coskewness remains the same, R^2 does not increase in comparison with specification (4), and adjusted R^2 even falls. Therefore, beta does not have any explanatory power in addition to coskewness, and the significance of beta in specification (2) can be explained by the fact that there is a high correlation of beta with skewness (-0.80) and coskewness (-0.85).

The results of the test of the three-moment CAPM are comparable to those of Harvey and Siddique (2000), who test it for the US stock market. The authors find that the addition of a coskewness factor to the CAPM and even to the three-factor Fama-French model increases R^2 for industry, size, B/M and momentum portfolios, and that the coefficient of coskewness is negative and both statistically and economically significant. The coskewness premium in the stock market is, on average, 3.6 percentage points per annum, which is similar to my estimates of 4-6 percentage points. But, contrary to my results for currencies, market beta remains significant after controlling for coskewness.

The above tests demonstrate that high-interest portfolios are more risky in all respects: they have higher risk of non-systematic crashes (measured skewness), higher risk of crashes in periods of high stock market volatility (measured by coskewness), and higher stock market and consumption betas. At the same time, the lowest-interest portfolio (the funding portfolio) serves as a hedge against stock market and consumption risks and has positive skewness and coskewness. But among alternative asset pricing models, the crash risk, measured by skewness or coskewness, seems to be more important in explaining the cross-section of returns.

It should be pointed out that the intercepts in specifications (1)-(5) are almost indistinguishable from zero, which suggests that no other orthogonal risk is priced in the currency market, and CAPM (especially its 3-moment version) is a relevant model for explaining carry trade returns.

Table 2. Fama-MacBeth cross-sectional regressions

	Dependent variable: Total annualized excess returns									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A: 10 portfolios										
Beta	0.28**	0.80**			0.25*					
	[6.27]	[6.52]			[2.02]					
Skewness			-0.06**							
			[-7.35]							
Coskewness				-0.06**	-0.06**					-0.06**
				[-6.75]	[-5.36]					[-5.34]
Upside beta						-0.56**			-0.24*	-0.03
						[-4.96]			[-2.43]	[-0.35]
Downside beta							0.50**		0.46**	0.64**
							[6.93]		[6.68]	[6.93]
AB								0.40**		
								[6.80]		
Intercept	-0.001	-0.03	0.004	-0.02	-0.02	0.07**	-0.03	0.003	-0.01	0.001
	[-0.04]	[-1.84]	[0.26]	[-1.38]	[-1.57]	[4.45]	[-1.63]	[0.18]	[-0.81]	[0.08]
R^2	0.34	0.42	0.70	0.55	0.55	0.21	0.66	0.68	0.70	0.79
Adjusted R^2	0.26	0.35	0.66	0.50	0.43	0.11	0.62	0.64	0.61	0.69
MSE	0.29	0.25	0.13	0.20	0.20	0.35	0.15	0.14	0.13	0.09
Panel B: 25 portfolios										
Beta	0.07**	0.22**			-0.001					
	[3.25]	[2.60]			[-0.01]					
Skewness			-0.06**							
			[-6.63]							
Coskewness				-0.04**	-0.04**					-0.06**
				[-5.22]	[-5.06]					[-5.91]
Upside beta						-0.33**			-0.25**	-0.25**
						[-4.17]			[-3.32]	[-3.28]
Downside beta							0.32**		0.28**	0.43**
							[5.58]		[5.02]	[6.07]
AB								0.27**		
								[5.79]		
Intercept	0.03*	0.02	0.006	0.008	0.01	0.06**	0.002	0.02	0.02	0.03*
	[2.14]	[1.51]	[0.41]	[0.53]	[0.95]	[3.66]	[0.11]	[1.34]	[1.23]	[2.08]
R^2	0.04	0.04	0.50	0.22	0.23	0.17	0.26	0.35	0.35	0.44
Adjusted R^2	0.00	0.00	0.48	0.18	0.16	0.13	0.22	0.32	0.29	0.36
MSE	0.50	0.50	0.30	0.43	0.42	0.45	0.41	0.37	0.37	0.33

t-statistics are in brackets.
** and * denote significance at 1% and 5% respectively.
Beta in specification (1) is a consumption beta, while betas in all other specifications are stock market betas.

5. Downside risk

High-interest currencies have high returns which compensate an investor for bearing the risk of occasional crashes, which is measured by skewness. Are these crashes really occasional, or is there a systematic relationship between these crashes and the performance of the stock market? To answer this question I look separately at upside and downside stock market betas of currency portfolios. To estimate the two betas, I run the following time series regression for each currency portfolio j:

$$\Delta er_{jt} = \alpha_j + \beta_j r_{mt} + \delta_j dummy_t * r_{mt} \tag{6}$$

where Δer_{jt} is the exchange rate return of portfolio j, r_{mt} is the stock market return and $dummy_t = \begin{cases} 0, r_{mt} < 0 \\ 1, r_{mt} > 0 \end{cases}$. Then $\beta_j^- \equiv \beta_j$ is the estimate of downside beta, and $\beta_j^+ \equiv \beta_j + \delta_j$ is the estimate of upside beta. Downside beta shows the extent to which an asset return varies with the stock market return given the stock market goes down. Similarly, upside beta is conditional on positive stock market performance. High downside beta means that an asset performs poorly in bad states of the world when the marginal utility of wealth is high. Hence, assets with high downside beta should have high expected returns to be attractive. Assets with high upside beta are, on the contrary, attractive and should have lower expected returns, *ceteris paribus*. But since the marginal utility of wealth decreases when the stock market goes up, upside beta is not as important as downside beta as a risk measure.

I also calculate a statistic *AB*, which measures asymmetry in the two betas: $AB_j \equiv \beta_j^- - \beta_j^+$. This statistic is a single risk factor which combines the information contained in the two betas and treats the two betas asymmetrically since their influence on expected returns is the opposite. The higher *AB*, the less attractive is the asset, because the asset has higher downside beta and lower upside beta, both of which is bad for an investor.

Figure 3 illustrates the relationship between excess returns and upside and downside betas and *AB* statistics for the three portfolio sets. We can see in column 1 that there is a pronounced positive relationship between excess returns and downside betas, with high R^2.[8] Low-interest portfolios have very low or even negative downside betas and, hence, they can be used to hedge the downside risk of the stock market. As portfolio rank increases, the downside beta increases too, reaching the level of 0.4 for the highest-interest portfolios[9]. We should notice that the downside beta of the top portfolio is much higher than the 'standard' beta. For example, the downside beta of portfolio 10 of the 10-portfolio set is 0.37 while its 'standard' beta is 0.17. Therefore, high-interest currencies have a tendency to crash when the stock market goes down. At the same time, the downside beta of portfolio 1 of the 10-portfolio set is -0.07 while its 'standard' beta is -0.01. Hence, the lowest-interest portfolio does not only go against the market on average, but it appreciates more when the stock market is down. As a result, carry trades seem to be very risky because the investment portfolio depreciates and the funding portfolio appreciates in the worst states of the world, and this risk is hard to diversify away.

Contrary to the relationship between the downside beta and excess returns, the relationship between the upside beta and excess returns (column 2 of figure 3) is negative and much less pronounced. Moreover, if the top portfolio is dropped out from each portfolio set, the relationship disappears. Therefore, we cannot conclude what happens to currencies of countries with different levels of interest rates on the upside systematically.

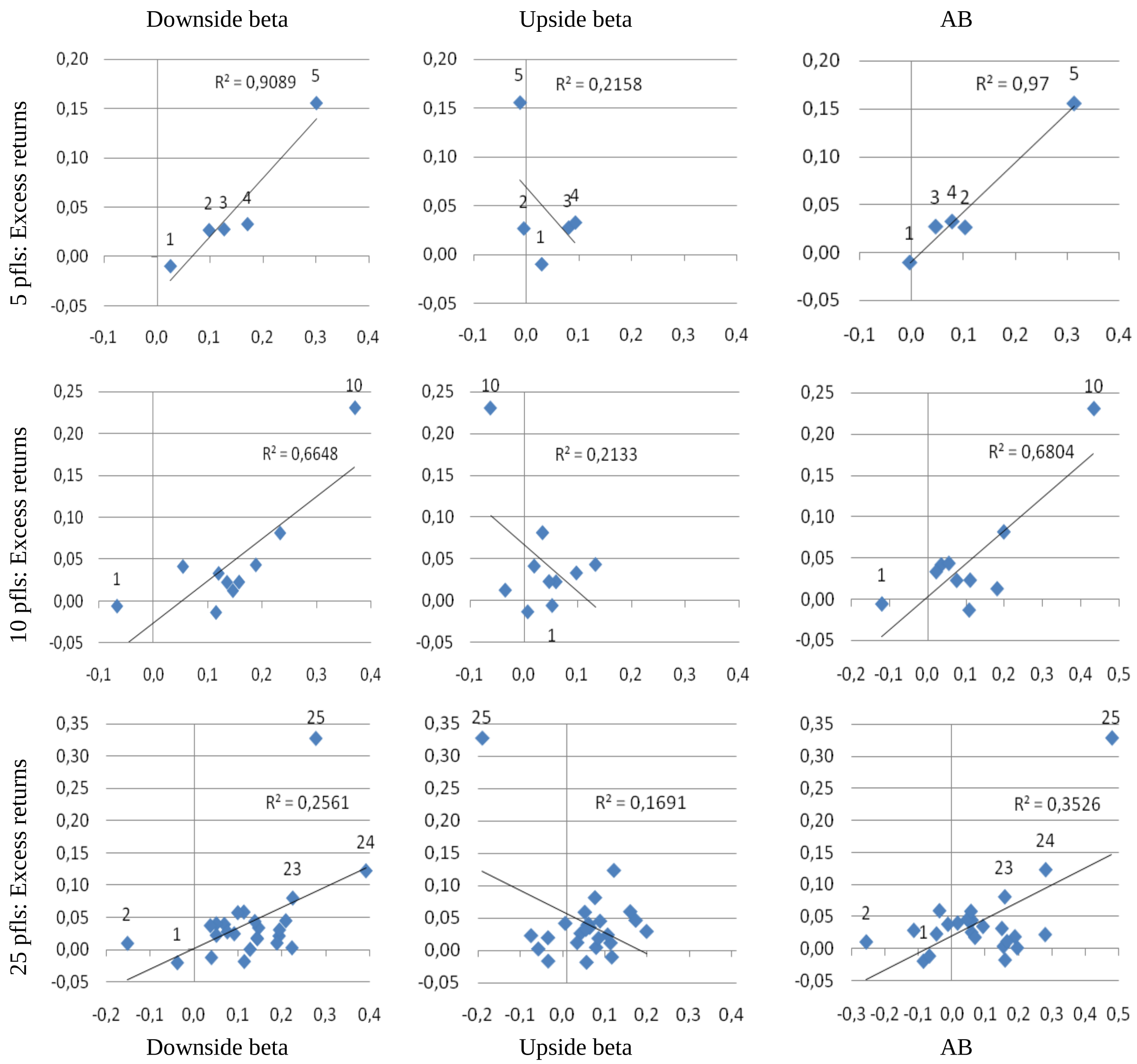
[8] But there is no such relationship for the 10 portfolios sorted once by the average interest rate during the whole period. Therefore, we can draw the same conclusion as for skewness: high downside beta is a feature of currencies with high contemporary interest rates, and as the interest rate falls, the downside beta falls too.

[9] It should be pointed out that downside betas of all portfolios expect portfolios 1 and 4 are statistically significant.

The relationship between *AB* and excess returns (column 3 of figure 3) is very similar to that of the downside beta, and R^2 is even higher for all portfolio sets. This suggests that there is some information in the upside beta in addition to the downside beta which is priced. Upside beta is a particularly important risk factor of the top portfolios as it is highly negative (e.g. portfolio 25), and taking it into account brings the top portfolios closer to the fitted line.

Figure 3 also demonstrates the importance of portfolio diversification. Including more currencies in a portfolio diversifies idiosyncratic risks (i.e. risks related to events in particular countries) and the relationship between the downside beta and excess returns becomes more pronounced. Hence, we may conclude that high downside beta is a necessary attribute of high-interest currencies, while low-interest currencies can serve as a hedge against the stock market plunges.

Figure 3. Downside and upside betas of currency portfolios



Columns (6)-(10) of table 2 report the estimation results of alternative models where the 'standard' beta is substituted by the upside and downside betas. Specification (6) tests the validity of upside beta alone in explaining the cross-section of excess returns. Although the upside beta premium is negative and statistically significant in the Fama-MacBeth regressions, it explains only about 20 percent of the returns. Moreover, the intercept is positive and significant, which means that there are other omitted risks which are priced. These risks, are, in fact, measured by the downside beta. Indeed, including the downside beta into the regression increases R^2 from 21 to 70 percent for the 10-portfolio set and from 17 to 35 percent for the 25-portfolio set and drives the intercepts close to zero. Both betas are significant risk factors in the two-beta CAPM with the premiums of the opposite signs, as theory would predict. Comparing specifications (7) and (9), we see that the upside beta adds little explanatory power, and the downside beta alone explains 66 percent of excess returns. Therefore, it is the downside risk which is priced in the currency market.

The single *AB* statistics (specification (8)) has the same explanatory power as the two betas, and its premium is positive and statistically significant. Adjusted R^2 is even higher in specification (8) than in specification (9), so the two specifications can be considered similar and *AB* alone provides the same information about portfolio risks as the two betas.

Finally, adding coskewness to the two betas increases R^2 further to 79 percent. Now, upside beta becomes insignificant in the 10-portfolio set, and the risk premiums have the same sign and magnitude as in the comparable single-factor specifications. *Ceteris paribus*, we would expect a portfolio return to be higher by 6 percenage points if its coskewness falls by 1, or by 25 percentage points if its upside beta falls by 1, or by 43 percentage points if its downside beta rises by 1 (according to the estimates for 25 portfolios). To make these figures meaningful it should be noted that coskewness ranges between -2.41 and 1.38, upside beta ranges between -0.20 and 0.19, and downside beta ranges between -0.15 and 0.39. Still, the risk premiums seem high, and I return to this issue in section 7.

Decomposing the ‘standard’ beta into its upside and downside counterparts improves the validity of the CAPM significantly.[10] The two betas have the same explanatory power as skewness, and the three-moment two-beta CAPM wins the horse race between all specifications. While the ‘standard’ beta did not have any explanatiory power in addition to coskewness, adding upside and downside betas to coskewness increases R^2 from 55 to 79 percent for 10 portfolios and from 22 to 44 percent for 25 portfolios. We may conclude that it is the downside risk that is priced in the currency market and the high carry trade returns, which have been observed historically, are a compensation for such downside risk.

Three alternative measures of downside risk explored in this paper: skewness, coskewness and downside beta, measure different risks, by construction. Low (negative) skewness means a high probability of occasional crashes, which may happen from time to time with no specific relation to the performance of the other assets (e.g., the stock market). Hence, risk, measured by skewness, is diversifiable, and should not be priced, according to CAPM. Low (negative) coskewness with the stock market means a high probability of crashes when the stock market exhibits high volatility. This risk is non-diversifiable, and, hence, should be

[10] A similar conclusion can be drawn for the consumption risk of the currency portfolios. Separating the consumption beta into its upside and downside counterparts increases the R^2 significantly (from 34 to 57 percent for the 10-portfolio set), and both beta premiums are positive and statistically significant in Fama-MacBeth cross-sectional regressions.

priced. But high volatility in the stock market can be observed both when the stock market goes up or down significantly. Therefore, the coskewness premium should be different depending on whether an asset usually crashes when the stock market goes up or down. If an asset usually crashes when the stock market goes up significantly and the marginal utility of wealth is low, then the risk, measured by coskewness, is not important. But if an asset usually crashes when the stock market goes down significantly, this asset is considered very risky and unattractive. Downside beta measures exactly this risk. Similarly to coskewness, it measures the performance of an asset relative to the market, but contrary to coskewness, it restricts to the downside events. Hence, it is the downside beta which should be the most important risk characteristic out of all measures of downside risk.

Then, why do we observe similar explanatory power of all three downside risk measures in the currency market? To answer this question I look at the relationship between all risk measures. Table 3 presents the estimates of the slope and correlation coefficients of regressions of beta and downside beta on skewness and coskewness of 10 portfolios. We can observe very high correlation between all risk measures. The lowest correlation is observed between beta and skewness (0.80), while the highest correlation is observed between downside beta and skewness (0.92) and downside beta and coskewness (0.98). Almost one-to-one relationship between the downside beta and coskewness can be explained by the fact that high volatility in the stock market is usually observed when the stock market goes down, not up. Hence, the famous saying that "currencies go up by stairs and down by the elevator" can be applied to to the stock market as well. In this case, coskewness and downside beta both measure the risk of a crash when the stock market crashes. The high (negative) correlation between skewness and the downside beta also suggests that if currencies crash, they crash systematically when the stock market goes down.

Table 3. Relationship between different risk measures of 10 currency portfolios

	Beta	Downside beta
Skewness	-0.04**	-0.10**
	[-3.78]	[-6.43]
Correlation coefficient	-0.80	-0.92
Coskewness	-0.06**	-0.13**
	[-4.66]	[-12.78]
Correlation coefficient	-0.85	-0.98

t-statistics are in brackets.
** denote significance at 1%.

We can conclude that although the three measures of downside risk are different by construction, they reflect the same risk in the currency market – a risk of co-crash with the stock market. The estimation results show that the higher the interest rate in an economy, the higher is the risk of depreciation of its currency when the stock market goes down. Low-interest currencies seem to be immune to this risk, they even appreciate when the stock market plunges and, hence, can hedge this risk. Therefore, these currencies yield negative excess returns on average. High excess returns of carry trades is not a free lunch. Carry trades tend to crash, and they crash in the worst states of the world, when the stock market goes down. The downside risk explains the cross-section of returns of currency portfolios, sorted by the interest rate, very well.

In the rest of this section, I look at the behavior of the 10 currency portfolios in sub-samples depending on the magnitude of the stock market return. I look separately at the upside and the downside of the stock market, and at sub-samples when the stock markets return is below (above) its mean by 0.5 standard deviations, 1 standard deviation and 1.5 standard deviations. The purpose is to test whether the behavior of the currency portfolios depends on how extreme the movements in the stock market are.

Table 4 shows the estimates of coskewness of each portfolio for the eight sub-samples and the whole sample. For each sub-sample of size n, coskewness is calculated using the following formula:

$$Coskew_{X,Y} = \frac{1}{n}\sum \frac{(X-\bar{X})(Y-\bar{Y})^2}{\sigma_Y^3}$$

where $X \equiv \Delta er_{jt}$ is the exchange rate return of portfolio j in each observation in the sub-sample, $Y \equiv r_{mt}$ is the stock market return in each observation in the sub-sample, $\bar{X}$ and $\bar{Y}$ are the *whole-sample* means of portfolio exchange rate and stock market returns, respectively, and σ_Y is the *whole-sample* standard deviation of the stock market return. Hence, a sub-sample coskewness shows the *contribution* of observations in the sub-sample to the whole-sample coskewness. For example, the whole-sample coskewness can be obtained from a weighted sum of coskewness in the downside (line 4 of table 4) and coskewness in the upside (line 5 of table 4), with the appropriate weights.

Previously, I estimated coskewness by regressing exchange rate returns on squared market returns. This is an alternative way to calculate coskewness. Indeed, the whole-sample coskewness in row 9 of table 4 has a one-to-one relationship with coskewness in row 8 of table 1. The only difference is in the magnitude.

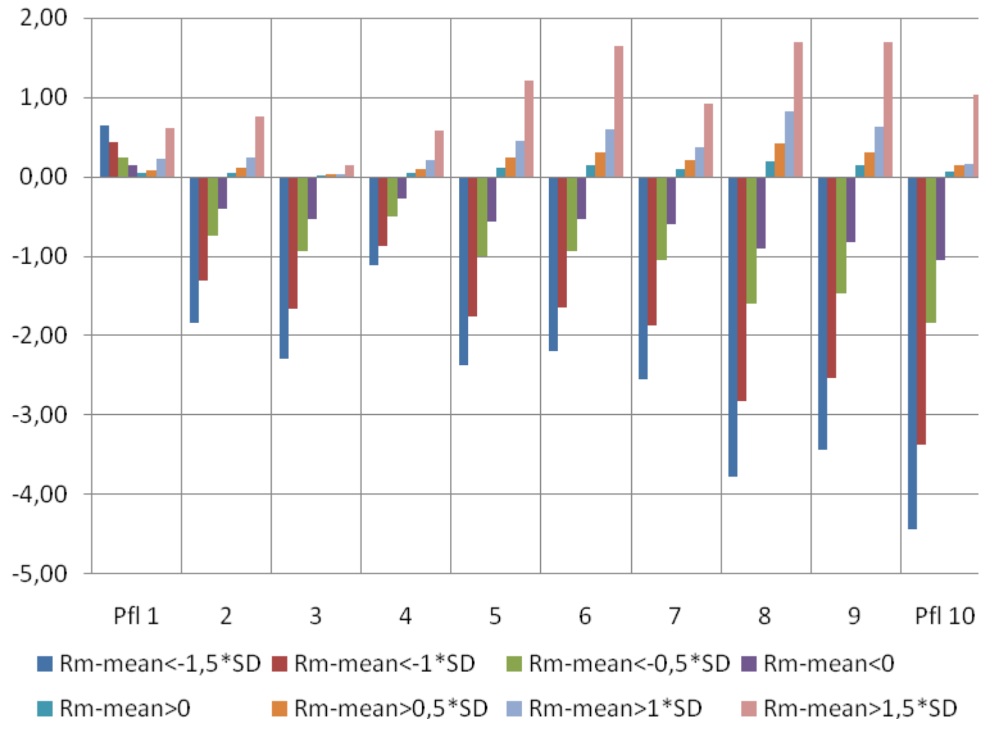
Table 4. Coskewness of 10 currency portfolios in sub-samples

	Sub-sample:	Pfl 1	2	3	4	5	6	7	8	9	Pfl 10
1	$r_M - \bar{r}_M < -1.5\sigma_M$	0.65	-1.84	-2.29	-1.11	-2.37	-2.20	-2.54	-3.78	-3.44	-4.43
2	$r_M - \bar{r}_M < -\sigma_M$	0.43	-1.30	-1.66	-0.87	-1.76	-1.65	-1.87	-2.82	-2.53	-3.38
3	$r_M - \bar{r}_M < -0.5\sigma_M$	0.24	-0.73	-0.94	-0.50	-1.00	-0.94	-1.05	-1.60	-1.46	-1.84
4	$r_M - \bar{r}_M < 0$	0.14	-0.41	-0.54	-0.27	-0.56	-0.53	-0.59	-0.90	-0.82	-1.04
5	$r_M - \bar{r}_M > 0$	0.04	0.06	0.01	0.05	0.11	0.14	0.10	0.20	0.14	0.06
6	$r_M - \bar{r}_M > 0.5\sigma_M$	0.09	0.11	0.03	0.10	0.23	0.30	0.21	0.42	0.31	0.14
7	$r_M - \bar{r}_M > \sigma_M$	0.23	0.24	0.03	0.21	0.45	0.60	0.37	0.82	0.63	0.16
8	$r_M - \bar{r}_M > 1.5\sigma_M$	0.61	0.76	0.14	0.58	1.21	1.65	0.91	1.69	1.69	1.03
9	Whole sample	0.08	-0.13	-0.20	-0.08	-0.15	-0.12	-0.17	-0.23	-0.23	-0.36

It is easier to analyze the sub-sample coskewness of the currency portfolios in Figure 4. Each bar represents a sub-sample coskewness of a portfolio. Coskewness in the sub-samples when the stock market is above its mean (the upside) is always positive, while coskewness in the sub-samples when the stock market is below its mean (the downside) is always negative, except for portfolio 1. This means that currencies of portfolios 2-10 generally move in the same direction as the stock market, and they are more volatile. Coskewness of portfolio 1 is positive and quite low in all sub-samples. Therefore, portfolio 1 usually appreciates (insignificantly) no matter what happens to stock returns. The same conclusion can be drawn from the negative downside beta and positive upside beta of portfolio 1.

Comparing portfolios 2-10, several observations can be made. First, coskewness in all sub-samples on the upside is always lower than coskewness in the respective sub-samples on the downside. Hence, the currencies react more to the downturn than to the upturn of the stock market. Second, while there is no monotonic relationship between coskewness on the upside and portfolio rank, there is a remarkable negative relationship between coskewness on the downside and portfolio rank. The higher is the rank of a portfolio, the lower is the coskewness of the portfolio in all sub-samples on the downside. Therefore, higher-interest currencies depreciate more when the stock market return is negative. Third, coskewness is the lowest in the most extreme sub-sample, when the stock market return is below its mean by 1.5 standard deviations. Hence, currencies of countries with higher interest rates are subject to greater crash risk when the stock market crashes.

Figure 4. Coskewness of 10 currency portfolios in sub-samples



I also estimate downside and upside betas in different sub-samples. I restrict the analysis to the downside since the downside is more important for an investor in terms of risks due to higher marginal utility of wealth. I look at sub-samples when the stock market return is below its mean by 0, 0.5, 1 and 1.5 standard deviations. Table 5 shows the sub-sample downside betas of the extreme portfolios (betas of the other portfolios are within this range), the respective risk premiums, estimated in the Fama-MacBeth cross-section regressions of two-beta CAPM similar to specification (9) in table 2, the regression statistics and the number of observations in each sub-sample. It should be pointed out that while each downside beta is estimated from the observations in each sub-sample, the respective 'upside' beta is estimated from the remaining observations, which do not fall into the sub-sample. Hence, except for the first sub-sample, the observations for the 'upside' beta include observations when the stock market return is negative, but not sufficiently low to be included into the sub-sample. As a result, the 'upside' betas are biased and not reported in table 5.

There is a little difference in the methodology used to estimate the betas for sub-sample 1 and those in column (9) of table 2. Initially, I split the sample at zero stock market return, while here I split the sample at the historical mean stock market return. But the estimation results are very similar. Hence, this alternative methodology can be considered as a robustness check.

Table 5. Two-beta CAPM for different sub-samples

	Sub-sample:	Downside			R^2	No of obs.
		Beta		Premium		
		Pfl 1	Pfl 10			
1	$r_M - \bar{r}_M < 0$	-0.07	0.37	0.47 [6.70]	0.71	101
2	$r_M - \bar{r}_M < -0.5\sigma_M$	-0.06	0.36	0.47 [6.75]	0.70	67
3	$r_M - \bar{r}_M < -\sigma_M$	-0.05	0.35	0.57 [7.00]	0.73	30
4	$r_M - \bar{r}_M < -1.5\sigma_M$	-0.06	0.36	0.51 [6.71]	0.61	21

Fama-MacBeth t-statistics are in brackets.

Comparing across sub-samples, we see surprisingly similar results. The estimates of the downside betas of all portfolios are almost the same no matter how significantly the stock market falls. This suggests that the currency portfolios move proportionally to the stock market. Portfolio 1 always appreciates when the stock return is below its mean, and the appreciation is more significant the greater is the fall in the stock market. At the other end, portfolio 10 always co-moves with the stock market, and these high-interest currencies provide particularly low returns when the stock market return is the lowest (sub-sample 4). The estimates of the downside beta premium are a bit higher in the most extreme sub-samples, so that the high carry trade returns can be considered a compensation for bearing the downside risk, particularly the risk in the worst stock market conditions.

6. Country risk and 'flight to quality'

Higher-interest currencies have higher market risk, especially in the worst states of the world. In this section I look at another common measure of currency risk – country risk, to see if these risks mirror each other or are they quite independent.

To measure country risk, I collect historical country ratings, provided by Fitch. This rating reflects the risk of investing in a country. The data is available from August 1994 and covers most countries in my sample. The Fitch rating ranges between AAA (lowest risk) and D (highest risk).

To quantify the risk, I assign 1 to countries with the highest rating, 2 to countries with the next rating on the scale and so on, so that the countries with the lowest rating are assigned 23 (see the appendix for details). Therefore, my country risk index varies between 1 and 23, and a higher index means a higher risk.

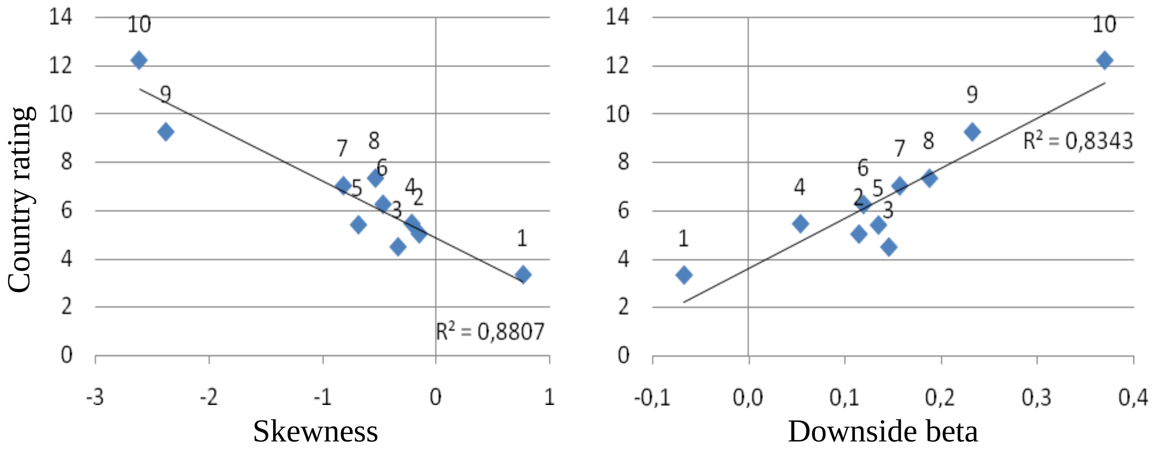
I calculate the average country risk index of each of the 10 currency portfolios, sorted by the interest rate. Since each portfolio consists of 3-4 countries at each point in time, the average index is calculated both in the cross-section and in the time series. As a result, the average portfolio country risk index varies between 3.36 (for portfolio 1) and 12.22 (for portfolio 10). The country risk index of 25 portfolios is calculated similarly.

Perhaps unsurprisingly, the country risk index is monotonically increasing with portfolio rank. The lowest-interest portfolio appears to consist of the safest countries in terms of investment, while the highest-interest portfolio consists of the most risky countries. But, although this relationship holds on average, there are cases when a country in the lowest-interest portfolio had a high country risk index (e.g. Thailand had an index of 10 in 2000-2001) and a country in the highest-interest portfolio had a rather low country risk index (e.g. Iceland had an index of 4-5 in 2005-2008). Hence, there is no strict one-to-one relationship between a country's interest rate and its rating.

But there appears to be a strong relationship between a portfolio country risk and various market risk measures, analyzed previously. The correlation of the country risk index with the stock market beta is 0.84, with the downside beta – 0.91, with coskewness – -0.83 and with skewness – -0.94. Hence, the country risk index proxies well for the market risk and can be used as an instrument if we are worried that the market risk is measured with error. In a cross-section regression of portfolio average excess returns on the country risk, the estimate of the country risk premium equals 2.5 percent per annum and is highly statistically significant for both 10-portfolio and 25-portfolio sets.

Figure 5 plots the country risk index against skewness and the downside beta of 10 currency portfolios. On one end, there is the lowest-interest portfolio 1 with the lowest country risk, positive skewness and negative downside beta. On the other end, there is the highest-interest portfolio 10 with the highest country risk, the lowest skewness and the highest downside beta. This suggests, that when the stock market return is negative, there is "flight to quality", which leads to depreciation of the high-interest portfolios and appreciation of the lowest-interest portfolio, and the lowest-interest – lowest-country-risk portfolio serves as the "safe haven".

Figure 5. Relationship between country rating, skewness and downside beta



A similar result was obtained in Ronaldo and Söderlind (2009). They study five major currencies at a very high frequency and find that some currencies consistently appreciate when the stock market crashes or some disasters (natural, political or economic) happen, while others depreciate. They call the currencies which appreciate in times of disasters "safe-haven currencies". Interestingly, the currencies with the most pronounced safe haven properties (namely, Swiss franc and Japanese yen) are the ones with the lowest interest rates and are all in my portfolio 1.

The following conclusion can be drawn. In normal stock market conditions, carry traders borrow portfolio 1 and invest in the other portfolios, depending on the acceptable level of risk. When the stock market crashes, investors sell their investments in high-interest high-risk currencies because of liquidity constraints (as in Brunnermeier and Pedersen, 2009) or increased risk aversion (due to narrow framing as in Barberis, Huang and Santos, 2001, or due to habits, as in Campbell and Cochrane, 1999, and Verdelhan, 2010). As a result, the investment currencies crash too (as evidenced by their high downside beta, particularly in the most extreme stock market conditions) while the funds flow into the safest currencies (as evidenced by their negative beta), which are also the funding currencies for carry trades. These funding currencies appreciate, which increases the losses for carry traders who need to repay their debts denominated in these currencies. The "flight to quality" in the currency market and the unwinding of the carry trade positions both may generate such exchange rate dynamics, which makes carry trade losses so high in bad stock market conditions.

7. Downside beta premium in the stock and currency markets

Downside risk explains the cross-section of currency portfolios, sorted by the interest rate, well. A high explanatory power of downside risk was also found in the stock market (Ang et al., 2006). In this section, I look at the downside risk premium of currency portfolios to answer the question: Are the high carry trade returns a fair compensation for bearing the downside risk? In other words, are the downside risk premiums in the currency and stock markets the same?

To estimate the downside risk premium in the stock market, I collect monthly total return data for all NYSE stocks for the period from January 1990 till December 2008 from CRSP. Following Ang et al. (2006), I restrict the sample to NYSE stocks to minimize the illiquidity effect of small firms[11]. Stocks with less than 25 observations are excluded from the sample due to the low number of observations to estimate the beta consistently. This leaves me with 3,349 stocks in the sample.

To minimize the measurement error of beta, I estimate it for portfolios of stocks using the following two-step procedure. In the first step, I estimate the downside market beta of each stock. The individual stock downside betas vary from -1.72 to 5.66. Then all stocks are sorted by their downside beta into 10 and 25 equally-weighted portfolios. Portfolio 1 always contains 10 percent or 4 percent of stocks with the lowest downside beta, depending on the portfolio set. Portfolios 10 and 25 consist of 10 percent and 4 percent of stocks with the highest downside beta, respectively. Since the number of stocks in the sample is very big, all portfolios are highly diversified, and this sorting procedure allows concentrating on the downside risk of the portfolios. In the second step, I estimate the downside and upside betas of each portfolio in time-series regressions and the respective risk premiums in the cross-section Fama-MacBeth regressions.

The results are reported in table 6. The column "Stocks" in Panel A shows that both the upside and the downside betas are statistically significant in 10 and 25 portfolio sets, and the estimated R^2 are very high. The downside beta premium is estimated at 1-2 percent per annum, depending on the portfolio set. My estimates are lower than in Ang et al. (2006), who estimate the downside beta premium of about 6 percent in a cross-section of individual stocks. The difference is probably attributable to the different period of study: their sample covers the period from January 1967 till December 2001, while I study a shorter and more recent period with lower returns, on average.

The downside beta premiums in the stock market cannot be directly compared to the currency downside beta premiums of 46 percent (for 10 portfolios) and 28 percent (for 25 portfolios), reported in column (9) of table 2. The reason is that those downside betas are estimated in a regression of *exchange rate returns* on the stock market return and the dummy variable (equation (6)), and, hence, measure only the exchange rate risk instead of the total risk of investing in a currency portfolio. To make the downside beta premiums comparable, in this section I estimate the

[11] Ang et al. (2006) show that the validity of the downside beta is confirmed in a wider sample of NYSE, AMEX and NASDAQ firms.

currency downside betas by regressing *total* currency portfolio returns on the stock market return and the dummy variable. Then, the downside beta premium is estimated in the cross-section regression of portfolio excess returns on the total-return downside betas. This alternative specification can also be considered as a robustness check.

The downside betas of total returns do not appear to be significantly different from the downside betas of exchange rate returns, which confirms that the interest rate risk is insignificant in carry trades. The downside risk premiums are also very similar in magnitude (Table 6, column “Currencies”). The estimates vary between 34 and 45 percent per annum, depending on portfolio set. Therefore, the downside beta premium (as well as the upside beta premium) in the currency market is much higher than that in the stock market. It should be noted that the explanatory power of the 2-beta CAPM, measured by R^2, is similar and very high in the both markets, if we consider well-diversified portfolios.

Table 6. Downside risk in the currency and stock markets

Panel A: Cross-section regression coefficients					*Panel B: Descriptive statistics of 25 portfolios*				
	Currencies		Stocks			Currencies		Stocks	
	10 pfls	25 pfls	10 pfls	25 pfls		Pfl 1	Pfl 25	Pfl 1	Pfl 25
Upside beta	0.128	0.122	0.032	0.012	Excess return	-0.02	0.33	0.04	0.11
	[1.57]	[2.12]	[7.25]	[3.51]	Upside beta	0.04	0.05	0.77	0.84
Downside beta	0.449	0.337	0.012	0.022	Downside beta	-0.04	0.39	0.04	2.20
	[6.83]	[6.17]	[4.74]	[7.95]	Country risk	2.71	12.83	na	na
R^2	0.77	0.41	0.81	0.81					

Panel C: Downside risk premium for currency portfolios

Portfolios	1-24	1-23	1-22	1-21	1-20	1-19	1-18	1-17	1-16	1-15
Downside beta	0.166	0.095	0.057	0.053	0.050	0.032	0.033	0.042	0.035	0.036
	(0.046)	(0.055)	(0.053)	(0.053)	(0.053)	(0.053)	(0.053)	(0.052)	(0.052)	(0.051)
	[3.58]	[1.72]	[1.09]	[1.02]	[0.95]	[0.61]	[0.63]	[0.82]	[0.68]	[0.69]
CR of top pfl	10.14	9.74	7.90	8.08	8.03	6.46	6.25	6.48	6.02	6.02

Fama-MacBeth standard errors are in parentheses and t-statistics are in brackets.

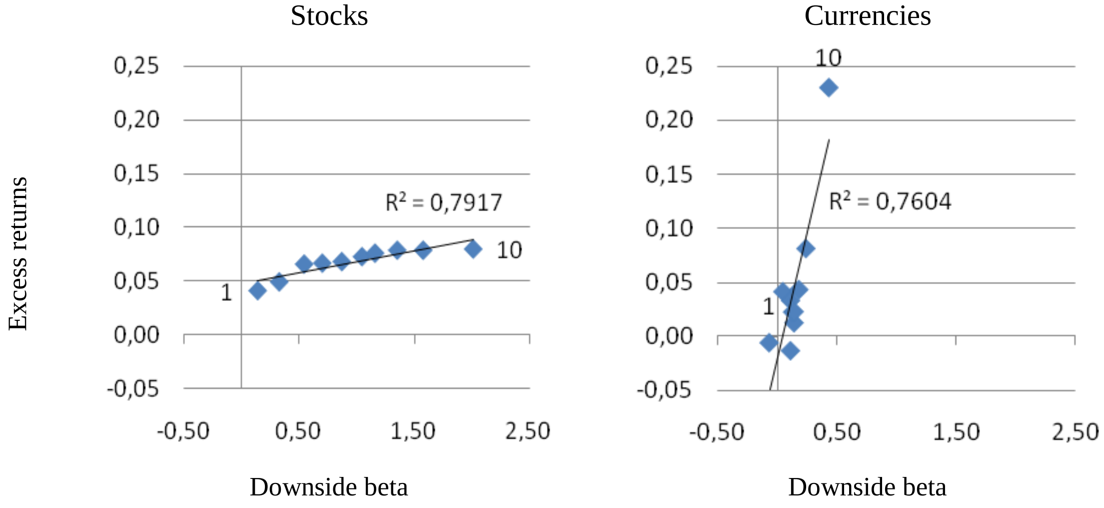
To understand the difference in the downside beta premiums, it is worth looking at the descriptive statistics of the currency and stock portfolios. Panel B of table 6 reports excess returns, the market risk, measured by the upside and downside betas, and the country risk of the most extreme portfolios of the 25-portfolio sets. The range of excess returns is quite similar in the currency and stock markets, with the exception of the top currency portfolio, which provides a much greater return, on average. The high excess return of the top portfolio might have contributed to the high estimate of the downside beta premium in the currency market.

But the most remarkable difference is observed in the estimates of betas. Although the downside betas increase with the portfolio rank in both currency and stock markets, the spread is much wider in the stock market. The 25^{th} stock portfolio has the downside beta of 2.2, while the

25th currency portfolio has the downside beta of only 0.39. Hence, currencies are less risky in terms of the stock market risk, while they offer higher returns.

The same conclusion can be drawn for 10-portfolio sets. Figure 6 plots excess returns against the downside betas in the stock and currency markets. In the both plots, the portfolios lie almost perfectly on a straight line, but the currency portfolios have a greater range of excess returns and a lower range of downside betas. This suggests that either the high excess returns of carry trades reflect a mispricing in the currency market, or they reflect a compensation for other risks.

Figure 6. Downside risk in the currency and stock markets



What is the difference between the stock portfolios and the currency portfolios? While the top stock portfolio differs from the previous stock portfolio in the ranking only by the higher market risk, measured by the downside beta, the top currency portfolio differs from the previous currency portfolio in the ranking by the higher market risk and higher country risk. Hence, the difference in the excess returns may partly be a compensation for the country risk. Indeed, after controlling for the country risk, the downside beta premium in the currency market shrinks from 45 to 4.7 percent per annum for the 10-portfolio set.

To make the analysis more rigorous, I estimate the downside beta premium in the cross-section of currency portfolios, dropping out the top portfolio in the ranking. Then I repeat the exercise, dropping out the next portfolio in the ranking, and so on. Since portfolio country risk is monotonically increasing with the portfolio rank, dropping out the most risky portfolios consecutively allows to trace the effect of the country risk on the estimates of the downside beta.

Each column on panel C of figure 6 shows the sample of currency portfolios, the respective downside beta premium and the country risk of the top portfolio, which remains in the sample. After dropping out portfolio 25 with the highest country risk index of 12.83, the estimate of the downside beta premium falls from 33.7 percent to 16.6 percent. After dropping out portfolio 24, the downside beta premium falls further to 9.5 percent. The same tendency continues, albeit at a slower pace, until 19 portfolios are left in the sample. Then the estimates of the downside beta stabilize at 3-4 percent per annum[12].

It is interesting to note that the estimates of the downside beta stabilize after portfolio 20 is dropped from the sample, and portfolio 20 is the last of the top portfolios which has a high country risk. A country risk is considered to be high if the Fitch country rating is BBB+ or below, which corresponds to my country risk index of 7 and above. Portfolios 20-25 have the country risk index above 7 and, hence, are risky, while portfolios 1-19 have the country risk index below 7, and hence are comparable to the US stock market in terms of the country risk. Since the downside beta premium in the sample of currency portfolios with low country risk is very similar in magnitude to that in the stock market, we may conclude that the downside risk is priced equally in the currency and stock markets, while the difference in the downside beta premiums of all portfolios in panel A is attributable to a bias due to omitted country risk. Since, in carry trades, the most common investment currencies are in the portfolios 23-25 and the most common funding currencies are in portfolios 1-2, the high returns of carry trades compensate an investor for both the downside risk and the country risk. These two risks are hard to diversify in currency portfolios since they go hand-in-hand.

8. Robustness tests

8.1. Evidence of the last decade

The first half of the studied period are the years of soaring interest rates, capital controls, political instability and the related currency crashes in several emerging countries in the sample. This was reflected in the extreme behavior of the top portfolios, such as very high return and very low skewness, and may have biased the results. Indeed, as we have seen in the previous section, excluding the top portfolios from the analysis reduces the downside beta premium significantly. To test the robustness of my results, in this section I concentrate on a shorter period from January 1999 until April 2009. This sample is chosen to omit the periods of political turbulences in Bulgaria and Romania in 1997 and the Russian default in August 1998 – the last episodes of significant currency crashes which were caused by political rather than market factors.

Table 7 reports the descriptive statistics of the 10 currency portfolios in the last decade. Comparing table 7 to table 1, several changes are evident. First, the excess return of the highest-interest portfolio is much lower than before (16.4 percent instead of 23 percent per annum) due to

[12] The precision of the estimation, measured by the Fama-MacBeth standard errors, is the same in all portfolio sets, and hence the estimate becomes statistically insignificant due to its low value.

the lower interest rates in these countries. Second, although we still observe a negative relationship between portfolio rank and skewness, skewness of the top portfolios is closer to zero. It follows that occasional crashes of high-interest currencies are nowadays much less common. Third, coskewness of the top portfolios is lower and stock market betas of the top portfolios are much higher. For instance, the market beta of portfolio 10 is now 0.43 instead of 0.17, and its downside beta is now 0.66 instead of 0.37. This suggests that the market risk of high-interest portfolios is now even higher, especially on the downside. Crashes of high-interest currencies seem to be less significant, but more systematic: they happen exactly when the stock market goes down.

Table 7. Descriptive statistics of 10 currency portfolios in 1999-2009

	Pfl 1	2	3	4	5	6	7	8	9	Pfl 10
Total excess return (p.a.)	-0.61	-1.38	2.35	5.09	2.08	4.27	0.10	4.99	7.74	16.40
Skewness	0.68	-0.03	-0.18	0.19	-0.90	-0.28	-0.77	-0.65	-0.44	-0.73
Coskewness	0.33	-1.44	-1.84	-0.98	-1.84	-1.68	-2.02	-2.81	-2.50	-4.23
	[1.21]	[-2.61]	[-1.78]	[-1.72]	[-1.75]	[-1.61]	[-2.06]	[-1.66]	[-2.02]	[-4.31]
Market beta	0.01	0.16	0.14	0.10	0.16	0.20	0.18	0.23	0.23	0.43
	[0.40]	[3.12]	[1.90]	[1.95]	[1.92]	[2.88]	[1.86]	[2.14]	[2.38]	[4.68]
Upside beta	0.07	0.08	0.05	0.06	0.05	0.12	0.05	0.09	0.04	0.09
Downside beta	-0.02	0.21	0.21	0.12	0.23	0.25	0.27	0.33	0.37	0.66
	[-0.46]	[2.77]	[1.53]	[1.55]	[1.60]	[2.40]	[1.80]	[1.70]	[2.33]	[5.50]

t-statistics are in brackets; t-statistics are calculated
using Newey-West heteroskedasticity consistent standard errors.

Table 8 presents the estimation results of Fama-MacBeth cross-sectional regressions with various risk measures as explanatory variables. Previously, skewness was competing with the downside beta in explaining the cross-section of returns. Now, the explanatory power of non-systematic skewness vanishes, and the stock market beta reigns. While previously, in the 3-moment CAPM, beta did not add any explanatory power to coskewness, now coskewness does not add explanatory power to beta. Upside beta is never statistically significant, while the downside beta alone explains the cross-section of returns well. The explanatory power of the downside beta is even higher in the last decade. But the three-moment two-beta CAPM wins the horse race by explaining 75 percent and 47 percent of excess returns of 10 and 25 currency portfolios, respectively

The downside beta premium falls from 28 to 17 percent per annum for the 25-portfolio set, but it is still much higher than the downside beta premium in the stock market. The downside beta premium again compensates for the country risk (e.g. the risk of a country default, the so-called “peso” event), and the lower premium is due to the lower country risk, as evidenced by the higher country ratings. The downside beta premium shrinks further from 17 percent to 2.6 percent if portfolios 25 and 24 are dropped out, and stabilizes around 1.3 percent in the sub-sample of the bottom 15 and 16 portfolios, which have low country risk.

It can be concluded, that the main results hold in the more recent period, and even become more pronounced. The downside risk of carry trades, measured by coskewness and downside beta, is higher, and there is a closer link between the currency and stock markets. High-interest currencies crash more when the stock market plunges, while low-interest currencies can hedge the stock market risk.

This change may have been driven by the rising carry trade activity. According to Galati et al. (2007), volume of carry trades has increased a lot during 2000s, and carry trades involve currencies of emerging economies (i.e. currencies of my top portfolios) increasingly. If carry traders have an impact on exchange rates, they may serve as a channel through which stock market dynamics is passed into the currency market.

Table 8. Fama-MacBeth cross-sectional regressions in 1999-2009

	Dependent variable: Total annualized returns									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
					Panel A: 10 portfolios					
Beta	0.10**	0.41**			0.56**					
	[2.63]	[4.02]			[3.05]					
Skewness			-0.03**							
			[-2.46]							
Coskewness				-0.03**	0.005					-0.02
				[-3.90]	[0.32]					[-0.71]
Upside beta						0.41			0.09	0.08
						[1.61]			[0.38]	[0.31]
Downside beta							0.25**		0.24**	0.26**
							[4.00]		[3.94]	[3.94]
AB								0.25**		
								[3.96]		
Intercept	0.01	-0.03	0.03	-0.02	-0.04	0.01	-0.02	-0.01	-0.03	-0.02
	[0.33]	[-1.41]	[1.43]	[-1.08]	[-1.43]	[0.48]	[-1.04]	[-0.31]	[-1.05]	[-0.70]
R^2	0.15	0.71	0.17	0.62	0.73	0.04	0.71	0.69	0.72	0.75
Adjusted R^2	0.04	0.68	0.07	0.57	0.66	-0.08	0.68	0.65	0.63	0.62
					Panel B: 25 portfolios					
Beta	0.02	0.27**			0.27**					
	[1.00]	[2.99]			[2.91]					
Skewness			-0.02*							
			[-1.83]							
Coskewness				-0.02**	-0.007					-0.02**
				[-2.50]	[-1.07]					[-2.32]
Upside beta						-0.01			0.04	0.02
						[-0.25]			[0.63]	[0.33]
Downside beta							0.16**		0.17**	0.22**
							[3.01]		[3.02]	[3.65]
AB								0.11**		
								[2.80]		
Intercept	0.03	-0.01	0.03	0.005	-0.01	0.04	-0.005	0.02	-0.01	0.0000
	[1.32]	[-0.53]	[1.33]	[0.24]	[-0.52]	[1.60]	[-0.23]	[0.80]	[-0.38]	[-0.002]
R^2	0.02	0.33	0.11	0.22	0.33	0.001	0.35	0.25	0.36	0.47
Adjusted R^2	-0.03	0.30	0.07	0.19	0.27	-0.04	0.32	0.21	0.30	0.39

t-statistics are in brackets, ** and * denote significance at 1% and 5% respectively.
Beta in specification (1) is a consumption beta, while betas in all other specifications are stock market betas.

8.2. Time-varying betas

While in the previous analysis betas were assumed constant in the sample, in this section, I allow betas to vary over time. I follow the two-step Fama-MacBeth procedure where, in the first step, betas are estimated in a five-year rolling window, and in the second step, the cross-section regression of portfolio returns on betas in the preceding five years is estimated. Hence, this is an out-of-sample test. I concentrate on the latest period from January 1999 until April 2009 when the stock market risk of currency portfolios seems to be more important. Since the first set of betas is estimated during the period from January 1999 until December 2003, the first cross-section regression is run for January 2004. Then the rolling window moves by one month and the procedure is repeated. This generates a time series of beta premiums, from which I find the average beta premium and its statistics.

Lustig and Verdelhan (2010) find significant time variation of betas of their currency portfolios, with betas increasing dramatically during crisis periods. I also find some variation in the estimated upside and downside betas over time, although the overall pattern is more monotonic (generally, stock market betas have increased over time in the studied period). This is probably due to the fact that downside betas are estimated in the sub-sample of negative stock market returns, which often corresponds to crisis periods, while upside betas are estimated in the sub-sample of favorable stock market performance.

The cross-section relationship of time-varying betas of 10 currency portfolios is the same as before. The lowest-interest portfolio downside beta is always negative with the average value of -0.09 and little variation. The downside beta of the highest-interest portfolio is always the highest in the cross-section with the average value of 0.58 and the maximum and minimum values of 0.78 and 0.17, respectively. It should be pointed out that the downside betas of all portfolios, except portfolio 1, increased significantly during the financial crisis in October 2008 – April 2009, when carry trades crashed dramatically. There is a particularly visible positive relationship between portfolio rank and the downside beta in this period.

In the Fama-MacBeth cross-section regressions for 10 currency portfolios, the downside beta premium is 14 percent with a t-statistic of 2.15, while the upside beta premium is -0.03 and insignificant, as before. The two betas explain 43 percent of portfolio excess returns, on average, while the standard beta explains only 33 percent of returns. Generally, the conclusion that the downside beta is a relevant factor in explaining returns of carry trades is robust when betas are time-varying, although the explanatory power of all betas is lower than in section 8.1. This can probably be explained by greater estimation errors since betas are estimated in short samples and, hence, may be noisier.

8.3. GMM

The two-pass estimation procedure employed previously does not take into account that betas are generated regressors and can be measured with error. Although Shanken (1992) correction of the second-stage standard errors is usually used to tackle this problem, in the presence of conditional heteroskedasticity uncorrected Fama-MacBeth standard errors are not necessarily underestimated (Jagannathan and Wang, 1998). Therefore, to deal with the problem of generated regressors I estimate factor betas and risk premiums jointly using efficient GMM.

I use the following moment conditions:

$$\begin{aligned} &E(\Delta er_{jt} - a_j - b_j f_t) = 0 \\ &E(\Delta er_{jt} - a_j - b_j f_t) \otimes f_t = 0 \\ &E(ret_j - b_j \lambda) = 0 \end{aligned} \tag{7}$$

where f_t is either a factor or a vector of factors (r_{mt}, r_{mt}^2, $dummy_t * r_{mt}$, non-durable consumption growth), Δer_{jt} is the exchange rate return of portfolio *j*, ret_j is the average total return of portfolio *j*, and λ is a risk premium or a vector of risk premia, depending on specification. The first two moments estimate factor betas of each portfolio, and the third moment estimates the risk premia. The covariance matrix between the two sets of moments captures the effects of generating regressors on the standard errors of the risk premia.

Table 9 presents the estimation results. As before, the market betas and the downside market betas are increasing with portfolio rank, while coskewness with the stock market return is decreasing (panel A). Downside betas of the top portfolios are highly significant and are much higher than their standard betas. At the same time, coskewness of the top portfolios is negative and highly significant. Betas and coskewness are very similar in magnitude to those estimated by OLS (tables 1 and 5). Again, the conclusion that high-interest currencies crash when the stock market goes down, while low-interest currencies hedge this risk, stands out clearly.

Panel B presents the factor risk premia and statistics of the cross-sectional regressions. As before, only the upside beta premium is insignificant. Also, this is the only model which is rejected by the J test. Downside beta, on the contrary, is highly significant, it is much more significant that consumption and market betas, and the model with downside beta has the lowest sum of squared residuals out of all specifications. There is no doubt that it is the downside risk which is priced in the currency market.

The GMM risk premia are much lower than those obtained in Fama-MacBeth regressions (table 2). The high premia in the Fama-MacBeth regressions are affected by the very high excess returns of the top portfolios, and once the top portfolios are dropped out, the premia decrease significantly (table 6). But the top portfolios are the ones which are most noisy, and their moments are likely to be measured imprecisely. Since the efficient GMM attaches lower weight to such moments, the risk premia are not affected that much by the top portfolios and, hence, appear to be lower. The downside beta premium of 7 percent per annum is similar to the premium obtained after excluding the top most risky currency portfolios from the sample, and it is closer to the downside beta premium in the stock market.

Table 9. GMM estimation of factor betas and risk premia

Panel A: Descriptive statistics										
	pfl 1	2	3	4	5	6	7	8	9	pfl 10
Market beta	-0.01	0.00	0.01	0.02	0.01	0.02	0.01	0.02	0.04	0.11
	[-0.93]	[-0.57]	[1.09]	[1.38]	[1.24]	[1.26]	[1.39]	[1.53]	[1.77]	[2.05]
Downside beta	-0.03	-0.02	0.01	0.04	0.02	0.03	0.03	0.04	0.10	0.32
	[-1.57]	[-0.93]	[0.52]	[1.90]	[1.06]	[1.31]	[1.60]	[1.76]	[3.48]	[4.94]
Coskewness	0.16	0.09	-0.14	-0.41	-0.23	-0.30	-0.33	-0.35	-0.84	-2.63
	[1.22]	[0.64]	[-0.90]	[-2.56]	[-1.35]	[-1.51]	[-1.91]	[-1.86]	[-4.23]	[-6.26]

Panel B: Risk premia						
	Consumption beta	Market beta	Upside beta	Downside beta	AB	Coskewness
Premium	0.052**	0.206*	-0.112	0.069**	0.073**	-0.008**
	[2.08]	[1.89]	[-1.45]	[4.14]	[2.31]	[-5.07]
P-value of T*J-stat	0.614	0.723	0.996	0.699	0.488	0.556
Av. sum of sq. res.	0.100	0.100	0.079	0.074	0.074	0.100

t-statistics are in brackets.
** and * denote significance at 1% and 5% respectively.

8.4. Global equity index as a proxy for the market portfolio

Since the main carry trade investors are hedge funds and investment banks which invest globally, a global equity index may be a better proxy for the market portfolio. In this section I estimate currency betas and coskewness in relation to MSCI AC World equity index, which aggregates the stock market performance in 45 countries (see the appendix for the country membership).

The world stock market index co-varies closely with the US stock market index (correlation coefficient 0.89). Therefore, in the presence of global diversification, the US stock market index is still a rather good proxy for the market portfolio of international investors.

Table 9 presents the estimation results of Fama-MacBeth cross-section regressions. Again, the two-beta CAPM (specification (7)) has a higher explanatory power than the standard CAPM (specification (1)), and the two-beta three-moment CAPM (specification (8)) wins the horse race. The downside beta and not the upside beta is a significant factor in the cross-section of currency portfolios. The downside beta increases monotonically with the rank of portfolios from -0.03 (portfolio 1) to 0.35 (portfolio 10), while the upside beta ranges between 0.11 and 0.23 with no particular order. Coskewness with the world stock market is also a relevant measure of currency risk. Coskewness is positive for portfolio 1 (0.55), it decreases monotonically with portfolio rank and reaches the level of -2.07 for portfolio 10. The conclusion of the paper that downside risk is priced in the currency market is confirmed when the global stock market index serves as a proxy for the market portfolio.

Table 10. Fama-MacBeth cross-sectional regressions with the global equity index as the market portfolio

	Dependent variable: Total annualized returns							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	10 portfolios, 1990-2009							
Beta	0.76**		0.84**					
	[6.70]		[4.88]					
Coskewness		-0.06**	-0.01					-0.05**
		[-6.68]	[-1.26]					[-3.78]
Upside beta				0.25*			-0.14	0.25*
				[2.21]			[-1.28]	[2.18]
Downside beta					0.51**		0.53**	0.88**
					[6.88]		[6.93]	[6.55]
AB						0.51**		
						[6.91]		
Intercept	-0.08**	-0.02	-0.09**	0.01	-0.05**	0.03*	-0.03	-0.09**
	[-4.03]	[-1.32]	[-3.45]	[0.41]	[-2.66]	[2.37]	[-1.29]	[-3.34]
R^2	0.50	0.44	0.50	0.02	0.56	0.52	0.56	0.71
Adjusted R^2	0.43	0.37	0.35	-0.10	0.50	0.46	0.43	0.57

t-statistics are in brackets.
** and * denote significance at 1% and 5% respectively.

It should be pointed out that the intercept is negative and statistically significant in most specifications in table 9, while previously it was insignificant. This means that the model with the world equity index overpredicts the returns on all currency portfolios. The intercept measures the price of dollar risk since all portfolio returns are calculated relative to the US dollar, and if dollar appreciates in effective terms the returns on all portfolios will be affected equally. Therefore, all portfolios load equally on this risk factor, and hence it is not important in the cross-section. Since the US stock market index also loads on this risk factor, the intercept was insignificant in the previous estimations (tables 2 and 8). Lustig and Verdelhan (2010) also estimate a negative intercept in their durable consumption CAPM specification. This is because consumption growth (as well as the world stock market return) is a rather diversified proxy for the stochastic discount factor in terms of dollar risk, while the US stock market return is not. But when the cross-section regression is run on carry trade portfolios, which go long in high-interest currencies and short in low-interest currencies and which are immune to dollar risk, the intercept becomes insignificant.

9. Conclusion

In this paper, I look at the downside risk of currencies to explain the high excess returns of carry trades, which have consistently been observed empirically and due to which the popularity of the strategy has increased dramatically among both institutional and private investors. I study portfolios of currencies sorted by the local interest rates to diversify away idiosyncratic risk and to concentrate on those properties of currencies which are specific to countries with different levels of interest rates.

I find that exchange rate risk is monotonically increasing in the local interest rate, so that returns of high-interest (investment) currencies have low negative skewness and coskewness with the stock market and high downside stock market beta, while returns of low-interest (funding) currencies, on the contrary, have positive skewness and coskewness and negative downside beta. This suggests that returns of carry trades are asymmetrically distributed with a high crash risk, and the crashes happen exactly in the worst states of the world, when the stock market goes down significantly.

Besides the high market risk of carry trades, there is a high country risk, measured by Fitch country rating. Country risk proxies well for the downside beta and coskewness, which suggests that there is "flight to quality" when the stock market crashes, and that the low-interest currencies serve as a "safe haven".

I run horse races between alternative asset-pricing models to explain the cross-section of currency portfolio returns. I find that the downside market beta has a much greater explanatory power than the standard market beta, and that skewness and coskewness are highly significant, so that the three-moment two-beta CAPM explains 79 percent of excess returns of 10 currency portfolios, sorted by the interest rate. The coskewness premium has the same magnitude as that in the stock market, while the downside beta premium is much higher. This is due to the fact that currencies yield higher returns while the range of their stock market betas is lower and the asymmetry of their returns is higher than in the stock market. I suggest that the downside beta premium partly compensates an investor for bearing country risk (e.g. a risk of a country default, the so-called "peso" event), and the two premiums are hard to separate because of an almost perfect correlation between the country risk and the downside beta. But after excluding the most risky portfolios from the cross-section, the downside beta premium becomes comparable to that in the stock market.

The results are robust to various specifications and methods of estimation, and are even stronger in the first decade of the 21st century. While non-systematic skewness of the high-interest portfolios is now lower (by the absolute value), their downside betas are higher, and the explanatory power of the market beta in the cross-section is greater. This suggests that there is a closer link between the currency and stock markets, which now co-move significantly. The rising volume of carry trade activity might have contributed to this trend. According to the head of Britain's financial regulator Adair Turner, the current carry trade could be destructive to emerging economies, and if the trades were reduced "the world would be a better place"[13].

[13] "Davos: FSA chief turns on 'valueless' carry trade", The Times, 30 January 2010.

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Appendix. Data

Sample of countries (period of available data in the parentheses): Australia (01.90-04.09), Austria (01.90-12.90), Belgium (01.90-12.98), Brazil (01.95-04.09), Bulgaria (01.92-01.08), Canada (01.90-04.09), Chile (07.97-04.09), China (01.02-04.09), Cyprus (01.90-12.07), Czech Republic (08.93-04.09), Denmark (01.90-07.07), Euro Zone (02.99-04.09), France (01.90-12.98), Germany (01.90-12.98), Greece (01.90-12.00), Hong Kong (06.91-04.09), Hungary (01.90-04.09), Iceland (01.90-04.09), India (01.93-04.09), Indonesia (02.00-12.03), Ireland (01.90-12.98), Italy (01.90-12-98), Japan (01.90-04.09), Latvia (05.94-03.08), Lithuania (08.96-04.09), Malaysia (01.90-04.09), Malta (01.90-12.07), Mexico (01.90-04.09), Netherlands (01.90-12.98), New Zealand (01.90-04.09), Norway (01.90-04.09), Philippines (01.90-02.09), Poland (05.91-04.09), Portugal (01.90-12.98), Romania (03.94-09.05), Russia (07.94-04.09), Singapore (01.90-04.09), Slovakia (02.93-12.07), Slovenia (05.98-12.06), South Africa (01.90-04.09), Spain (01.90-12.98), Sweden (01.90-04.09), Switzerland (01.92-04.09), Taiwan (01.90-03.09), Thailand (01.97-04.09), Turkey (01.90-04.09), UK (01.90-04.09).

Dates of denominations: Mexico (01.93), Poland (01.95), Russia (01.98), Turkey (01.05), Romania (07.05).

Country risk index: Each Fitch rating is assigned the following number:

	AA+ = 2	A+ = 5	BBB+ = 8	BB+ = 11	B+ = 14	CCC+ = 17				
AAA = 1	AA = 3	A = 6	BBB = 9	BB = 12	B = 15	CCC = 18	CC = 20	C = 21	DDD = 22	D = 23
	AA- = 4	A- = 7	BBB- = 10	BB- = 13	B- = 16	CCC- = 19				

Country membership of MSCI AC World index: AUSTRALIA AUSTRIA BELGIUM BRAZIL CANADA CHILE CHINA COLOMBIA CZECH REPUBLIC DENMARK EGYPT FINLAND FRANCE GERMANY GREECE HONG KONG HUNGARY INDIA INDONESIA IRELAND ISRAEL ITALY JAPAN KOREA MALAYSIA MEXICO MOROCCO NETHERLANDS NEW ZEALAND NORWAY PERU PHILIPPINES POLAND PORTUGAL RUSSIA SINGAPORE SOUTH AFRICA SPAIN SWEDEN SWITZERLAND TAIWAN THAILAND TURKEY UNITED KINGDOM USA

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