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Carry Trades: Betting Against Safe Haven

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Abstract

We examine contagion and flight-to-quality phenomena implied by carry strategies. More specifically, we analyze correlation dynamics between returns on a global equity index and returns on an investment strategy with a long position in high-yield and a short position in low-yield markets. Modeling information spillovers in a multivariate GARCH framework reveals that correlation increases considerably in response to a negative stock market shock. Moreover, a test for symmetry in exceedance correlation shows that correlation is indeed significantly larger for joint market downturns as opposed to joint market upturns. Our findings suggest that conditional correlation exposes carry traders to a severe diversification meltdown in times of global stock market crises.

Keywords

Carry trades, contagion, multivariate GARCH, exceedance correlation

JEL Classification

C32, F31

1 Introduction

Nominal exchange rates frequently deviate by substantial magnitude from what is thought to be a fair value. Carry speculators borrowing cheaply in currencies with relatively low interest rates and lending for more elsewhere are often blamed for causing such decoupling. The critics argue that carry traders run large risks. After all, unexpected currency movements might quickly erase profits implied by cross-currency interest rate differentials which are relatively small in comparison to volatility in foreign exchange markets. In this paper, we focus on yet another risk exposure incurred by carry traders, viz correlation spillovers which are sometimes referred to as contagion. More specifically, we analyze the variance-covariance dynamics between carry trades and nominal returns on world stock markets in a multivariate GARCH (MV-GARCH) as well as in an exceedance correlation framework. A thorough understanding of variance-covariance spillovers is of crucial importance for optimal portfolio decisions. Carry investors not taking account of time-variation in second moments are likely to be over-invested in high-yield currencies which makes them prone to unexpected diversification meltdowns in times of crisis. Moreover, a good description of variance-covariance dynamics between currency and equity markets is important for various other financial applications ranging from currency risk management to the pricing of currency derivatives.

As a matter of fact, the standard carry strategy boils down to a double speculation on uncovered interest rate parity (UIP) where investors hope to profit twofold from risk premia in their favor. First, carry traders speculate that default-free investments in high-yield currencies outperform default-free investments in domestic currency. Since interest payments are known at the beginning of the contract period, the carry trader is solely exposed to stochastic in exchange rate movements. He would incur a loss on his foreign deposit if the domestic currency experienced an unexpected sharp appreciation. Instead of investing in foreign money markets, investors can alternatively lock in interest rate differentials by entering a forward contract promising delivery of domestic currency at some future date. Assuming rational expectations, the difference between forward rates and future spot exchange rates is known as currency risk premium and is precisely equal in magnitude to deviation from UIP. That is due to covered interest rate parity which must hold permanently by virtue of arbitrage. [1] In contrast to the forward premium which measures the difference between forward rates and current spot rates, the currency risk premium measures the difference between forward rates and future spot rates and is only known ex-post. The second speculation concerns borrowing costs and might be interpreted as a bet on UIP with reversed sign. By borrowing in low-yield markets, carry traders hope to end up with lower borrowing costs than for a comparable loan in domestic currency. As before, interest rates are known at the time of entering a credit agreement and stochastic stems solely from foreign exchange movements. However, the carry investor would now incur a loss on his foreign loan if the domestic currency experienced an unexpected depreciation. Again, low foreign interest rates could be alternatively locked in via forward markets by promising to deliver foreign currency at some future date.

For some currencies, risk premia are surprisingly persistent meaning that forward

[1] Subsequently we use the expressions (currency) risk premium and deviation from UIP synonymously.

rates systematically under- or over-predict future spot exchange rates. The Swiss Franc (CHF), for instance, is a notorious low performer leaving investors usually with a negative currency risk premium. By contrast, money market deposits in commodity currencies such as the Australian Dollar (AUD), the Canadian Dollar (CAD) or the New Zealand Dollar (NZD) performed relatively well historically. Our analysis is therefore based on carry strategies where investors incur debt in CHF and invest the proceeds in commodity currency deposits. Do persistent forward premia, a phenomenon which is sometimes referred to as the forward rate puzzle, make certain currencies a foolproof prey for carry traders? A note of caution is advisable, after all, deviation from UIP is not simply a consequence of market irrationality. There exists increasing evidence that deviation from UIP can be - at least partly - explained by exposure to systematic or non-diversifiable risk (see, for instance, Sarkissian, 2003 or Lustig and Verdelhan, 2005). In virtually all asset pricing models, systematic risk is driven by a covariance term between payoffs or returns and some explicit or implicit measure of utility. The CAPM, for instance, postulates that the risk premium arises due to positive covariance between returns on some asset i and returns on the market portfolio whereas the latter is seen as a proxy for agents' total wealth and hence utility. In this paper, we demonstrate that there exists a relationship between the sign and magnitude of currency risk premia on the one hand and correlation between currency risk premia and returns on global equity markets on the other. Whereas we initially take a static perspective in the sense that correlation is calculated as a sample average, the paper's main focus lies in analyzing time-varying correlation within both a MV-GARCH and an exceedance correlation framework. In the MV-GARCH section, we explore changes in correlation between profits from carry investments and returns on global equities in response to shocks in stock markets. Besides analyzing the aggregate carry effect, we find revealing to decompose the carry into two separate bets on UIP. This allows to track the correlation dynamics of low- and high-yield currencies separately. The MV-GARCH analysis leaves us with illustrative news impact surfaces (NIS) demonstrating the impact of past asset price shocks in a three-dimensional graph. However, the results from MV-GARCH estimation do not allow to straightforwardly determine whether movements in correlation are large in a statistical significant sense. For that purpose, we complementary calculate exceedance correlations which are defined as correlations in the tails of a bivariate distribution. A test statistic for asymmetry allows to determine whether exceedance correlations are significantly different in times of joint positive market shocks as opposed to times of joint negative shocks.

As our analysis shows, unconditional correlation obscures the true magnitude of correlation exposure. In fact, in volatile market environments and particularly during market downturns, the correlation between equity markets and commodity currency deposits increases considerably. Intuitively, the rise in correlation can be explained by investors avoiding procyclical currency positions in periods of market turbulence. In other words, a carry trader's long position is subject to particularly unfavorable correlation in times of general market downturns when diversification benefits would be most desirable. To make things worse, correlation dynamics are precisely the other way round on the borrowing side of the carry. In our empirical analysis, we assume that carry traders' long positions are financed by incurring debts on the Swiss Franc (CHF) money market. Unfortunately, carry investors borrowing in CHF are moreover penalized by unfavorable correlation characteristics. In contrast to commodity currencies, the CHF moves against the cycle which means that it has a tendency to appreciate during global market downturns and to lose strength in boom phases. That explains why the CHF is sometimes referred to as a safe haven currency. Obviously, a carry trader holding a short position in CHF does not appreciate countercyclicality, since it leaves him with a larger debt burden in times of stock market downturns. If, moreover, correlation is conditioned on past asset price shocks or exceedance levels, borrowing in CHF appears even less attractive. Our analysis reveals that the correlation between CHF deposits and equity markets gets considerably more negative in bear markets as opposed to bull markets. Intuitively, that is what one would expect from a safe haven currency which, as a consequence of flight-to-quality, is in particular high demand in times of market turmoil. In short, we can say that carry traders face unfavorable correlation exposure on their long as well as on their short position and this notably in times of crises. Not taking account of that might result in an over-frivolous carry trade activity.

2 Contagion literature

Our analysis is part of a broader literature on contagion which analyzes the dispersion of financial crises across assets and markets. As noted by Pericoli and Sbracia (2003), there does not exist an unambiguous definition of contagion yet. Some propose to measure contagion as the probability of a shock conditional on the probability of a shock in another market. Others define contagion as comovements in asset prices which do not seem to be justified by changes in economic fundamentals. Again others focus on volatility- rather than asset price spillovers. Our study is in accordance with this latter definition, which defines contagion as a rise in covariance or correlation in response to crisis. Crises are usually defined as times of large market downturns or times of increased financial volatility. Alternatively, some authors define crises exogenously by some major geopolitical event such as the war in Iraq or September 11$^{\text{th}}$ 2001. Empirical research on variance-covariance spillovers is usually conducted in a MV-GARCH framework. One of the earliest studies is from Longin and Solnik (1995) who investigate variance-covariance spillovers between national stock market indices. Introducing dummy variables to a bivariate constant correlation model, Longin and Solnik report an increase in correlation between national stock markets in times of above average volatilities in US equity markets. However, they do not find much evidence for asymmetric effects, which means that stock market correlation does not seem to depend on whether the US stock market suffers a positive or a negative shock. Longin and Solnik's investigation is representative for the bulk of the contagion literature, which usually analyzes spillover effects within the same asset class. Usually, the focus is on covariance dynamics across national stock market indices. By contrast, we are interested in spillover effects across asset classes, viz between movements in global stock markets and foreign currency money deposits. Research focusing on variance-covariance dynamics across asset classes is rare. One example is a paper by Hartmann, Straetmann and de Vries (2001) who investigate spillovers between stock and bond markets. However, they do not base their investigation on a MV-GARCH analysis but on a conditional probability measure which captures the probability of a crash given a downturn in another market. It is found that the probability of a bond market crash conditioned on a stock market crash is relatively low. Similar to our investigation is Capiello et al's (2003) MV-GARCH study on correlation dynamics between national stock- and bond markets. Like most studies on contagion, they report an increase in correlation across national equity markets during crisis. In addition, they provide evidence for a flight-to-quality phenomenon between stock and bond markets. In contrast to contagion, flight-to-quality is defined as a decrease in asset price covariance or correlation in response to market downturns. Divergence in asset prices is a consequence of investors who reallocating wealth from risky to safer assets as crises hit. Moreover, Capiello et al's GARCH specification captures asymmetric effects which allow to disentangle the covariance impact of positive as opposed to negative asset price shocks. The inclusion of asymmetries proves to be crucial since contagion and flight-to-quality phenomena depend not only on the absolute magnitude of shocks but also - and probably even more importantly - on the shock's sign. Baur and Lucey (2006) do a similar study and find that the correlation between stock and bond markets decreased significantly in the aftermath of the Asian crisis in October 1997 and also in response to the Russian crisis in June 1998. Furthermore, Baur and Lucey study flight-to-quality effects by including gold as an additional asset. From a methodological viewpoint, our study is closely related to those of Capiello et al. and Baur and Lucey. We also investigate covariance spillovers across asset classes using an asymmetric MV-GARCH specification. Moreover, by analyzing covariance dynamics of commodity as well as safe haven currencies separately, we obtain contagion as well as flight-to-quality effects. The main difference concerns the subject of investigation. Whereas Capiello et al. and Baur and Lucey focus on spillover effects between equity and bond markets, our analysis disentangles correlation dynamics between equity markets and returns on currency forwards. To the best of our knowledge, there does not exist any such study yet. Tastan (2006), however, runs a MV-GARCH analysis between movements in exchange rates and stock market returns. Since the bulk of the variation in currency risk premia stems from exchange rate movements, Tastan's subject of investigation is related to ours. He finds significant GARCH effects and concludes that average covariance measures obscure that conditional covariances vary considerably over time. In contrast to our analysis, Tastan does neither focus on safe haven or commodity currency effects, nor does he specify an asymmetric process.

The theory around exceedance correlation offers an alternative framework to analyze contagion and flight-to-quality phenomena. Judging by the number of studies, the exceedance correlation literature is overshadowed by MV-GARCH analyses. Nevertheless, the framework allows to gain important complementary insights on variance-covariance behavior. In contrast to MV-GARCH analyses, it notably provides a simple framework to test whether asymmetric effects exhibit statistical significance.

Exceedance correlation is based on extreme value theory and measures how correlation changes as one moves towards the outer tails of a multivariate - usually bivariate - distribution. In a landmark paper, Longin and Solnik (2001) study conditional correlations between international stock markets. They focus on asymmetric effects by distinguishing between correlation in bull as opposed to correlation in bear markets and find that a bivariate normal distribution provides a good description of correlation in bull markets but underestimates correlation during market downturns. Ang and Chen (2002) investigate correlation dynamics between US aggregate equity markets and sub-portfolios sorted by characteristics such as size and book-to-market. They conclude that correlations are much larger for extreme downside moves in comparison to upside moves of the same magnitude. Like Longin and Solnik they find that downside correlations are larger than what would be implied by a normal distribution. A key innovation of their paper is that they develop a procedure allowing to test whether exceedance correlations differ in a statistically significant sense from correlations implied by some prespecified distribution and whether there exist correlation asymmetries. However, their procedure requires information about theoretical exceedance correlations of multivariate distributions which can only be obtained by diving into extreme value theory. Besides the fact that closed-form calculations of exceedance correlations are rather cumbersome, there remains the difficulty of choosing an appropriate benchmark distribution. Fortunately, Hong et al. (2003) suggest an alternative test for asymmetry which circumvents both difficulties, rendering the exceedance correlation framework more accessible for empirical work (see, for instance, Michayluk et al. (2006) who investigate exceedance correlations between US and UK securitized real estate markets). In section 6, we analyze exceedance correlations between profits on carry trade strategies and returns on world equity markets making use of Hong et al.'s (2003) test procedure.

3 Data description

Our data set contains weekly observations from Friday, 11$^{\text{th}}$ April 1997 until Friday, 29$^{\text{th}}$ December 2006. This leaves us with a total sample size of 508 observations covering a period of almost 10 years. A weekly frequency was chosen because GARCH effects were found to level off at longer frequencies such as monthly or quarterly intervals. In fact, it is well possible that daily data leads to even more distinctive results. Since we use data from various markets, a daily or even shorter frequency would, however, complicate timing calibration enormously.

We use the world equity market total return index provided by Datastream to calculate logarithmic returns on the global market portfolio. The excess market return is obtained by subtracting the USD Euromarket rate for 1-week deposits from world market returns. Euromarket rates are obtained from the Financial Times and exchange rate data from Reuters. Deviation from UIP was calculated as follows:

$$uip_{t,t+1} = i^f_{t,t+1} - i_{t,t+1} + ln(s_{t+1}/s_t) \tag{1}$$

where $uip_{t,t+1}$ denotes deviation from UIP between t and $t+1$. $i^f_{t,t+1}$ is the foreign 1-week Euromarket rate, $i_{t,t+1}$ the corresponding domestic rate and s the exchange rate. Note that all returns are expressed in logarithmic form. As mentioned previously, a carry strategy boils down to a double speculation on UIP where investors hold a long position in some high-yield currency and a short position in a low yield currency. The returns on the carry investment are simply obtained by summing up currency risk premia from long and short positions. Since $uip_{t,t+1}$ measures deviation from UIP in logarithmic terms, we must first run a transformation to obtain discrete returns. Only then can we perform a cross-sectional summation. With deviation from UIP defined as in equation 1, we can write:

$$r_{ij,t,t+1} = ln(1 + e^{uip_{i,t,t+1}} - e^{uip_{j,t,t+1}}) \tag{2}$$

where r_{ij} denotes the logarithmic return on a carry trade investment with a long position in high interest rate markets i and a short position in low interest rate markets j. We calculate three carry strategies with investors holding a short position on the CHF money market and going long in the AUD, the CAD or the NZD respectively. Analyses in the main text refers primarily to the case of an USD-investor. The appendix contains additional uncommented results taking the viewpoint of EUR- and GBP-investors. We use DEM series prior to the launch of the EUR on January 1^{st} 1999.

4 Preliminary analysis

Figure 1 shows a scatter plot with average currency risk premia on the vertical axis and correlations between returns on foreign currency deposits and returns on global equities on the horizontal axis. Note that the scatter cloud is upward-sloping, a phenomenon which is also observed if the perspective of an EUR- or GBP-investor is taken (see figures 5 and 6 in the appendix). That means that currencies with a positive risk premium, on average, are exposed to higher correlation and therefore to more systematic risk in comparison to currencies providing a relatively low or even negative risk premium. This observation is in contrast to that part of the literature which attributes deviation from UIP to market anomalies and investor irrationality (see, for instance, Froot and Frankel 1989 and Chinn and Meredith 1994). As figures 1, 5 and 6 indicate, cross-market differences in currency risk premia can be explained - at least partly - by differing exposures to systematic risk in terms of an unfavorable correlation exposure with global equity markets.

Historically, USD-investors would have earned a sizable currency risk premium, on average, by investing in AUD, CAD or NZD money markets. For that reason, we assume that carry investors take a long position in one of these currencies which are commonly referred to as commodity currencies. The reason is that they stem from countries where exports of primary materials account for a relatively large fraction of total GDP. This dependency makes currency movements prone to fluctuations in commodity prices and therefore to the state of the global economy (see Djoudad et al., 2000 for an analysis of the relationship between commodity prices and fluctuations in the AUD, the CAD and the NZD or Chen and Rogoff, 2002). On the other hand, the CHF money market seems predestined for borrowing, after all, CHF interest rates are much lower than in most other countries and interest rate differentials are surprisingly stable. In fact, there exists extensive literature investigating the phenomenon of the so-called Swiss interest rate island (see, for example, Buomberger, Höfert and van Bergeijk, 2000 or Kugler and Weder, 2004). Even after accounting for currency movements, debt in CHF would have been, on average, much cheaper than loans in almost any other currency.

In table 1, we report distribution statistics for carry trade investments. It is assumed that the carry trader invests in a deposit in AUD, CAD or NZD by borrowing on the CHF money market. The returns of this zero fund investment are obtained by sum-

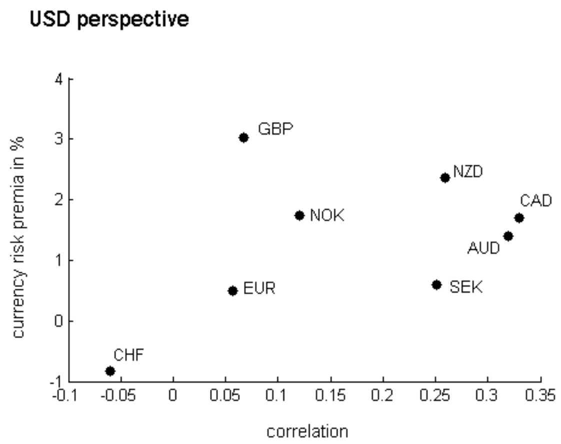

Figure 1: *Shows deviation from UIP in % p.a. on the vertical axis and unconditional correlation between currency risk premia and returns on global equity markets on the horizontal axis. Calculations are based on weekly returns from April 1997 to December 2006 denominated in USD.*

ming up the two resulting currency risk premia.[2] As mentioned previously, interest rate levels in commodity currencies are relatively high in comparison to comparable investments in other currencies which renders them attractive for carry trade long positions. Over the last decade, for instance, average interest rates on 1-week Euromarket deposits were 1.94% p.a. for weekly deposits in NZD and 1.81% p.a. for weekly deposits in AUD. Among our three commodity currencies, the lowest interest rate level was obtained in CAD with 1.52% p.a. which is still higher than in most industrialized countries. Whereas USD-investors had to settle for 1.48%, the corresponding rate in the Euro-area was 1.38%. As expected, CHF investments were - accompanied by deposits in Japanese Yen (JPY) - at the very bottom of the league. A CHF Euromarket deposit yielded only 0.76%, which renders the CHF debt market highly attractive for carry trades. Besides interest rate differentials which are known at the time of entering a trade, carry investors' profits are driven by movements in exchange rates. The first row of table 1 takes account of profits stemming from the exchange rate as well as the interest rate side by showing average deviation from UIP. We report test statistics for three carry trade strategies with investors entering a long position in either AUD, CAD or NZD deposits by borrowing on the CHF money market. It can be seen that over the last decade, all carry trade strategies yielded a positive average return in the range of 0.030% for the AUD-to-CHF and 0.049% for the NZD-to-CHF carry. Note that these small numbers arise due to the fact that we report weekly returns. In annualized terms,

[2]Note that it is not entirely correct to talk of returns when referring to carry trades. After all, the latter are zero investments which do not require any upfront payment. Therefore, it would be more correct to talk of profits in USD terms thereby assuming that the carry trader has an exposure of 100 USD on the long as well as on the short side of the trade. For better comparability with interest rate levels and returns from UIP speculation, we subsequently apply the terms profit and return synonymously for carry trade investments.

we receive 1.56% and 2.55% respectively which is relatively large in comparison to interest rate levels. Note, however, that standard deviations for mean returns are large which indicates that carry trade speculation is indeed a risky venture. The t-statistics are far from significant at conventional significance levels so that the null hypothesis cannot be rejected.

Table 1 reveals more interesting facts. Carry investments with a long position in commodity currency markets and a short position in CHF exhibit strong positive correlation with returns on the global equity market. We obtain a correlation coefficient in the vicinity of 0.3 for all three strategies. In other words, carry investments are strongly procyclical, generating profits during general market upturns and losses in bearish market environments. Risk-averse investors try to avoid positive correlation since it exposes their total wealth to large fluctuations. Moreover, as shown by the values for kurtosis, all carry trade returns exhibit fatter tails than under normality. By definition, the normal distribution has a kurtosis of 3 which lies below kurtosis values reported in table 1. To make things worse, the carry suffers moreover from negative skewness meaning that returns are asymmetrically distributed. More specifically, negative skewness signifies that the return distribution has a longer tail to the left than to the right which means that carry trade investments entail a larger probability of making a huge loss than of making a huge gain. Given anomalies in third and forth moments, it is not surprising that the Jarque-Bera test is rejected for all strategies indicating that carry returns are not normally distributed.[3] In summary, we can say that carry speculation involves multiple risks stemming from unfavorable distribution characteristics. Besides positive correlation between equity returns and profits from carry trades, considerable excess kurtosis along with negative skewness is observed.

As mentioned previously, a carry trade can be decomposed into two separate UIP components, viz a currency risk premium from a long position in a commodity currency and a risk premium from a short position in CHF money markets. In order to get an insight into a carry trade's underlying dynamics, table 2 reports statistics on each of these components separately. We restrict annotations to table 2 which is based on the perspective of an USD-investor. Results are however similar if the viewpoint of an EUR- or GBP-investor were taken.[4] The first column of table 2 shows statistics on deviation from UIP with respect to CHF deposits whereas columns to the right contain distribution statistics on currency risk premia for commodity currencies. To emphasize the difference between CHF and commodity currency investments, all statistics are based on long positions. Note that results on currency risk premia with respect to CHF long positions are usually the converse of those reported for commodity currencies. First, an USD-investor would have outperformed a corresponding domestic investment by holding commodity currency deposits. For instance, an investment in AUD money markets would have brought an outperformance of 0.027% per week (1.4% p.a.). By contrast, CHF investments underperformed in comparison to the USD money market by -0.016% (-0.8% p.a.). Second, the CHF investment seems to compensate for underperformance by providing a hedge against stock-market downturns in the form of a slightly negative correlation with returns on global equities. Hence, the CHF seems to live up to its reputation as a safe haven currency providing protection

[3] See Jarque and Bera (1980) for a description of the Jarque-Bera test for normality.

[4] Results can be obtained from the author upon request.

in turbulent times. On the other hand, the correlation between returns on commodity currency deposits and returns on world equities are all strongly positive, which reflects the procyclical stance of these markets. Third, whereas currency risk premia on CHF deposits exhibit positive skewness, UIP deviations vis-à-vis commodity currency investments are negatively skewed. Positive skewness means that a series tail is longer to the right than to the left. In other words, an investment in CHF entails a larger probability of making a huge gain than of making a huge loss and vice versa for an investment in commodity currencies. Intuitively, positive skewness is what one would expect from a safe haven currency which is expected to appreciate sharply in the immediate aftermath of a crisis. On the other hand, it is rather unlikely that a safe haven loses much of its value within a short period of time. This results in a higher probability of large upward moves as opposed to large downward moves. Fourth, currency risk premia with respect to commodity currency investments suffer from excess kurtosis. In contrast, the probability of large fluctuations in the value of CHF deposits is slightly smaller than what would be implied by a normal distribution. In contrast to the carry strategy, an isolated analysis of commodity currency investments and CHF deposits generates less distinctive anomalies in kurtosis and skewness. As a consequence, the Jarque-Bera test's null hypothesis of normality cannot be rejected, neither for commodity currency nor CHF risk premia.

The difference between commodity currency deposits and CHF investments is also evident in figures 1, 5 and 6. Commodity currencies are located on the upper-right which indicates that they provide above average risk premia while suffering from positive correlation. On the other hand, CHF deposits are located on the lower-left meaning that negative correlation compensates investors for the negative average risk premium. In contrast to commodity currencies, the CHF moves against the cycle having a tendency to appreciate during global market downturns and to lose strength in boom phases. Obviously, a carry trader holding a short position in CHF does not appreciate countercyclicality, since it leaves him with a larger debt burden in times of market downturns.

The preceding analysis shows that a carry trader can expect to gain twofold from currency risk premia in his favor. However, in order to take advantage of deviations from UIP, he must take on board systematic risk exposing his long as well as his short position to positive correlation with world equities. So far, the analysis is based on unconditional correlations which obscure the true magnitude of correlation exposure. In the remainder of this paper, we show that a carry trader's correlation exposure worsens considerably if one switches from an unconditional to a more realistic time-varying correlation perspective.

5 Correlation analysis in an asymmetric MV-GARCH framework

Autoregressive conditional heteroscedasticity (ARCH) models have originally been developed in the first half of the 1980s by Engle (1982) and were later extended by Bollerslev (1986) to the more flexible GARCH framework. GARCH models allow to forecast the conditional variance of a financial time series by an autoregressive moving average structure where variances are driven by past asset price shocks and

	AUD - CHF	CAD - CHF	NZD - CHF
Mean	0.030 %	0.032 %	0.049 %
Stddev of Mean	0.074 %	0.066 %	0.076 %
T-statistic	0.404	0.486	0.649
Stddev	0.017	0.015	0.017
Skewness	-0.564	-0.567	-0.437
Kurtosis	5.382	4.130	3.990
Maximum	0.054	0.038	0.053
Minimum	-0.093	-0.067	-0.081
Jarque-Bera	144.783	53.339	36.204
Cor with wld mkt	0.345	0.267	0.296

Table 1: *Descriptive statistics for returns on carry trades. The AUD-to-CHF column is based on returns from a carry going long in AUD and short in CHF money markets. The CAD-to-CHF and the NZD-to-CHF show analogous statistics for CAD, respectively NZD investments. Calculations are based on weekly returns from April 1997 to December 2006 denominated in USD.*

	CHF	AUD	CAD	NZD
Mean	-0.016 %	0.027 %	0.033 %	0.045 %
Stddev of Mean	0.064 %	0.067 %	0.042 %	0.072 %
T-statistic	-0.249	0.401	0.784	0.629
Stddev	0.014	0.015	0.009	0.016
Skewness	0.108	-0.197	-0.019	-0.280
Kurtosis	2.881	3.335	3.384	3.404
Maximum	0.051	0.052	0.031	0.055
Minimum	-0.043	-0.059	-0.030	-0.050
Jarque-Bera	1.349	5.465	2.935	9.821
Cor with world Mkt	-0.060	0.320	0.330	0.260

Table 2: *Descriptive statistics for currency risk premia for CHF, AUD, CAD and NZD deposits. The statistics are based on weekly returns from April 1997 to December denominated in USD.*

an autoregressive variance component. But variances are not only driven autoregressively as univariate GARCH specifications suggest. In addition, there seem to exist significant variance-covariance spillovers across assets which can only be captured in a multivariate GARCH (MV-GARCH) framework. The latter allows to model second moments of systems with several assets simultaneously resulting in a process for the conditional variance-covariance matrix. Obviously, contagion and flight-to-quality are spillover phenomena which can only be modeled in multivariate settings. These are considerably more complex than their univariate counterparts, after all, the dynamics of every element in the variance-covariance matrix need to be modelled. As the system is extended to more and more assets, the elements of the variance-covariance matrix multiply to the square which results in an explosion of free parameters boding trouble for estimation. To avoid parameter explosion, the econometrician either needs to restrict the number of assets or chose a model specification which uses parameters parsimoniously, usually at the cost of losing some of the model's flexibility. We therefore restrict analyses to a two-asset-system by only including time-series of global equity market returns and some currency risk premium. This means that we are unlikely to suffer from parameter explosion, irrespective of which model is chosen. However, our choice of model is somewhat restricted by the requirement that it should capture asymmetric effects. After all, contagion and flight-to-quality phenomena emerge predominantly during bear as opposed to bull markets. Put differently, the conditional variance-covariance matrix between stock market returns and currency risk premia is not only driven by the absolute magnitude of past shocks, but also - and maybe even more importantly - by a past shock's sign.

From the large universe of MV-GARCH models, we chose Engle and Kroner's (1995) BEKK specification in its fully-fledged form. In comparison to the widely applied diagonal BEKK model, the fully-fledged version is richer in parameters. But since we maneuver in a bivariate system, we are not much affected by parameter explosion and can easily cope with the fully-fledged specification. The latter brings the advantage that it enhances model flexibility considerably leading to more detailed insights into the dynamics of the variance-covariance matrix. The BEKK specification postulates a quadratic form which brings the additional advantage of guaranteeing positivity of the variance-covariance matrix under relatively mild parameter restrictions. Within the framework of their general dynamic covariance (GDC) model, which can be seen as a more general version of the BEKK model, Kroner and Ng (1998) propose to include asymmetric effects. These allow to disentangle the impact of positive from negative shocks. In analogy to Kroner and Ng's GDC model, we incorporate asymmetric effects in our BEKK specification. Finally, the BEKK model was chosen because we encountered difficulties in estimating the dynamic conditional correlation model recently introduced by Engle (2002) and extended to an asymmetric version by Cappiello et al. (2003). It was notably found that the estimation results of the latter depend crucially on the choice of start values.

The BEKK MV-GARCH(1,1,1) model is defined as follows:

$$r_t = \mu + \epsilon_t \tag{3}$$

where r_t is a vector of excess returns. In our analysis, r_t is a bivariate vector denoting excess returns on the global equity index and returns resulting from a commodity currency-to-CHF carry trade strategy. The term μ is the corresponding vector of expected returns which we assume to be constant. We furthermore assume that the error term ϵ_t follows a normal distribution given the information set Ω_{t-1}. In mathematical terms, ϵ_t is written as follows:

$$\epsilon_t \mid \Omega_{t-1} \backsim N(0, H_t) \tag{4}$$

with

$$H_t = C \cdot C' + A'\epsilon_{t-1}\epsilon'_{t-1}A + B'H_{t-1}B + G'\eta_{t-1}\eta'_{t-1}G \tag{5}$$

where H_t denotes the conditional variance-covariance matrix. C, A, B and G are $n \times n$ parameter matrices with C being lower triangular. The variance-covariance matrix is thus driven by a constant term denoted as CC', previous return shocks ϵ_{t-1}, an autoregressive variance-covariance component H_{t-1} and η_{t-1}. The $n \times 1$ vector η_{t-1} is the asymmetric innovation term which corresponds to the value of ϵ_{t-1} if the latter is negative and zero otherwise. In mathematical terms, η_{t-1} is defined as follows:

$$\eta_{t-1} = min(0, \epsilon_{t-1}) \tag{6}$$

The model is estimated in a two-step procedure. First, ϵ_t is obtained by demeaning r_t (see equation 3). Secondly, ϵ_t are plugged into the cumulative log-likelihood function given by:

$$lnL(\theta) = -\frac{tn}{2} - \frac{1}{2}\sum_{t=1}^{T} ln|H_t| - \frac{1}{2}\sum_{t=1}^{T} \epsilon'_t H_t^{-1} \epsilon_t \tag{7}$$

where t is the total number of observations, n is the number of assets and $|H_t|$ denotes the determinant of matrix H_t. We subsequently estimate bivariate MV-GARCH systems using Newton's interior-reflective method to maximize the log-likelihood function.[5] As shown in section 4, the Jarque-Bera test leads to a rejection of the null hypothesis of normality for all carry strategies. For that reason, we apply the Quasi Maximum Likelihood estimator which allows to compute valid standard errors under non-normality (see Bollerslev and Wooldridge, 1992).

5.1 GARCH results

Table 3 shows estimation results for three bivariate systems, each reporting on a different commodity currency-to-CHF carry by taking the perspective of an USD-investor.[6] The estimates c_{ij}, a_{ij}, b_{ij} and g_{ij} denote elements of the matrices C, A, B and G in equation 5. Since the latter enter in quadratic form, each estimate influences several elements of the variance-covariance matrix rendering interpretation of the estimation output difficult.

[5] See Matlab's Optimization Toolbox documentation and the references therein for a description of Newton's interior-reflective optimization procedure.

[6] The appendix contains estimation output from the perspective of an EUR- and GBP-investor. Results turn out to be very similar which is why we leave them uncommented.

	MSCI world - Carry AUD-CHF			MSCI world - Carry CAD-CHF			MSCI world - Carry NZD-CHF		
	params	stddev	t-stats	params	stddev	t-stats	params	stddev	t-stats
c(11)	0.0104	0.0028	3.65	0.008	0.003	2.73	0.004	0.002	1.83
c(21)	-0.0033	0.0039	-0.85	-0.010	0.003	-3.68	0.004	0.003	1.27
c(22)	0.0000	0.0006	0.00	0.001	0.023	0.02	0.004	0.002	2.05
a(11)	-0.0036	0.1325	-0.03	0.031	0.183	0.17	0.050	0.114	0.44
a(12)	0.1029	0.0908	1.13	0.028	0.169	0.17	-0.086	0.091	-0.94
a(21)	-0.2114	0.2022	-1.05	0.268	0.172	1.56	0.021	0.054	0.38
a(22)	0.1297	0.0819	1.58	0.006	0.023	0.25	0.249	0.065	3.84
b(11)	0.5449	0.2944	1.85	0.644	0.126	5.10	0.941	0.049	19.12
b(12)	-0.2012	0.0693	-2.90	0.105	0.051	2.07	-0.035	0.037	-0.93
b(21)	0.4686	0.2539	1.85	0.543	0.153	3.54	-0.032	0.059	-0.54
b(22)	0.9524	0.0643	14.80	0.641	0.181	3.53	0.878	0.081	10.89
g(11)	0.2523	0.1395	1.81	0.204	0.083	2.45	0.198	0.085	2.32
g(12)	0.3674	0.1267	2.90	0.241	0.094	2.57	0.294	0.086	3.41
g(21)	0.4211	0.3233	1.30	0.453	0.216	2.09	0.318	0.104	3.07
g(22)	0.0072	0.2316	0.03	-0.054	0.067	-0.80	0.006	0.035	0.18

Table 3: *Shows results from GARCH(1,1,1) estimations for three bivariate systems, each based on returns from a carry and returns on global equity markets. The estimation output on the left assumes a carry with a long position in AUD and a short position in CHF money markets. Estimations in the middle and on the right are analogous for CAD, respectively NZD investments. Calculations are based on weekly returns from April 1997 to December 2006 denominated in USD.*

To see that, take estimate a_{22} in the NZD-to-CHF example which has a value of 0.249 and a highly significant t-statistic of 3.84. The a-estimates correspond to the elements of the A-matrix which capture the impact of past shocks to asset prices. Since a_{22} influences the variance of the return on the carry investment as well as the covariance between returns on the carry and returns on global equities, we cannot directly determine one-to-one whether past shocks have a significant influence on variances, covariances or both. Nevertheless, table 3 allows to draw some conclusions. For instance, b_{11} and b_{22} are highly significant in virtually all estimations which is an indication for autocorrelation in variance-covariance dynamics. Furthermore, most g-estimates are positive in sign which provides evidence for an increase in the variance-covariance matrix in response to downturn movements in returns. Moreover, most asymmetry parameters have a t-statistic of at least 2 which shows that the inclusion of an asymmetric component is important. By contrast, we cannot reject the null-hypothesis for most a-estimates which indicates that the absolute magnitude of past shocks does not matter once asymmetric effects are taken into account.

A better notion of the dynamics of the variance-covariance matrix H_t can be gained by investigating news impact surfaces (NIS). We therefore plot correlation surfaces between returns on the global equity market and carry trades where we assume a long position in a commodity currency and a short position in CHF money markets. Introduced by Kroner and Ng (1998), NIS are three-dimensional graphs plotting conditional variances, covariances or correlations against past return shocks. We choose a range from -3 to $+3$ standard deviations for return shocks to global equity markets and carry trade positions which results in a grid of shock combinations. The elements of the variance-covariance matrix are then obtained by plugging generated shock combinations into equation 5. Thereby, the conditional variance-covariance matrix at time $t-1$, H_{t-1}, is kept constant at unconditional levels. Since we are interested in correlation dynamics, conditional covariances, $H_{12,t}$, were divided by the product of conditional standard deviations, $\sqrt{H_{11,t}H_{22,t}}$. Finally, conditional correlations could be plotted against generated shock combinations resulting in correlation surfaces as shown on the left-hand side of figure 2. The top panel on the left is the correlation surface of an AUD-to-CHF carry and the middle and lower panels show correlation surfaces of a CAD-to-CHF and NZD-to-CHF carry respectively. The panels on the right are explained below and show corresponding "average" correlation responses to equity market shocks.

It can be seen that the shape of the correlation surface is very much the same for all carry strategies. All graphs exhibit a considerable increase in correlation in response to a negative shock to global equity markets. In other words, an investor with a stake in a carry investment as well as in global equities suffers from diversification meltdown during stock market crises. These are precisely the times when diversification would be most desirable. By contrast, positive stock market shocks do hardly lead to a change in correlation. This underlines the importance of including asymmetric effects in GARCH specifications. Note as well, that correlation surfaces are for the greater part located in positive correlation regions. That does not come as a surprise, after all, it was shown in section 4 that unconditional correlation between carry trades and global equity markets is considerably positive.

Be aware that NIS do not reveal anything about the occurrence probability of certain stock and carry trade shock combinations. If one falsely assumed equal occurrence

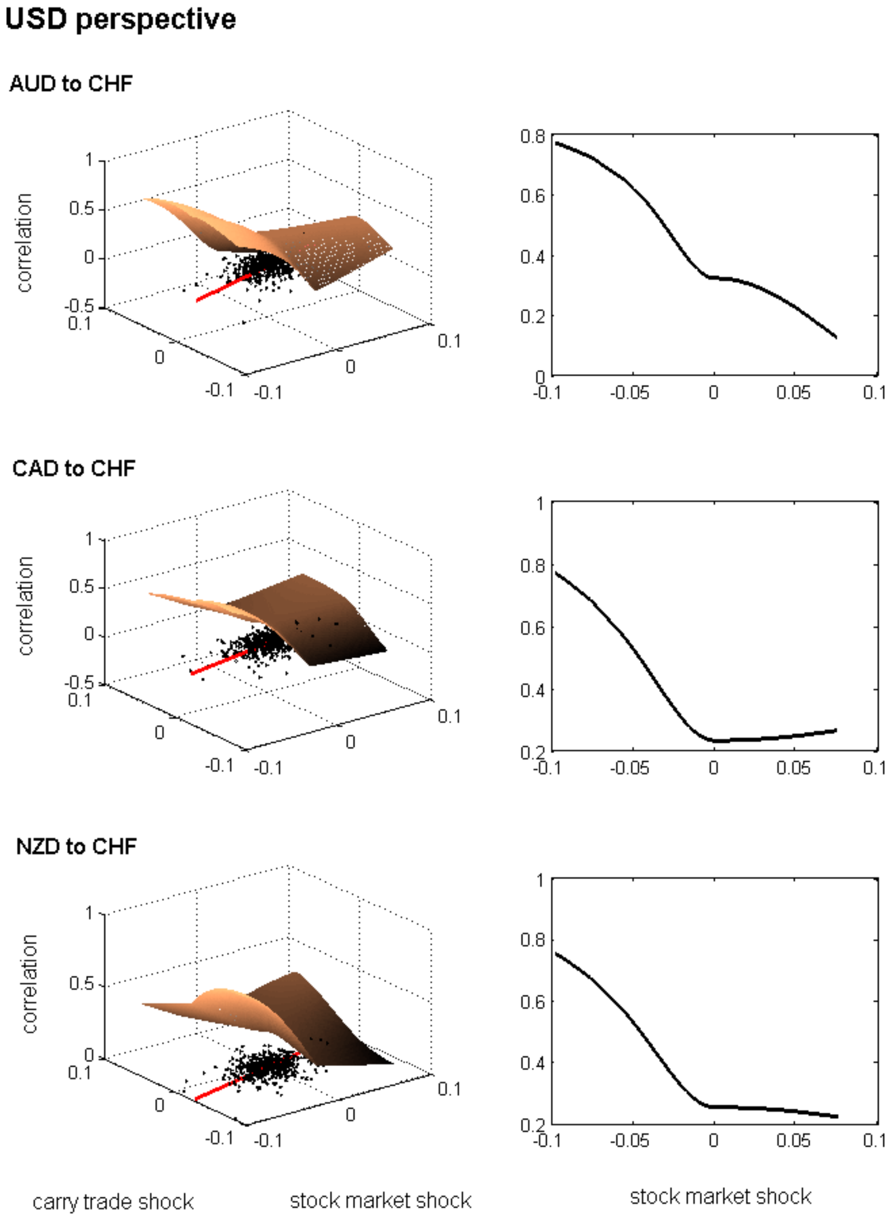

Figure 2: *Correlation surfaces and "average" correlations between returns from a carry strategy and returns on global equities from the perspective of an USD-investor. The figures on the top are based on a carry going long in AUD deposits by borrowing on the CHF money market. Estimation in the middle and bottom panels are analogous for CAD-to-CHF, respectively NZD-to-CHF carry trades. Estimation is based on weekly returns from April 1997 to December 2006.*

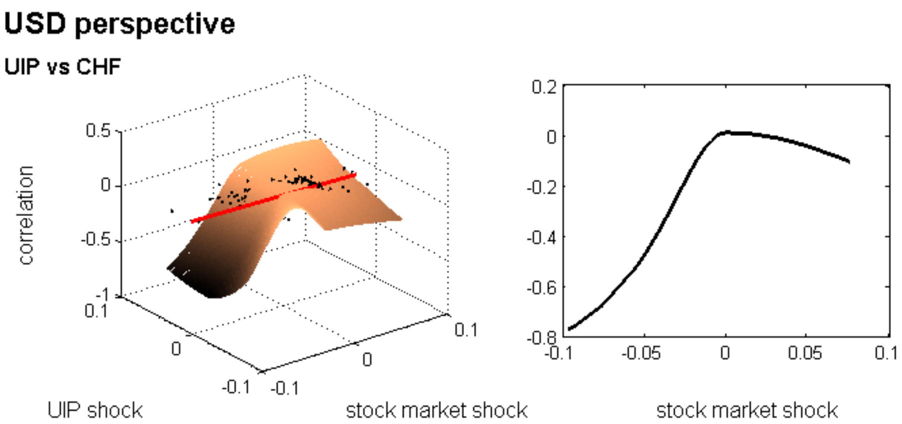

Figure 3: *The correlation surface and "average" correlations between returns on a CHF money market deposit and returns on global equity markets. Estimation is based on weekly returns from April 1997 to December 2006 denominated in USD.*

probability of every point on the grid, a strongly distorted view of correlation dynamics is obtained. To enhance explanatory power, we therefore extend NIS by a scatter plot revealing how shock combinations occurred historically. Since we work with demeaned data, the bulk of the scatter points are located around the center of the grid. That is unsurprising, after all, small shocks are more likely to occur than large shocks. There emerges an additional pattern, viz negative shocks in global equities occur predominantly in times of negative shocks on carry trade investments and vice versa for positive shocks. The scatter clouds are therefore upward pointing, which is not surprising given the positivity of unconditional correlation estimates. Whether there is an upward- or downward slope can be more clearly seen by putting a regression line through the scatter cloud. The regression line can be interpreted as showing a kind of "average" carry trade shock given a global equity market shock of certain magnitude. To see the "average" correlation response more clearly, we cut the correlation surface along the regression line. The result is depicted in the panels just beneath NIS'. It can be clearly seen that the "average" correlation response is upward sloping for negative shocks to stock markets. That holds for all carry strategies. Note that the difference between the correlation at the center and the correlation in response to large stock market downturns is relatively large in magnitude. In the CAD-to-CHF example, "average" correlation is slightly more than 0.2 at the center and increases to almost 0.8 on the very left of the graph, i.e. when the stock market experiences a drop of three standard deviations. In contrast, correlation does hardly change in response to positive stock market shocks. That is at least true for the CAD-to-CHF and the NZD-to-CHF example. For the AUD-to-CHF carry investment, a decrease in correlation is observed in response to a positive shock.

Decomposing carry trades into two separate currency risk premia allows to study NIS for commodity currency and CHF money market deposits separately. Whereas figure 3 shows correlation surfaces between returns on CHF deposits and returns on global equity markets, figure 4 investigates corresponding correlation surfaces for

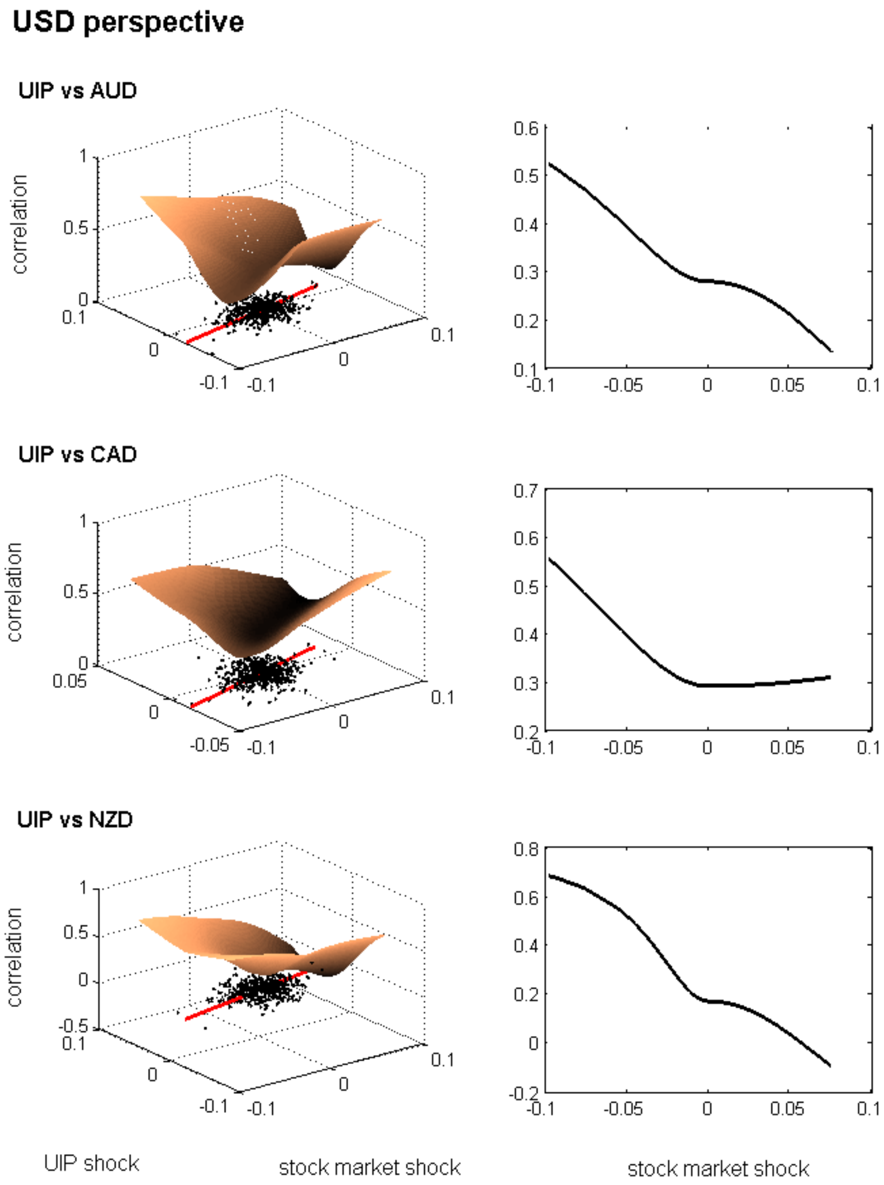

Figure 4: *The correlation surfaces and "average" correlations between returns on a commodity currency deposit and returns on global equity markets. The top panels show correlation dynamics for AUD deposits whereas the middle and the bottom panels depict corresponding graphs for CAD and NZD deposits, respectively. Estimation is based on weekly returns from April 1997 to December 2006 denominated in USD.*

commodity currencies. In order that differences in variance-covariance dynamics clearly crystalize, we assume long positions in both CHF and commodity currency deposits. Notice the shape of the NIS for the conditional correlation between CHF deposits and global equity markets. Conditional correlation is not only negative on average but decreases significantly in response to a negative stock market shock. Apparently, the CHF does come up to its reputation as a safe haven currency exhibiting a particularly beneficial correlation structure in times of market downturns. Furthermore, the differing shapes of the NIS in response to positive and negative shocks provides evidence for considerable asymmetries. Conditional correlation decreases by far more in response to negative stock market shocks in comparison to positive shocks of similar magnitude. Note that movements in correlation are fairly small if we keep stock market shocks constant and move along the money market axis. Correlations are hence primarily driven by stock markets. Interestingly, the NIS for conditional correlations between returns on global equity markets and returns on commodity currency deposits is quite the opposite. As the bottom-left panel in figure 4 shows, deposits in NZD exhibit increasing correlation in response to negative stock market shocks. Conditional correlation is not only positive on average but seems to change unfavorably in times of large downward movements in equity markets. Though a bit less pronounced, the same can be said for correlation surfaces between equities and currency risk premia on AUD, respectively on CAD investments. To see that more clearly, we again cut the correlation surface along the scatter plot regression line. The resulting graphs shown on the right-hand side can be interpreted as showing a kind of "average" correlation response to shocks in global equity markets. For all commodity currencies, an increase in "average" correlation is registered in the aftermath of equity market downturns. The correlation dynamics between commodity currency investments and world equity markets are thus precisely opposite to the correlation between CHF deposits and equities. That provides further evidence for the hypothesis that deviation from UIP is driven by systematic risk as postulated by standard asset pricing theories such as the CAPM.

6 Exceedance correlation analysis

The preceding MV-GARCH investigation gave a good notion for correlation- and covariance dynamics by plotting illustrative NIS. The NIS in figure 3 show, for instance, that the correlation between CHF deposits and equity markets becomes more negative in periods of market downturns as opposed to market upturns. However, NIS do not reveal whether such asymmetries are of significance in a statistical sense. The literature on exceedance correlation offers a variety of complementary tools for correlation analyses, among others a simple procedure allowing to test for statistical significance of asymmetric effects. In contrast to MV-GARCH specifications, in which variance-covariance dynamics are modeled as a function of past asset price shocks and which can be applied for variance-covariance forecasting, exceedance correlation measures the correlation in the tails of a bivariate distribution.

Ang and Chen (2002) define exceedance correlation as the correlation between two standardized variables, $\hat{x}$ and $\hat{y}$, whereby both of these deviate from their mean by a certain threshold level. Calculation is straightforward. First, observations are sorted into subsets depending on how much they deviate from their mean. For that purpose, threshold levels, usually expressed in terms of standard deviations, are defined. Second, exceedance correlations are obtained by calculating correlations within these subsets. Technically speaking, we can say:

$$\begin{aligned}\hat{\rho}^{+}(\vartheta) &= corr(\hat{x}, \hat{y} \mid \hat{x} > \vartheta, \hat{y} > \vartheta) \\ \hat{\rho}^{-}(\vartheta) &= corr(\hat{x}, \hat{y} \mid \hat{x} < -\vartheta, \hat{y} < -\vartheta)\end{aligned} \tag{8}$$

where $\hat{\rho}^{+}$ ($\hat{\rho}^{-}$) denotes the correlation when both variables register an upward (downward) increase of at least ϑ standard deviations. Note that observations are standardized which simplifies notation in that time-series means and variances can be dropped from the right-hand side of equation 8. As emphasized by Longin and Solnik (2001) and Forbes and Rigobon (2002), conditioning correlation on whether returns increase by at least ϑ standard deviations introduces a conditioning bias. Longin and Solnik show that a bivariate normal distribution with constant correlation implies a tent-shaped exceedance correlation pattern. This means that exceedance correlations calculated along the lines outlined above decrease with larger ϑ, even though the data stems from a bivariate normal distribution where correlation is constant by definition. A simple comparison of exceedance correlations at different threshold levels, ϑ, might thus lead to the wrong conclusion that correlations decrease as markets become more volatile. Longin and Solnik (2001) propose to compare empirical exceedance correlations with correlations implied by a bivariate normal distribution. Ang and Chen (2002) extend Longin and Solnik's approach by developing a test statistic which quantifies the degree of deviation between exceedance correlations implied by the data and exceedance correlations implied by a bivariate normal or any other bivariate distribution. If the discrepancy is too large, the data is inappropriately described by the chosen distribution. By applying Ang and Chen's test to two subsets separately, once conditioning on upside moves $(\hat{x}, \hat{y} \mid \hat{x} > 0, \hat{y} > 0)$ and once on downside moves $(\hat{x}, \hat{y} \mid \hat{x} < 0, \hat{y} < 0)$, one can assess whether there exist asymmetric correlation effects. For equity markets, it is found that exceedance correlations on the downside deviate considerably more from a bivariate normal than exceedance correlations on the upside. Ang and Chen's (2002) test procedure requires information on theoretical exceedance correlations of bivariate distributions which can only be obtained by diving into extreme value theory. Besides the fact that closed-form calculations of exceedance correlations are rather cumbersome, there remains the difficulty of choosing an appropriate distributional form. We subsequently follow Hong et al. (2003) who suggest an elegant alternative for testing asymmetric correlations allowing to circumvent both difficulties.

Hong et al's (2003) test is based on the idea, that under symmetry exceedance correlations on the upside should not be significantly different form exceedance correlations on the downside. In terms of equation 8, the H_0-hypothesis demands that

$$H_0: \qquad \hat{\rho}^{+}(\vartheta) = \hat{\rho}^{-}(-\vartheta) \qquad \text{for all} \qquad \vartheta > 0 \tag{9}$$

In other words, tail correlations of a symmetric distribution are a function of the absolute distance measure $\mid \vartheta \mid$ and do not depend on sign. Under the null hypothesis of symmetry, all elements of the following vector must thus lie in the vicinity of zero:

$$\hat{\rho}^{+} - \hat{\rho}^{-} = [\hat{\rho}^{+}(\vartheta_1) - \hat{\rho}^{-}(-\vartheta_1), \cdots, \hat{\rho}^{+}(\vartheta_m) - \hat{\rho}^{-}(-\vartheta_m)]' \tag{10}$$

where m denotes the number of exceedance levels. Introducing certain regularity conditions, Hong et al. (2003) show that the vector $\hat{\rho}^{+} - \hat{\rho}^{-}$ is asymptotically normal distributed with a mean of zero and a positive definite variance-covariance matrix Ω. This allows to postulate a simple test statistic for the null hypothesis of symmetry, viz.:

$$J_\rho = t(\hat{\rho}^{+} - \hat{\rho}^{-})'\hat{\Omega}^{-1}(\hat{\rho}^{+} - \hat{\rho}^{-}) \tag{11}$$

where t denotes the number of observations. As t approaches infinity, J_ρ converges towards a χ-square distribution with m degrees of freedom.

6.1 Results

In this section, we calculate exceedance correlations between profits from carry-trade investments and returns on the world equity portfolio. We thereby take the viewpoint of an USD carry investor who borrows on the CHF Euromarket to invest the proceeds in a commodity currency deposit. On average, such a strategy yields a positive return and investors can expect to profit twice from a forward rate bias in their favor. First, due to the low level of interest rates, debt in CHF is cheaper than debt in USD. Second, by investing in commodity currencies which yield relatively high interest rates, the investor can, on average, expect an outperformance in comparison to a comparable USD deposit. However, as shown in the preceding GARCH analysis, carry trades lead to a double exposure to correlation risk. The correlation between returns on commodity currency deposits and returns on global equity markets, becomes particularly unfavorable in times of stock market downturns. By contrast, the opposite pattern is observed for CHF deposits which register a decrease in correlation with global equities as the latter suffers a negative shock. Since our carry-trade investor has a short exposure to the CHF money market, he is unfavorably affected by correlation dynamics on the commodity currency deposit as well as on the CHF debt side.

Our calculation is based on four exceedance levels with $\vartheta = [0, 0.33, 0.66, 1]$. In contrast to Hong et al. (2003) who include four cut-offs by setting ϑ equal to $[0, 0.5, 1, 1.5]$, we choose a step-size of only 0.33 standard deviations. The optimal number of exceedance levels and the optimal width for step-sizes depend crucially on the sample size. The reason is that the number of observations decreases as we move towards the outer tails of a distribution. Choosing too many exceedance levels or a step-size which is too wide, might hence lead to inaccurate correlation estimates due to lack of observations in outer buckets. On the other hand, we might lose valuable information on asymmetry for extreme values if the number of exceedance levels is insufficient or if the step-width is too narrow. While Hong et al's data set includes 1825 weekly observations, our sample size contains merely 508 values which justifies our smaller step-width.

Table 4 reveals asymmetric effects in correlations between returns on the world equity portfolio and profits from a carry trade strategy where investors buy commodity currency deposits by incurring debts on the CHF money market. The second column provides χ-square test statistics, whereas the third column shows corresponding p-values. P-values reveal that only one symmetry hypothesis is rejected at the 10% sig-

	J_p	p-value	$\hat{\rho}_1^+ - \hat{\rho}_1^-$	$\hat{\rho}_2^+ - \hat{\rho}_2^-$	$\hat{\rho}_3^+ - \hat{\rho}_3^-$	$\hat{\rho}_4^+ - \hat{\rho}_4^-$
AUD-CHF	1.2	0.87	-0.08	-0.14	-0.12	-0.12
CAD-CHF	9.5	0.05	-0.25	-0.10	0.01	-0.53
NZD-CHF	1.6	0.81	-0.20	-0.15	-0.20	-0.09

Table 4: *Exceedance correlations between returns on carry strategies and returns on global equity. The first row is based on a carry with a long position in AUD and a short position in CHF. The second and third rows are analogously calculated for a carry with a long position in CAD and NZD deposits respectively. The sample includes weekly returns from April 1997 to December 2006 denominated in USD.*

nificance level, viz. for correlations between returns on global equities and returns on a CAD-to-CHF carry. For that case, correlations are significantly larger in stock market downturns as opposed to stock market upturns. Although we cannot reject the null of symmetry for other strategies, it is interesting that almost all entries of the $\hat{\rho}^+ - \hat{\rho}^-$-vector bear a negative sign. An exception is the CAD-to-CHF example for movements exceeding 0.66 standard deviations where $\hat{\rho}^+ - \hat{\rho}^-$ is slightly positive. Apart from that, we observe that downside correlations are larger than corresponding upside correlations for all strategies and at all exceedance levels. In other words, correlations between carry investments and equity market returns are larger during joint downturns as opposed to joint upturns. Note moreover, that differences in exceedance correlations are substantial in magnitude. For the $\hat{\rho}_4^+ - \hat{\rho}_4^-$-entry in the CAD-to-CHF example, the correlation difference amounts to -0.5328 which is large given that correlation is bounded to values between -1 and +1. Similar conclusions can be drawn from tables 9 and 10 in the appendix which provide results from the viewpoint of an EUR- and GBP-investor respectively. Note that from the perspective of an EUR-investor, Hong's test statistic indicates significant asymmetries for CAD-to-CHF as well as for NZD-to-CHF carry trade investments. Another interesting observation emerges from tables 4, 9 and 10. The $\hat{\rho}^+ - \hat{\rho}^-$-vector shows particularly large differences for the fourth exceedance level, i.e. when movements exceed one standard deviation. It seems that asymmetries widen as we move towards more extreme values. Intuitively, that could be explained by safe haven characteristics of the CHF which unfolds its full strength only in case of severe market downturns.

7 Conclusion

We show that carry trade positions are exposed to considerable correlation risk with global stock markets. That is true for unconditional correlation and emerges even more clearly if time-varying correlations are analyzed. A MV-GARCH analysis reveals that correlation between returns on the carry and returns on global equities are not only positive on average, but change unfavorably in response to negative stock market shocks. A considerable increase in correlation in periods of crises is observed for all carry strategies, irrespective whether we take the viewpoint of an USD-, EUR- or GBP-investor. Asymmetry in correlations is confirmed by an exceedance correlation analysis which measures the correlation in the tails of a bivariate distribution. It is found that correlations are larger during joint downward moves as opposed to joint upward moves with asymmetries being statistically significant at the 10% significance level for the CAD-to-CHF carries from the perspective of an USD-investor as well as for the CAD-to-CHF and the NZD-to-CHF carries from the perspective of an EUR-investor. Movements in correlation seem to be large in magnitude so that neglect of time-variation in second moments might lead to severe portfolio misallocations in terms of an ill-founded overweight in carry trade positions. Investors not aware of conditional correlation dynamics might face an unexpected diversification meltdown in times of crises when diversification is most desirable.

We argue that carry trades boil down to a double speculation on UIP. A decomposition of carry trades into UIP components reveals that high-yielding commodity currencies are exposed to considerable contagion. This means that correlation between global equities and currency risk premia on commodity currencies are not only positive on average but increase in response to negative shocks on global stock markets. By contrast, a converse pattern is observed for long positions in CHF deposits which yield much lower interest rates. In fact, unconditional correlation between currency risk premia on CHF and global equities is negative and decreases in the aftermath of stock market crises. The CHF seems to offer protection against diversification meltdown in turbulent times thereby living up to its expectation as a safe haven currency.

Our analyses suggest that expected excess returns from UIP speculation are accompanied by systematic risks in terms of unfavorable exposure to global equity markets. On the basis of these findings, we conjecture that a conditional CAPM which relates excess returns to time-varying correlation risk with equity markets might get a long way towards explaining the forward rate bias - at least for the polar currency pairs investigated in this paper. That investigation is however left for future research.

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A Appendix

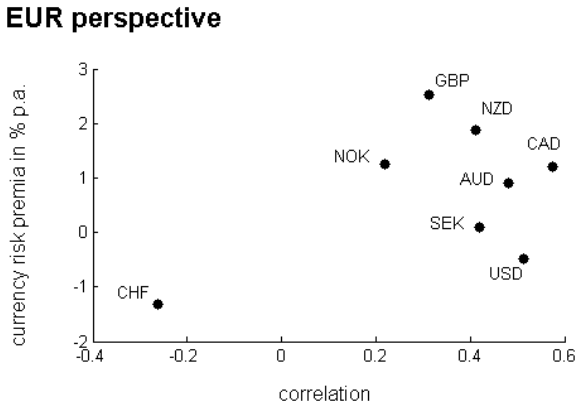

Figure 5: *Shows deviation from UIP in % p.a. on the vertical axis and unconditional correlation between currency risk premia and returns on global equity markets on the horizontal axis. Calculations are based on weekly returns from April 1997 to December 2006 denominated in EUR.*

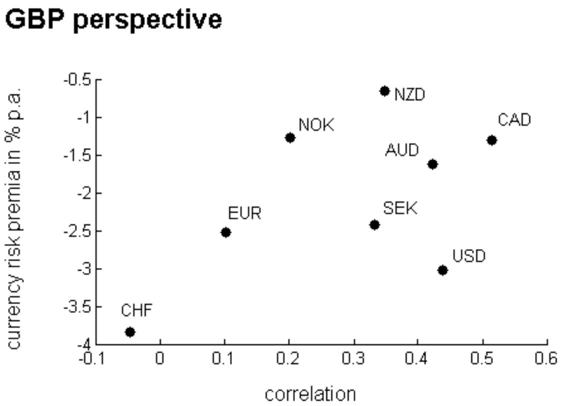

Figure 6: *Shows deviation from UIP in % p.a. on the vertical axis and unconditional correlation between currency risk premia and returns on global equity markets on the horizontal axis. Calculations are based on weekly returns from April 1997 to December 2006 denominated in GBP.*

	AUD - CHF	CAD - CHF	NZD - CHF
Mean	0.039%	0.045%	0.058%
Stddev of Mean	0.074%	0.066%	0.076%
T-statistic	0.525	0.690	0.757
Stddev	0.017	0.015	0.017
Skewness	-0.531	-0.501	-0.410
Kurtosis	5.402	3.992	3.962
Maximum	0.055	0.039	0.052
Minimum	-0.093	-0.065	-0.081
Jarque-Bera	143.727	41.332	33.073
Cor with wld mkt	0.517	0.617	0.459

Table 5: *Descriptive statistics for returns on carry trades. The AUD-to-CHF column is based on returns from a carry going long in AUD and short in CHF money markets. The CAD-to-CHF and the NZD-to-CHF show analogous statistics for CAD, respectively NZD investments. Calculations are based on weekly returns from April 1997 to December 2006 denominated in EUR. Note that prior to the introduction of the EUR on January 1st 1999, DEM data was used.*

	AUD - CHF	CAD - CHF	NZD - CHF
Mean	0.000%	0.040%	0.052%
Stddev of Mean	0.077%	0.066%	0.076%
T-statistic	0.004	0.603	0.684
Stddev	0.017	0.015	0.017
Skewness	-0.558	-0.526	-0.436
Kurtosis	5.419	4.022	3.985
Maximum	0.054	0.038	0.051
Minimum	-0.093	-0.065	-0.081
Jarque-Bera	147.889	44.764	35.879
Cor with wld mkt	0.404	0.481	0.339

Table 6: *Descriptive statistics for returns on carry trades. The AUD-to-CHF column is based on returns from a carry going long in AUD and short in CHF money markets. The CAD-to-CHF and the NZD-to-CHF show analogous statistics for CAD, respectively NZD investments. Calculations are based on weekly returns from April 1997 to December 2006 denominated in GBP.*

	MSCI world - Carry AUD-CHF			MSCI world - Carry CAD-CHF			MSCI world - Carry NZD-CHF		
	params	stddev	t-stats	params	stddev	t-stats	params	stddev	t-stats
c(11)	0.0045	0.0099	0.45	0.0024	0.0025	0.98	0.0022	0.0020	1.08
c(21)	0.0088	0.0401	0.22	0.0108	0.0015	7.38	0.0122	0.0027	4.49
c(22)	0.0000	0.0172	0.00	0.0001	0.0013	0.08	-0.0001	0.0355	0.00
a(11)	0.2439	2.2715	0.11	-0.0033	0.0189	-0.18	0.1240	0.0851	1.46
a(12)	0.2551	1.9213	0.13	-0.0053	0.0228	-0.23	0.1875	0.1104	1.70
a(21)	-0.1764	3.3941	-0.05	0.1721	0.0749	2.30	0.1122	0.2549	0.44
a(22)	0.0194	4.2583	0.00	-0.0233	0.0493	-0.47	-0.0401	0.4102	-0.10
b(11)	0.9845	0.5714	1.72	1.0183	0.0338	30.16	0.9996	0.0263	38.01
b(12)	0.0192	0.8537	0.02	0.1740	0.1203	1.45	0.0928	0.0512	1.81
b(21)	-0.1870	0.8859	-0.21	-0.1317	0.1188	-1.11	-0.1401	0.1231	-1.14
b(22)	0.7034	2.1410	0.33	0.4548	0.2717	1.67	0.5321	0.2180	2.44
g(11)	0.2341	1.0461	0.22	0.2497	0.0581	4.30	0.1981	0.1484	1.33
g(12)	0.0519	1.7864	0.03	0.1747	0.0510	3.43	-0.0413	0.1803	-0.23
g(21)	0.2184	1.6097	0.14	0.0072	0.0272	0.26	0.1452	0.2760	0.53
g(22)	0.2859	2.3649	0.12	-0.1700	0.0907	-1.87	0.3757	0.2294	1.64

Table 7: *Shows results from GARCH(1,1,1) estimations for three bivariate systems, each based on returns from a carry and returns on global equity markets. The estimation output on the left assumes a carry with a long position in AUD and a short position in CHF money markets. Estimations in the middle and on the right are analogous for CAD, respectively NZD investments. Calculations are based on weekly returns from April 1997 to December 2006 denominated in EUR. Note that prior to the introduction of the EUR on January 1st 1999 DEM data was applied.*

	MSCI world - Carry AUD-CHF			MSCI world - Carry CAD-CHF			MSCI world - Carry NZD-CHF		
	params	stddev	t-stats	params	stddev	t-stats	params	stddev	t-stats
c(11)	-0.0001	0.0061	-0.02	0.0043	0.0012	3.58	0.0021	0.0023	0.94
c(21)	-0.0005	0.0283	-0.02	0.0035	0.0011	3.18	0.0124	0.0024	5.19
c(22)	0.0127	0.0030	4.23	0.0000	0.0000	0.00	0.0001	0.0060	0.01
a(11)	0.1372	0.0871	1.58	0.1751	0.0960	1.82	0.1234	0.0712	1.73
a(12)	0.1052	0.1358	0.77	0.0721	0.0516	1.40	0.1862	0.1165	1.60
a(21)	-0.2225	0.0955	-2.33	-0.2386	0.0822	-2.90	0.1180	0.1534	0.77
a(22)	0.1371	0.0762	1.80	-0.0056	0.0321	-0.17	-0.0300	0.4049	-0.07
b(11)	0.9811	0.0183	53.61	0.9387	0.0197	47.65	1.0000	0.0244	40.95
b(12)	0.1601	0.1022	1.57	-0.0280	0.0096	-2.92	0.0977	0.0527	1.85
b(21)	-0.1439	0.0845	-1.70	-0.0346	0.0284	-1.22	-0.1422	0.1294	-1.10
b(22)	0.3669	0.3641	1.01	0.9682	0.0234	41.38	0.5122	0.2176	2.35
g(11)	0.3849	0.0910	4.23	0.3888	0.0679	5.73	0.2015	0.1071	1.88
g(12)	0.2392	0.0857	2.79	0.1694	0.0405	4.18	-0.0346	0.1161	-0.30
g(21)	0.0133	0.0736	0.18	-0.0363	0.0420	-0.86	0.1343	0.1674	0.80
g(22)	0.1686	0.1569	1.07	-0.0064	0.0488	-0.13	0.3634	0.1671	2.18

Table 8: *Shows results from GARCH(1,1,1) estimations for three bivariate systems, each based on returns from a carry and returns on global equity markets. The estimation output on the left assumes a carry with a long position in AUD and a short position in CHF money markets. Estimations in the middle and on the right are analogous for CAD, respectively NZD investments. Calculations are based on weekly returns from April 1997 to December 2006 denominated in GBP.*

	J_p	p-value	$\hat{\rho}_1^+ - \hat{\rho}_1^-$	$\hat{\rho}_2^+ - \hat{\rho}_2^-$	$\hat{\rho}_3^+ - \hat{\rho}_3^-$	$\hat{\rho}_4^+ - \hat{\rho}_4^-$
AUD-CHF	4.8	0.31	0.02	0.04	-0.05	-0.28
CAD-CHF	8.8	0.07	-0.18	-0.05	-0.24	-0.52
NZD-CHF	8.1	0.09	-0.12	0.01	-0.20	-0.34

Table 9: *Exceedance correlations between returns on carry strategies and returns on global equity. The first row is based on a carry with a long position in AUD and a short position in CHF. The second and third rows are analogously calculated for a carry with a long position in CAD and NZD deposits respectively. The sample includes weekly returns from April 1997 to December 2006 denominated in EUR. Note that prior to the introduction of the EUR on January 1999, DEM data was applied.*

	J_p	p-value	$\hat{\rho}_1^+ - \hat{\rho}_1^-$	$\hat{\rho}_2^+ - \hat{\rho}_2^-$	$\hat{\rho}_3^+ - \hat{\rho}_3^-$	$\hat{\rho}_4^+ - \hat{\rho}_4^-$
AUD-CHF	4.6	0.34	-0.02	-0.09	-0.26	-0.32
CAD-CHF	3.6	0.46	-0.23	-0.14	-0.18	-0.20
NZD-CHF	6.1	0.19	-0.12	-0.11	-0.32	-0.29

Table 10: *Exceedance correlations between returns on carry strategies and returns on global equity. The first row is based on a carry with a long position in AUD and a short position in CHF. The second and third rows are analogously calculated for a carry with a long position in CAD and NZD deposits respectively. The sample includes weekly returns from April 1997 to December 2006 denominated in GBP.*

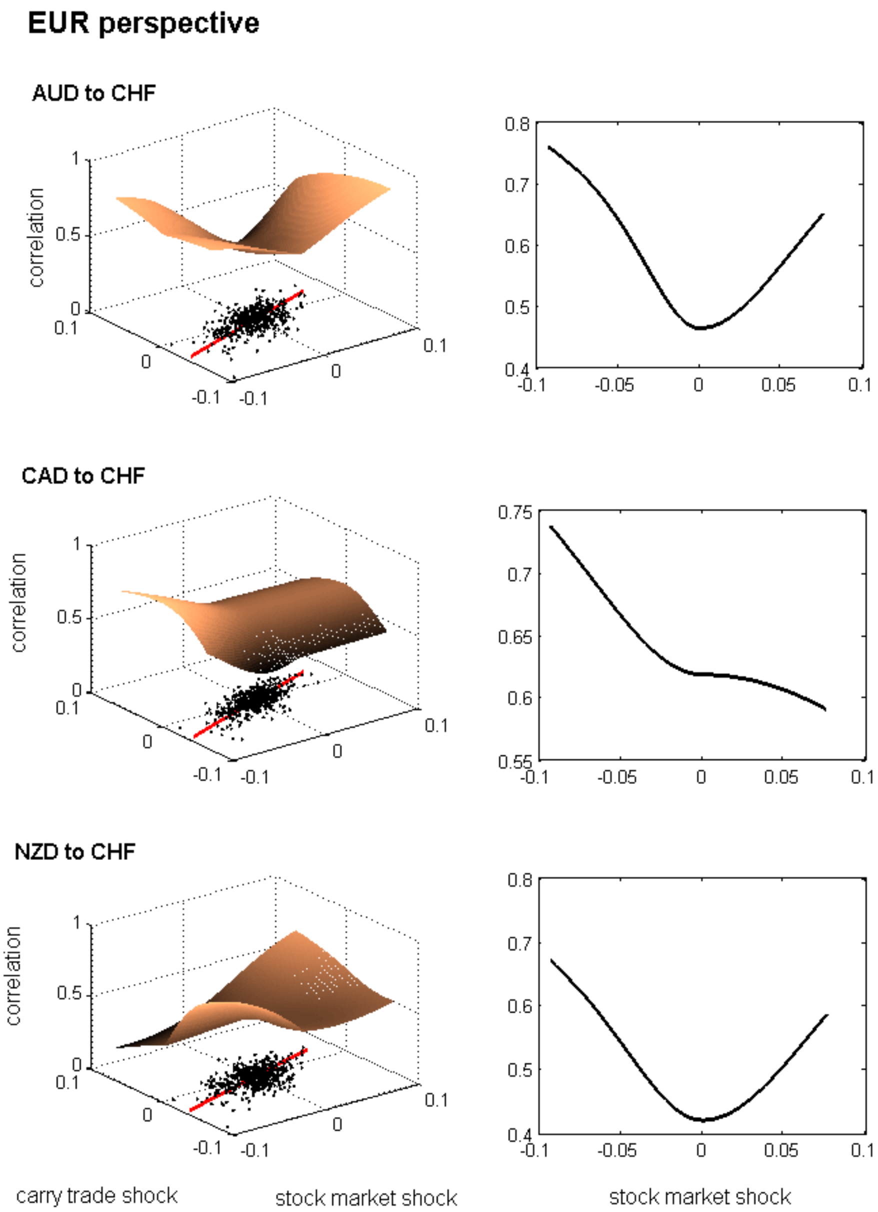

Figure 7: *Correlation surfaces and "average" correlations between returns from a carry strategy and returns on global equities from the perspective of an EUR-investor. The figures on the top are based on a carry going long in AUD deposits by borrowing on the CHF money market. Estimation in the middle and bottom panels are analogous for CAD-to-CHF, respectively NZD-to-CHF carry trades. Estimation is based on weekly returns from April 1997 to December 2006. Note that prior to the introduction of the EUR on January 1st 1999 DEM data was applied.*

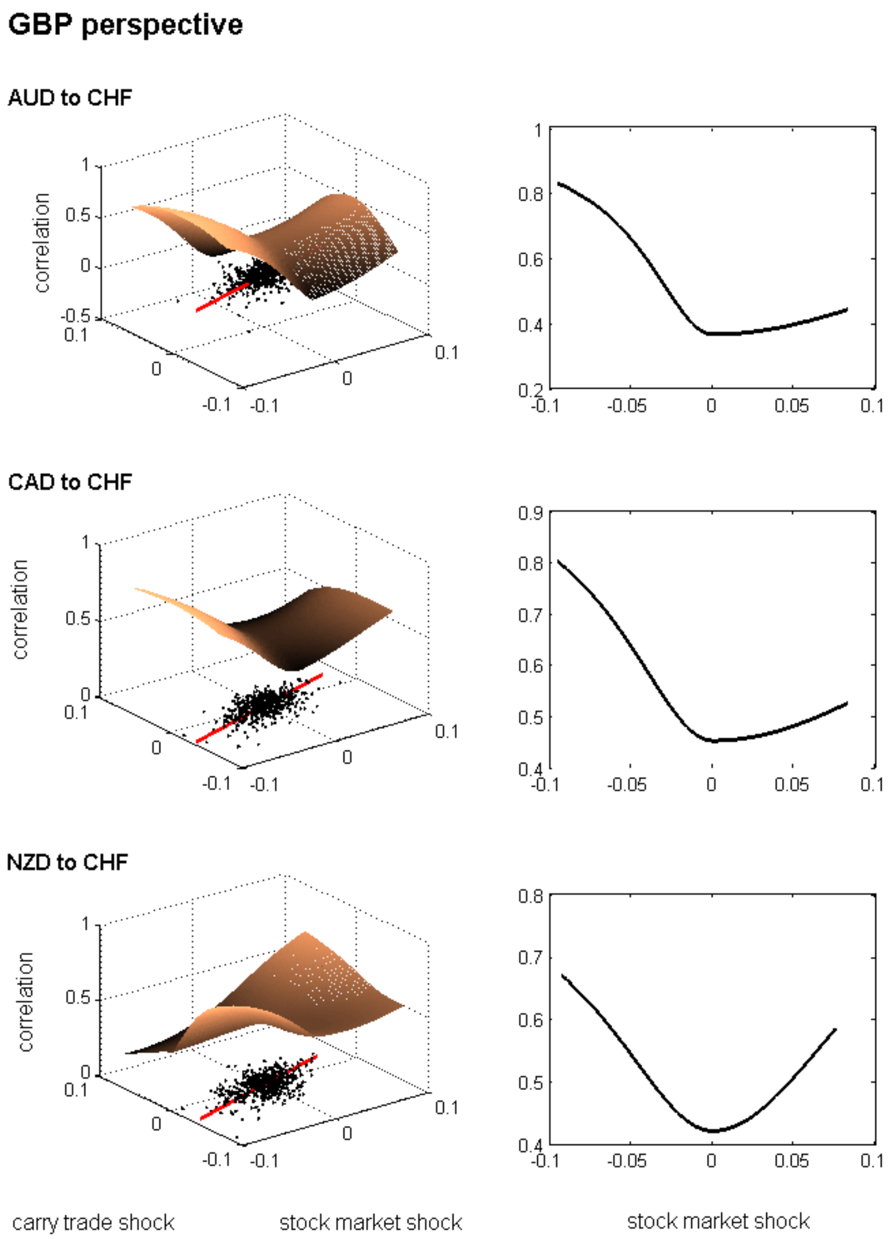

Figure 8: *Correlation surfaces and "average" correlations between returns from a carry strategy and returns on global equities from the perspective of an GBP-investor. The figures on the top are based on a carry going long in AUD deposits by borrowing on the CHF money market. Estimation in the middle and bottom panels are analogous for CAD-to-CHF, respectively NZD-to-CHF carry trades. Estimation is based on weekly returns from April 1997 to December 2006.*