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The Revenge of Fundamentals on Carry Trades during Crises

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Abstract

Over the past 20 years, FX carry trades have performed superbly while fundamental strategies have produced disappointing results. But the real picture is much more complex, for at least two reasons: carry trading exhibits strong extreme risks, and the track records of both strategies vary considerably over time. In this paper, we show that the carry trade and a fundamental strategy based on purchasing power parity (PPP) have alternated between periods of profitability and underperformance. When carry trade strategies perform well, fundamental strategies do poorly, and vice versa. Crises appear to play a significant role in this alternation. A portfolio that rotates between these two types of strategies, according to a VIX-based risk aversion indicator, would substantially outperform a pure carry trade strategy, with a sharp reduction in extreme risks, and would also be robust to crises.

Keywords: Exchange rate, carry trades, purchasing power parity, crisis-robust strategy
JEL codes: G11, G15

0. Introduction

There is broad agreement, both among practitioners and in the academic literature, that fundamental models for predicting exchange rates produce disappointing performance. Meese and Rogoff (1983) and Cheung *et al.* (2005) test the forecasting power of some of the most popular models, including Purchasing Power Parity (PPP), Uncovered Interest rate Parity (UIP), the sticky-price monetarist model and the monetarist model enhanced by a productivity differential, as well as purely statistical models in the behavioural equilibrium exchange rate category, which take various macroeconomic variables into account. The authors conclude that the models' predictive abilities are mixed and vary with the exchange rates and periods studied. In particular, the UIP postulates that the expected variation in the exchange rates of two countries should offset their interest rate differential. The failure of this parity is usually referred as the forward premium puzzle, and the best-known carry trade strategies counter it. Investors go long currencies with high interest rates and short those with low interest rates, betting that the former will appreciate against the latter. Several explanations have been proposed to explain the forward premium puzzle, including illiquidity spirals (Plantin and Shin, 2008), crash risk (Brunnermeier *et al.*, 2009), and peso problems (Burnside *et al.*, 2008; Fahri and Gabaix, 2008). Many authors (Christiansen *et al.*, 2010; Clarida *et al.*, 2009; Ichiue and Koyama, 2007, Plantin and Shin, 2008) demonstrate that nonlinearities have to be taken into account to explain the carry trade returns because the dependence on traditional risk factors differs strongly according to the volatility regime (high or low). Although the carry trade strategy clashes formally with the UIP only, Brunnermeier *et al.* (2009), Gagnon and Chaboud (2007), Plantin and Shin (2008) suggest that carry trades can increase divergence between the nominal exchange rate and its equilibrium value as defined by different kinds of fundamental valuation models.

From an investment point of view, Binny (2005), Gyntelberg and Remolona (2007), Pukthuanthong-Le and Thomas (2008) highlight the excellent returns to carry trade strategies in the last decade compared with other investment styles on the FX market. But Brunnermeier *et al.*

(2009) and Gyntelberg and Remolona (2007) show that carry trade strategies exhibit a pronounced asymmetry to the left of the return distribution and incur huge losses during periods of financial turmoil (Cairns *et al.*, 2007; Kohler, 2007). This was especially true during the recent subprime crisis. In fact, currencies with high (low) interest rates alternate long periods of slight appreciation (depreciation) with short periods of high depreciation (appreciation). This pronounced skew is often interpreted as a sudden reversion of the exchange rate to its fundamental value, from which it diverged because of the accumulation of carry trade positions[i] (Brunnermeier *et al*., 2009; Gagnon and Chaboud, 2007; Plantin and Shin, 2008). For that reason, a pure carry trade strategy portfolio may be particularly risky for investors.

Conversely, recent research has explored new methodologies to take into account the impact of financial crises on asset allocation so as to robustify portfolio performance. One initial approach is to construct an allocation that will withstand the shift to a crisis regime at lower cost and without the need to rebalance the portfolio (Chow *et al.*, 1999; Dash and Moran, 2005; Brière and Szafarz, 2008; Brière *et al*., 2010). Another approach consists in changing the optimal asset allocation when a crisis erupts in order to mitigate its harmful effects (Ang and Bekaert, 2002, 2004). However, to our knowledge, the construction of crisis-robust strategies on the FX market has still not been addressed in the literature.

In this paper, we compare the performance of a carry trade strategy with that of one of the most widely used fundamental strategies, PPP, over the period from 1993 to 2009 for eight main developed-country currencies. Carry trades perform much better on average than PPP when considering standard performance measures such as the Sharpe ratio or success rate, but they exhibit much higher extreme risks. A dynamic analysis shows that, in fact, PPP performs very well during crises, unlike carry trade strategies, and that the opposite applies during calm periods. The relatively low occurrence of crises explains why carry trades perform much better than fundamental strategies during the study period. A simple strategy is constructed, exploiting the rotation between

these two types of strategies: carry trade during calm periods and PPP during crises (identified as periods of implied equity volatility higher than their short term average). This new strategy clearly outperforms a pure carry trade strategy and even a portfolio that halts carry trades during crises periods. Moreover, it makes it possible to achieve robust-to-crises performances, sharply reducing extreme risks for the portfolio.

We consider this work to be original for three reasons. First, while most studies mention the theoretical clash between carry trades and the UIP, we know of no analysis of a possible clash with other fundamental strategies, especially the most frequently used by practitioners, PPP. Second, the predictive ability of PPP has never been tested with respect to market episodes, particularly crises. Last, we propose a simple investment strategy that can be implemented directly, with significantly better performance than that of a pure carry trade strategy. We believe this strategy can outperform during the bouts of high volatility that characterise financial crises.

Our paper is organised as follows. Section 1 presents our data and methodology. Section 2 presents our results. Section 3 concludes.

1. Data and methodology

Data

The strategies are based on eight major developed-country currencies: US dollar (USD), euro (EUR), Japanese yen (JPY), UK pound sterling (GBP), Swiss franc (CHF), Australian dollar (AUD), Canadian dollar (CAD) and New Zealand dollar (NZD). These eight currencies allow us to work with 28 currency pairs[ii]. The exchange rate series are sourced from Reuters at 4:00 p.m., London time. They are downloaded from Datastream and are collected monthly from March 1980 to December 2009. One-month interbank rates have been used to implement currency strategies, which involve lending and borrowing in the currencies of two countries[iii]. Monthly consumer price

indices have been used in the eight countries[iv] to estimate the PPP model. All data are supplied monthly by Datastream from January 1993 to December 2009.

Table 1 in Appendix 1 gives descriptive statistics for monthly returns of exchange rates against USD. We note a major discrepancy in average returns and volatilities. During the study period, CAD and GBP had the lowest returns and volatility against the dollar (returns close to zero, volatility of 6.59% and 10.50%, respectively), while JPY and CHF had the highest returns and volatilities (returns close to 3%, volatility in excess of 14%). Moreover, these are the only two currencies with very pronounced right-skewed returns against USD (skewness of 0.63 and 0.37, respectively). For all currencies, return kurtosis is much higher than 3, indicating that the distribution tails are much fatter than those of a normal distribution. An analysis of extreme returns produces a similar picture, making it possible to contrast JPY and CHF, with high maximum monthly gains and lower maximum losses, with AUD, GBP and NZD, which, by contrast, had low maximum gains and high maximum losses.

Descriptive statistics for 1-month interbank interest rates for the period 1993-2009 are displayed in Table 2 (Appendix 1). They highlight sharp differences between the average interest rates of the eight countries. The UK, Australia and New Zealand had the highest rates on average during the study period (5.13%, 5.63% and 6.69%, respectively). By contrast, Japan and Switzerland had very low rates (0.65% and 1.81% respectively). These interest rate levels have to be related to inflation rates. Table 3 in Appendix 1 gives descriptive statistics for monthly changes in consumer price indices. In accordance with intuition, it highlights a contrast between currencies with high interest rates and inflation (AUD, NZD, GBP) and those with low interest rates and inflation (JPY, CHF).

Estimation of the PPP model

PPP is one of the simplest and most widely used currency models[v]. One of its main advantages is that it can be estimated monthly and is therefore especially well-suited to implementing strategies.

PPP is derived from the law of one price and assumes an equality relationship between exchange rates and the ratio of price levels:

$$E_{ij} = \frac{P_i}{P_j} \quad (1)$$

where P_i is the price level in country *i*, P_j is the price level in country *j* and E_{ij} is the number of units of currency *i* in exchange for one unit of currency *j*.

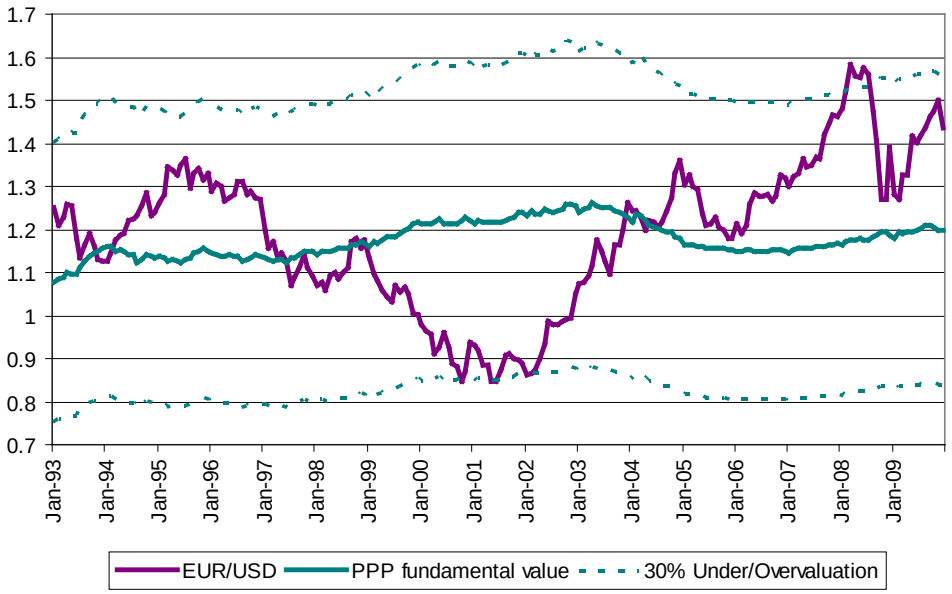
Empirically, equality is not verified, but the stationarity of real exchange rates over the long term is postulated. The long-term cointegration relationship between nominal exchange rates and the ratio of consumer price indices for the two countries is thus estimated by a OLS regression[vi]:

$$e_{ij} = \alpha + \beta\,(p_i - p_j) + \varepsilon_{ij} \quad (2)$$

where $p_i = \ln(P_i)$, $p_j = \ln(P_j)$, $e_{ij} = \ln(E_{ij})$ and ε_{ij} a white noise.

Table 4 in Appendix 2 summarises the estimation results from March 1980 to December 2009 for the 28 currency crosses. A strong cointegration relationship between the exchange rate and the price level differential is detected among all crosses. The β coefficient has the expected positive sign for 26 of the 28 crosses and significant at the 1% level for 25 of them. To test a realistic implementation of the fundamental strategy, an initial "in-sample" estimate is made of equation (2) on the sample from March 1980 to January 1993. Then we consider that in each month starting from 1993, the investor runs a new recursive regression to estimate, based on the last available data sample, a new relationship between currency crosses and inflation. Graph 1 below presents the fundamental PPP value estimated recursively compared to the realised EUR/USD evolution.

Graph 1: EUR/USD and PPP fundamental value, January 1993-December 2009



Exchange rate deviations from the equilibrium value rarely exceed 30% but periods of fundamental overvaluation or undervaluation can last several years. Reversion to the equilibrium value may occur rather suddenly. This was the case for example during the recent subprime crisis. The strongly overvalued euro (more than 30%) depreciated sharply against the US dollar in October and November 2008, returning to a level very close to its equilibrium value.

Strategy construction

We consider the case of a US investor rebalancing his/her portfolio monthly. He/she can implement a carry trade (CT) or a fundamental (PPP) strategy. For the CT strategy, at each month-end the investor borrows for one month at the interbank rate in the currency with the lowest interest rate and invests this amount in the currency with the highest one-month rate[vii]. For the PPP strategy, the investor observes at each month-end the difference between the realised exchange rate and its fundamental equilibrium level and bets on a reversion to fundamental value. For each of the 28 pairs, the investor then borrows for one month in the overvalued currency and invests this amount for one month in the undervalued currency.

In theory, currency strategies (on the spot market or via forwards) do not require any capital up-front and can therefore be infinitely leveraged. Accordingly, one key step in the investment process is to calibrate the risk of these strategies. One hundred per cent of the capital is assumed to be invested on the US money market, and the amount borrowed in the financing currency is then calibrated so that the annualised volatility of each portfolio over the period January 1993-December 2009 is equal to 5%, which corresponds to the calibration used in practice by many currency funds. This does not influence the performance measures (Sharpe ratio and success rate) but makes it easier to compare returns over the different strategies.

2. Results

Performance over the entire period

Table 5 presents descriptive statistics of returns to the CT and PPP strategies for the portfolios from January 1993 to December 2009 and tests of the significance of the difference between the Sharpe ratios of the two strategies (Jobson and Korkie (1981)).

Table 5: Descriptive statistics of returns on CT and PPP strategies,

January 1993 – December 2009

	CT	PPP	Difference
Ann. mean	6.73%	4.58%	-2.15%
Ann. Std. Deviation	5.00%	5.00%	0.00%
Sharpe Ratio	0.55***	0.12***	-0.43***
Skewness	-1.08	1.19	
Kurtosis	6.77	7.71	
Maximum	5.09%	8.06%	
Minimum	-6.75%	-4.59%	
Success Rate	73.53%	59.31%	
Maximum Drawdown	-16.38%	-7.61%	

*** indicates significance at 1%, level for the test of nullity of the Sharpe ratio (Lo (2002)) and for the test of significance of the difference of the Sharpe ratios of two strategies (Jobson and Korkie (1981)).

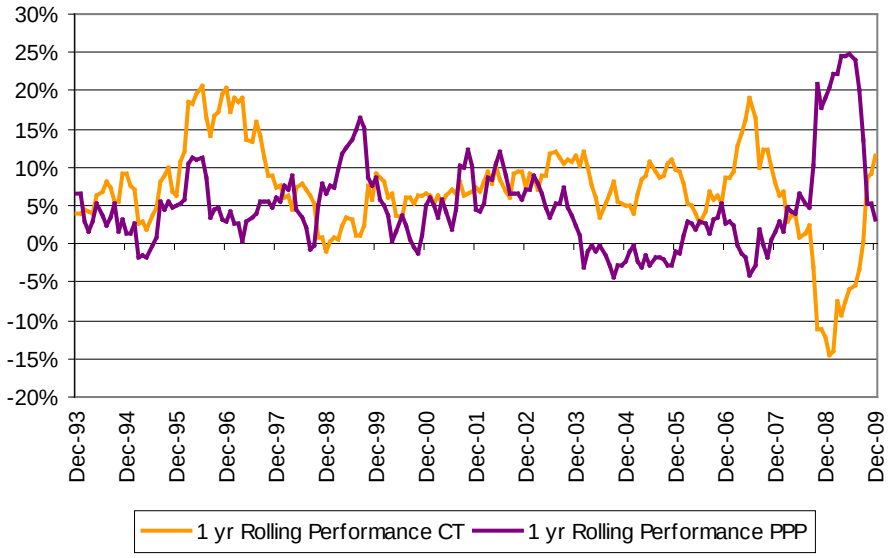
The CT and the PPP strategies consistently outperform a cash investment during the 1993-2009 period: the Sharpe ratio is 0.55 and 0.12, respectively, and is significantly positive according to the Lo (2002) test. Over the entire period, the CT strategy clearly performs better than the PPP

strategy and the difference in Sharpe ratios is significantly different from 0 according to the Jobson and Korkie (1981) test. Similarly, the success rates (percentage of months with positive returns) are clearly better for the CT strategy (73%) than for the PPP strategy (59%).

One important difference between the two strategies is their extreme risks. Kurtosis values for all strategies are well above 3, indicating that the distribution tails are much fatter than those of a normal distribution. For an identical level of volatility, the CT strategy has very left-skewed returns (skewness of -1.08), a result previously emphasised by Brunnermeier *et al.* (2009) and Gyntelberg and Remolona (2007). In contrast, the PPP strategy has a highly positive skew (1.19). This asymmetry of returns is also visible in the maximum levels of monthly gains and losses during the study period. The maximum loss is much larger for CT (-6.75% within a month) than for PPP (-4.59%), while the opposite is true for the maximum gains (respectively 5.09% versus 8.06%). The maximum drawdown, that is to say the maximal loss incurred by the investor from a historical peak, is also much higher for the CT than for the PPP (-16.4% versus -7.61%). Thus, the better performance of the CT strategy in terms of returns and Sharpe ratios is partially offset by higher extreme risks, particularly the higher negative skewness of returns.

Graph 2 shows one-year rolling performance for the two strategies. This dynamic analysis shows that performances are not stable over time.

Graph 2: One-year rolling performance for CT and PPP strategies, January 1993 – December 2009



For both portfolios, there is an alternation between periods of attractive performance for the CT and PPP strategy. The accumulation of carry trade positions during "calm" periods leads to an attractive performance of that strategy, making it even more appealing for investors. From this point of view, Plantin and Shin (2008) describe this strategy as self-reinforcing arbitrages. Indeed, the greater the number of investors taking part in a carry trade, the more the high- (low-) interest rate currency appreciates (depreciates), the more remote fundamental valuations become (because all of them are based on economic indicators and show a much stronger inertia, Brunnermeier *et al*., 2009; Gagnon and Chaboud, 2007) and this makes finally the carry strategies very attractive to investors, compared with fundamental ones. Actually, as long as investors enter the carry trades, the divergence to fundamental values increases and weakens the performances of the fundamental strategies (Plantin and Shin, 2008; Brunnermeier *et al*., 2009).

The rolling performances of the two strategies are negatively correlated at -32%. But this anticorrelation is even stronger during crises, and particularly visible during the recent subprime meltdown. As already noted by Cairns *et al.* (2007) and Brunnermeier *et al.* (2009), the

performance of CT strategies declines during financial crises. This is particularly true during the Russian crisis and bankruptcy of the LTCM hedge fund in 1998 and the subprime crisis in 2007 and 2008. It also recovers very rapidly at the end of the crisis. Although the nonlinear adjustment of the real exchange rate towards its equilibrium value has been clearly underlined (see Béreau *et al.*, 2010), its link with crises has not been assessed yet and, moreover, it has not been exploited in the construction of currency strategies. The following section aims to measure more precisely how crises impact on the performance of currency strategies.

Influence of crises

Many studies have demonstrated that implied equity volatility, as measured by a synthetic index, the VIX, is an accurate measure of risk aversion on markets (Collin-Dufresne et al., 2001; Pan and Singleton, 2007; Traub et al., 2000; Whaley, 2000). VIX was introduced by Whaley (1993) and is commonly referred as the "investor fear gauge" (Whaley, 2000): the higher the VIX, the greater the concern about global markets. Most financial crises since the 1990s have produced large increases in the VIX index (Brunnermeier *et al.*, 2009; Whaley, 2009). In order to identify crisis periods simply, we consider periods in which the VIX is above its 3-year average plus 0.75 standard deviation (Traub *et al.*, 2000). The advantage of this definition is that it relies solely on market data and can provide an indicator that may be directly used to implement strategies for any date. Graph 8 in Appendix 3 presents the crisis periods identified by this indicator. From January 1993 to December 2009 we identify 62 months of high risk aversion on financial markets (30% of the observations).

The performances of the CT and PPP strategies are calculated specifically during crisis and non-crisis periods. Table 6 presents the descriptive statistics of returns in the two regimes.

Table 6: Descriptive statistics of the returns of CT and PPP strategies in crisis and non-crisis periods, January 1993 – December 2009

	No crises			Crises		
	CT	PPP	Difference	CT	PPP	Difference
Ann. mean	7.26%	1.86%	-5.40%	5.52%	10.82%	5.30%
Ann. Std. Dev.	3.98%	4.21%	0.23%	6.81%	6.11%	-0.70%
Sharpe Ratio	0.85***	-0.48***	-1.33***	0.20***	1.09***	0.89***
Skewness	-0.41	0.26		-1.14	1.48	
Kurtosis	4.14	5.27		5.25	6.50	
Maximum	3.78%	4.92%		5.09%	8.06%	
Minimum	-3.80%	-4.59%		-6.75%	-1.75%	
Success Rate	73.94%	54.90%		72.58%	69.35%	

*** indicates the significance at 1% level for the test of nullity of the Sharpe Ratio (Lo (2002)) and for the test of significance of the difference of the Sharpe Ratios of two strategies (Jobson and Korkie (1981)).

Financial crises have a strong impact on the strategies' performance. They sharply depress the returns and Sharpe ratios of the CT strategy. In calm periods, the CT's Sharpe ratio is highly significantly positive (0.85), but it becomes very weak in crisis periods (0.20). For the PPP strategy, crises have the opposite effect, boosting its returns and Sharpe ratios. Performance is significantly negative in calm periods, but becomes highly significantly positive in crisis periods (the Sharpe ratio rises from -0.48 to 1.09). The picture is similar for the success rates of the strategies: slightly higher in calm periods than in crisis periods for CT (74% versus 73%) and much lower for PPP (55% versus 69%). In sum, although the CT strategy sharply outperforms the PPP strategy during calm periods (Sharpe ratio of 0.85 versus -0.48), the opposite is true in crisis times (Sharpe ratio of 0.20 versus 1.09).

For both strategies, the "pair" moments (volatility and kurtosis) increase sharply during crises. For the CT strategy, volatility rises from 3.98% to 6.81% and kurtosis from 4.24 to 5.25. For the PPP strategy, the rise is smaller for volatility (from 4.21% to 6.11%) but larger for kurtosis (from 5.27 to 6.50). But the situation is radically different in terms of asymmetry of the return distribution. For the CT strategy, the pronounced left asymmetry increases during crises (skewness decreases from -0.41 to 1.14 during crises) whereas for the PPP strategy, the positive asymmetry is reinforced, with a strong rise in skewness from 0.36 to 1.48. The usual rise in volatility during a crisis is linked to

strong positive returns in this case. Maximum gains from the PPP strategy are clearly higher in crisis periods than in calm periods, while for the CT strategy, maximum losses are much greater. Calm periods therefore appear to be associated with a very good performance for the CT strategy and a lacklustre showing for the PPP strategy, whereas the opposite is true during periods of high risk aversion. These results confirm that crises are a catalyst for carry trade unwinding (Gagnon and Chaboud, 2007; Plantin and Shin, 2008). Furthermore, our results show that exchange rates return to fundamental PPP value during these periods.

Crisis-robust strategies

We propose two different strategies, constructed by taking advantage of the excellent performance of CT in calm periods but without suffering poor performance during crises. The first strategy (CTC) implements the carry trade in calm periods and halts it without making any bets as soon as the risk aversion indicator signals the onset of a crisis period. The second strategy (CTPPP) also implements the standard CT strategy in calm periods but uses the PPP strategy in crisis periods. Table 7 presents descriptive statistics of returns of these two strategies compared to standard carry trading (CT) from January 1993 to December 2009.

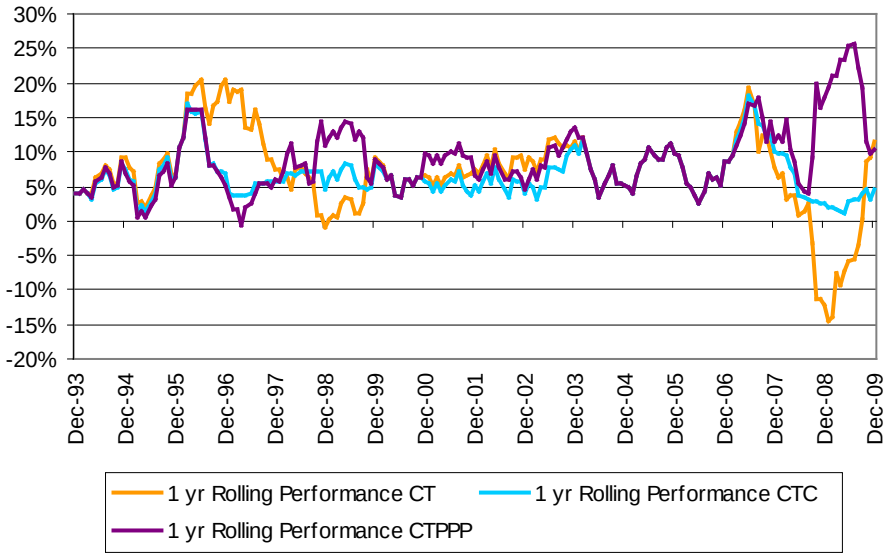
Table 7: Descriptive statistics of the returns of the CT, CTC and CTPPP strategies, January 1993 – December 2009

	CT	CTC	Difference	CTPPP	Difference
Ann. mean	6.73%	6.28%	-0.45%	8.34%	1.61%
Ann. Std. Dev.	5.00%	3.36%	-1.64%	4.74%	-0.26%
Sharpe Ratio	0.55***	0.69***	0.14***	0.92***	0.37***
Skewness	-1.08	-0.23		0.91	
Kurtosis	6.77	5.57		7.48	
Maximum	5.09%	3.78%		8.06%	
Minimum	-6.75%	-3.80%		-3.80%	
Success Rate	73.53%	81.86%		72.55%	
Maximum Drawdown	-16.38%	-5.19%		-5.42%	

*** indicates the significance at 1% level for the test of nullity of the Sharpe Ratio (Lo (2002)) and for the test of significance of the difference of the Sharpe Ratios of two strategies (Jobson and Korkie (1981)).

Halting the CT strategy during crises markedly improves portfolio performance. Not only is the annualised return considerably better, but volatility is also lower overall. The Sharpe ratio rises from 0.55 to 0.69 (adopting no strategy during crises), and as high as 0.92 when CT is replaced by PPP during crises. The extreme risks of the strategies are also reduced. The portfolio's skewness declines from -1.08 to -0.23 when the CT strategy is halted during crises, and it even becomes positive (0.91) when CT is replaced by PPP during crises. The maximum loss of the CTC and the CTPPP strategies (-3.8% within one month) are much lower than for the pure CT strategy (-6.75%), a result consistent with the fact that the high negative returns of carry trades mainly come from crisis periods. The same result holds for maximum drawdown (-5.19% and -5.42% vs -16.38% respectively). Things are different for maximal gain. It is much higher for the CTPPP strategy (8.06%) than for the CT strategy (5.09%), but it is smaller for the CTC strategy (3.78%). Simply halting carry trades during periods of high risk aversion reduces the strong positive returns, whereas replacing them by the PPP strategy increases them considerably. Graph 3 presents one-year rolling performance for the three strategies – CT, CTC and CTPPP.

Graph 3: One-year rolling performance for CT, CTC and CTPPP strategies, January 1993 – December 2009



If the CT strategies are halted during crisis periods, it is possible to avoid many of the periods of negative performance. However, replacing the CT strategy with the PPP strategy during crises improves the results even more: negative performances are replaced by highly positive performances.

3. Conclusion

The recent literature emphasises the failure of fundamental models in predicting short-term changes in exchange rates. However, our work goes some way towards rehabilitating them. We analysed the performance of the two types of strategies, carry trade and fundamental PPP, for 28 currency pairs from 1993 to 2008. Carry trades have been widely used in recent years by more and more investors (hedge funds, asset management firms, etc.), as reflected in the proliferation of carry trade funds and indices. Our results confirm that they have delivered outstanding performances, recently hailed in the academic literature (Cairns *et al.*, 2007; Gyntelberg and Remolona, 2007). This is true on average since 1993, even after including the latest and most dramatic episode of the subprime crisis. But those performances deserve to be questioned. Indeed, the performance of the CT strategy is significantly better than that of the PPP strategy, but it fluctuates widely over time. Crises appear to play a significant role in this alternation. Although carry trades perform well in calm periods, fundamental strategies prove their mettle during crises. These results confirm that carry trade strategies cause exchange rates to diverge markedly from their fundamental values during calm periods (Brunnermeier *et al.*, 2009; Gagnon and Chaboud, 2007; Plantin and Shin, 2008) and that financial crises are periods of a sudden "return to fundamentals". The stronger the carry trades' performance and the greater the divergence from fundamental value, the more violent the subsequent return to equilibrium. This leads to huge losses that ultimately wipe out much of the earlier gains. It is therefore possible to construct a strategy that will take advantage of this finding. Backtesting the performance of a portfolio that rotates between the two types of strategies (CT in

calm periods and PPP in crises) based on a risk aversion indicator such as implied equity volatility (the VIX index), we show that it would have achieved substantially better performance than a pure carry trade strategy. It would also have avoided most of the periods of negative carry-trade performance, particularly the recent subprime crisis, which was particularly painful for CT strategies.

One of the limitations of our study is related to the very simple approach taken to identify periods of market stress. A risk aversion metric, the VIX index, was used as a market indicator. Although the use of the VIX, which represents investors' expectations of future equity volatility, is warranted by the strong relationship between the performances of carry trades and equity markets (Kohler, 2007), an interesting extension of this paper would be to analyse more precisely the role of financial crises in performance variability. Other methods of crisis identification may be used, including a more refined analysis of crisis origins (currency movements, loss of confidence, stock market crash, etc.), and the results should be compared and contrasted. Furthermore, other fundamental currency models could be reviewed in the light of these new findings.

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Appendix

Appendix 1: Descriptive statistics

Table 1: Descriptive statistics – monthly returns of exchange rates versus US dollar, March 1980 – December 2009

	AUD	CAD	CHF	EUR	GBP	JPY	NZD
Ann. Mean	0.01%	0.65%	2.67%	0.32%	-0.43%	4.02%	-0.11%
Maximum	8.95%	8.42%	14.12%	9.55%	14.58%	16.81%	13.96%
Minimum	-16.36%	-12.55%	-10.46%	-10.23%	-12.29%	-10.11%	-22.00%
Ann. Std. Dev.	11.11%	6.59%	11.96%	10.56%	10.50%	11.89%	12.16%
Skewness	-0.72	-0.36	0.37	-0.04	-0.01	0.63	-0.75
Kurtosis	5.86	9.74	3.78	3.42	5.27	4.60	9.04

Table 2: Descriptive statistics – 1-month interbank rates, January 1993 – December 2009

	AUD	CAD	CHF	EUR	GBP	JPY	NZD	USD
Mean	5.63	3.91	1.81	3.55	5.13	0.65	6.69	3.95
Maximum	7.94	8.06	5.50	8.60	7.52	3.63	10.13	6.80
Minimum	3.09	0.28	0.08	0.38	0.50	0.04	2.73	0.23
Std. Dev.	1.10	1.55	1.36	1.48	1.50	0.84	1.73	1.90
Skewness	0.12	-0.10	0.72	0.76	-1.28	1.92	-0.19	-0.47
Kurtosis	2.69	3.14	2.76	4.53	5.16	5.82	2.53	1.86

Table 3: Descriptive statistics – monthly changes in consumer price index, March 1980 – December 2009

	AUD	CAD	CHF	EUR	GBP	JPY	NZD	USD
Ann. Mean	4.44%	3.37%	2.12%	3.29%	4.14%	0.98%	5.10%	3.36%
Maximum	4.22%	2.63%	1.56%	1.24%	3.41%	2.08%	8.92%	1.25%
Minimum	-0.46%	-1.04%	-1.05%	-0.83%	-1.44%	-1.08%	-0.81%	-1.92%
Ann. Std. Dev.	2.59%	1.38%	1.29%	0.99%	1.74%	1.57%	3.53%	1.18%
Skewness	2.24	0.75	0.31	0.07	1.44	1.00	3.65	-0.82
Kurtosis	7.87	6.78	3.92	4.24	11.19	5.29	20.79	8.61

Appendix 2: Estimation of PPP model

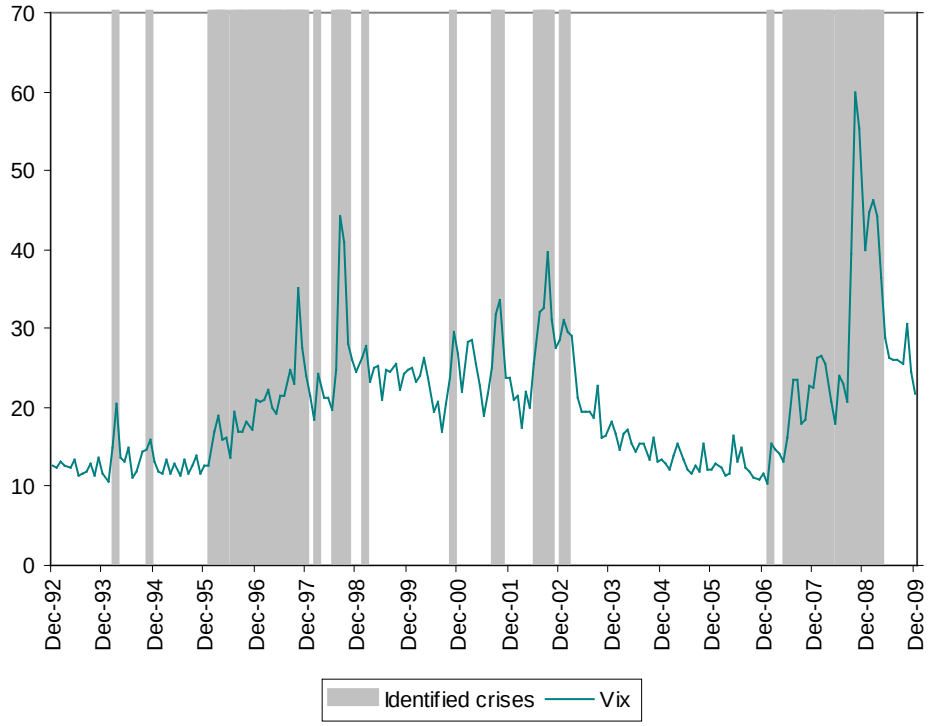
Table 4: Results of PPP model estimation, March 1980 – December 2009

Pair	Average interest rate differential	α (t-stat)	β (t-stat)	Adj. R^2	SE	DW
NZD / JPY	5.65	-0.30*** (-26.67)	1.06*** (30.94)	0.73	0.20	0.05
JPY / AUD	4.80	-0.28*** (-21.38)	1.29*** (28.52)	0.70	0.23	0.04
GBP / JPY	4.62	-0.13*** (-10.70)	0.95*** (21.97)	0.58	0.21	0.03
NZD / CHF	4.41	-0.04*** (-5.92)	1.06*** (40.89)	0.82	0.11	0.14
AUD / CHF	3.57	-0.01* (-1.70)	1.50*** (35.20)	0.78	0.14	0.10
GBP / CHF	3.39	0.14*** (18.70)	1.00*** (23.02)	0.60	0.13	0.05
CAD / JPY	3.17	-0.25*** (-20.07)	1.36*** (20.35)	0.54	0.22	0.03
NZD / USD	2.94	-0.20*** (-21.81)	0.55*** (9.32)	0.19	0.17	0.05
NZD / EUR	2.83	0.01 (1.47)	0.77*** (22.97)	0.60	0.09	0.15
EUR / JPY	2.82	-0.31*** (-30.49)	1.20*** (22.24)	0.58	0.18	0.04
USD / JPY	2.71	-0.11*** (-10.69)	1.18*** (23.33)	0.60	0.19	0.03
NZD / CAD	2.48	-0.08*** (-10.48)	0.40*** (8.40)	0.16	0.13	0.07
USD / AUD	2.09	-0.18*** (-22.14)	1.17*** (14.41)	0.37	0.15	0.05
EUR / AUD	1.99	0.03*** (5.68)	1.47*** (26.48)	0.66	0.11	0.12
CAD / CHF	1.93	0.01 (0.88)	1.7*** (15.93)	0.42	0.16	0.06
GBP / USD	1.91	-0.04*** (-4.80)	0.11 (0.99)	0.00	0.13	0.06
GBP / EUR	1.81	0.16*** (24.10)	0.35*** (5.22)	0.07	0.10	0.06
CAD / AUD	1.63	-0.04*** (-7.92)	0.94*** (19.54)	0.52	0.09	0.10
EUR / CHF	1.58	-0.05*** (-11.92)	1.58*** (33.97)	0.76	0.07	0.06
USD / CHF	1.48	0.16*** (18.24)	1.50*** (18.50)	0.49	0.15	0.05
GBP / CAD	1.45	0.05*** (6.65)	-0.30*** (-4.27)	0.05	0.11	0.08
JPY / CHF	1.24	-0.28*** (-35.78)	0.85*** (12.17)	0.29	0.13	0.06
NZD / GBP	1.03	-0.18*** (-29.77)	0.51*** (8.74)	0.17	0.11	0.11
NZD / AUD	0.85	-0.03*** (-6.29)	-0.34*** (-4.52)	0.05	0.09	0.10
CAD / USD	0.46	-0.12*** (-19.14)	0.23 (1.64)	0.00	0.11	0.03
EUR / CAD	0.36	0.07*** (8.53)	0.19 (0.53)	0.00	0.13	0.06
GBP / AUD	0.18	-0.2*** (-21.35)	1.36*** (8.20)	0.16	0.14	0.07
EUR / USD	0.10	-0.21*** (-23.94)	1.72*** (7.28)	0.13	0.16	0.04

***, **, * indicate that the variable is significant respectively at the 1% 5% and 10% level. SE represents the standard error of the regression and DW represents the Durbin-Watson statistic.

Appendix 3: Crises

Graph 8: VIX and crisis periods



Crises periods are identified as periods of high implied equity market volatility (VIX index above its 3 year-average plus 0.75 standard deviation over January 1993 – December 2009)

[i] Given the diversity of the methods for implementing carry trade strategies (particularly through derivatives), it is hard to quantify their share of total currency trading. Galati and Melvin (2004), as well as Galati et *al.* (2007) identify hedge funds as the key players in the carry trade, but they highlight the growing presence of long-only asset managers, who use these strategies to diversify outside conventional asset classes. In any case, carry trade strategies have definitely become routine for a great many financial market participants.

[ii] The 28 currency crosses are recovered from seven exchange rates against sterling. Note that as a proxy for the euro before 1999 we use a synthetic series calculated by weighting various European exchange rates.

[iii] An alternative would have been to implement this strategy via currency forwards but data were unfortunately not available on the same history for each cross. Since the covered interest rate parity holds closely (Akram *et al.*, 2008) results are be very similar. We checked it on the available sample period.

[iv] German data are used as a proxy for the Euro zone, as no aggregate data are available on the entire period under study.

[v] PPP is widely used by market practitioners and provided annually by large multinational institutions, such as the International Monetary Fund and the Organisation for Economic Co-operation and Development. We re-estimated this model on a monthly schedule, which was better-suited to our strategies.

[vi] All series are integrated of the first order, the cointegration relationship is estimated by Engle-Granger methodology.

[6] As the transaction costs are very low on the currency market, they are not taken into account in this study.

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