Carry Trades and Currency Crashes

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November 2007
Preliminary
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Carry Trades and Currency Crashes:

Motivation

We study the drivers of risk (and return) in FX markets:

- Forecasting currency crashes: drivers of conditional FX skewness
- Pricing currency crashes: drivers of conditional FX skewness
- Co-movement of currencies: what makes FX rates move together?
- "Up by the stairs and down by the elevator"

Key drivers:

- Carry traders
- Funding liquidity and unwinding of carry trades
- Global volatility and/or risk aversion
- Carry traders
What is the Carry Trade?

- Example: Yen-Aussie carry trade (Nov. 8, 2007)
  - **Borrow** at 0.87% 3m JPY LIBOR ("funding currency")
  - **Invest** at 7.09% 3m AUD LIBOR ("investment currency")
  - **Hope** that AUD doesn’t depreciate much vs. JPY
Uncovered Interest Rate Parity (UIP)

Background: Uncovered Interest Parity (UIP)

Carry trade activity could be self-reinforcing

Bubble?

Suggests insufficient carry trade activity

Underreaction to interest rate shocks?

Possible causes

Source of carry trade profitability

Large literature on "forward premium puzzle"

not depreciate

Empirically UIP is violated: High-yield currencies tend to appreciate,'

\[ E_t \left( x_t \right) = 0 \]

where

\[ t^{\text{AUD}} - t^{\text{JPY}} + t^{\text{s}} = 1 \]

Equivalently:

\[ E \left( t^{\text{AUD}} - t^{\text{JPY}} + t^{\text{s}} \right) = 0 \]

Uncovered interest rate parity, with \( s_t = \log \left( \text{AUD} / \text{JPY} \right) \), states:


High-yield currencies tend to appreciate,

Bubbles?

Underreaction to interest rate shocks?
Transaction costs (Burnside et al. 2006)

- Excess co-movement of funding currencies (investment currencies)
- Gains are not amplified
- Losses are amplified: funding problems unwind
- Unwinding of carry trades when funding liquidity dries up
- Endogenous negative skewness of carry trade returns

Funding liquidity constraints of speculators

- Large literature on UIP
- Macro: little/no predictability of FX (e.g. Meese and Rogoff 1983)

Funding liquidity and speculative carry trades

Macro: little/no predictability of FX (e.g. Meese and Rogoff 1983)

Large literature on UIP

Unwinding of carry trades when funding liquidity dries up

Endogenous negative skewness of carry trade returns

Gains are not amplified

Losses are amplified: funding problems unwind

Excess co-movement of funding currencies (investment currencies)
Our Main Results

- FX crash risk increases with Interest rate differential (i.e. carry), but face crash risk due to their own funding liquidity constraints.
- Speculators trade carry, partly “correcting” UIP, but crash risk.
- Carry trade exposed to – and may lead to – crash risk.
- Investment currencies move together, funding currencies ditto.
- Carry unwind.

An increase in VIX (cf. global risk or risk aversion) associated with carry unwind.

The price of FX crash insurance behaves “perversely” and decreases with price of insurance (risk reversal).

- Speculator carry futures positions
- Past FX carry returns
- Interest rate differential (i.e. carry)
- FX crash risk increases with
Overview of Talk

1. Data, definitions, and summary statistics
2. Does carry predict currency (return and) crash risk?
3. Document the behavior of speculators: do they trade carry?
4. What else predicts currency crashes?
5. Pricing of crash risk
6. Comovement of currencies
Recall UIP: $E^t_x t^{I+1} = 0$

Return from a carry trade where foreign currency is investment currency

$3m$-LIBOR minus USD 3m-LIBOR

Interest rate differentials (1986-2006): $r^f_t - r^{d,t-1} \equiv r^f_t - r^{d,t-1} - D^t_s$

Units of foreign currency per USD

AUD, CAD, JPY, NZD, JPY, DEM

FX rates (1986-2006): $s^f_t$ (in logs) [Datastream]
currency crash

i.e., risk of foreign currency crash and/or risk premium for foreign

negative value implies negatively skewed risk-neutral distribution of \( x_t \)

volatility of foreign currency put option (both at 25%)

implied volatility of foreign currency call option minus implied


scaled by total open interest

Investing at AUD LIBOR, financed by borrowing in USD at USD LIBOR

Example: Taking a long futures position in AUD ≈ Buying AUD,

CAD, JPY, CHF, GBP, EUR (DEM)

Proxy for carry trade activity

(1986-2006): Futures [CFTC]

Futures positions of non-commercial traders on the CME
### Summary Statistics

<table>
<thead>
<tr>
<th></th>
<th>AUD</th>
<th>CAD</th>
<th>JPY</th>
<th>NZD</th>
<th>NOK</th>
<th>CHF</th>
<th>GBP</th>
<th>EUR</th>
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<tbody>
<tr>
<td>Panel A: Means</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta s_t$</td>
<td>-0.003</td>
<td>-0.002</td>
<td>-0.003</td>
<td>-0.005</td>
<td>-0.002</td>
<td>-0.004</td>
<td>-0.004</td>
<td>-0.004</td>
</tr>
<tr>
<td>$\lambda t$</td>
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<td>0.004</td>
<td>-0.004</td>
<td>0.013</td>
<td>0.007</td>
<td>-0.001</td>
<td>0.009</td>
<td>0.003</td>
</tr>
<tr>
<td>$r_{f,t-1} - r_{d,t-1}$</td>
<td>0.006</td>
<td>0.002</td>
<td>-0.007</td>
<td>0.009</td>
<td>0.005</td>
<td>-0.004</td>
<td>0.005</td>
<td>-0.001</td>
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<tr>
<td>Futures</td>
<td>-</td>
<td>0.059</td>
<td>-0.097</td>
<td>-</td>
<td>-</td>
<td>-0.067</td>
<td>0.052</td>
<td>0.031</td>
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<td>Skewness</td>
<td>-0.322</td>
<td>-0.143</td>
<td>0.318</td>
<td>-0.297</td>
<td>-0.019</td>
<td>0.144</td>
<td>-0.094</td>
<td>0.131</td>
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<td>Risk reversals</td>
<td>-0.426</td>
<td>-0.099</td>
<td>1.059</td>
<td>-0.467</td>
<td>0.350</td>
<td>0.409</td>
<td>0.009</td>
<td>0.329</td>
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</tbody>
</table>

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**Skewness vs. Interest-Rate Differentials**

![Skewness vs. Interest-Rate Differentials](image)
### Table 1: Summary Statistics (cont.)

<table>
<thead>
<tr>
<th></th>
<th>AUD</th>
<th>CAD</th>
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<th>NZD</th>
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<th>CHF</th>
<th>GBP</th>
<th>EUR</th>
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<tbody>
<tr>
<td><strong>Panel B: Standard deviations</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta s_t )</td>
<td>0.049</td>
<td>0.028</td>
<td>0.062</td>
<td>0.050</td>
<td>0.053</td>
<td>0.063</td>
<td>0.049</td>
<td>0.059</td>
</tr>
<tr>
<td>( x_t )</td>
<td>0.050</td>
<td>0.029</td>
<td>0.064</td>
<td>0.053</td>
<td>0.053</td>
<td>0.064</td>
<td>0.049</td>
<td>0.060</td>
</tr>
<tr>
<td>( r_{f,t-1} - r_{d,t-1} )</td>
<td>0.006</td>
<td>0.004</td>
<td>0.005</td>
<td>0.007</td>
<td>0.008</td>
<td>0.006</td>
<td>0.005</td>
<td>0.006</td>
</tr>
<tr>
<td>Futures</td>
<td>-</td>
<td>0.248</td>
<td>0.242</td>
<td>-</td>
<td>0.000</td>
<td>0.296</td>
<td>0.272</td>
<td>0.202</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.712</td>
<td>0.585</td>
<td>0.627</td>
<td>0.685</td>
<td>0.472</td>
<td>0.438</td>
<td>0.528</td>
<td>0.510</td>
</tr>
<tr>
<td>Risk reversals</td>
<td>0.436</td>
<td>0.343</td>
<td>1.204</td>
<td>0.466</td>
<td>0.515</td>
<td>0.550</td>
<td>0.391</td>
<td>0.534</td>
</tr>
</tbody>
</table>
Predicting Crash Risk

Use $r_{t+1} - r_d$ to predict

- Futures positions at end of quarter $t+J$
- Skewness of daily $x_t$ within quarter $t+J$
- FX excess return $x_{t+J}$ during quarter $t+J$
- Positive coefficient: consistent with carry trade activity
- Negative coefficient: Carry trades are exposed to crash risk
- Positive coefficient: carry trade pays off
Predicting Crash Risk

Table 2: Future FX excess returns, futures positions, and skewness regressed on $r_{f,t} - r_{d,t}$

<table>
<thead>
<tr>
<th></th>
<th>FX excess return</th>
<th>Futures</th>
<th>Skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t+1$</td>
<td>2.17</td>
<td>8.30</td>
<td>-23.98</td>
</tr>
<tr>
<td></td>
<td>(0.77)</td>
<td>(5.06)</td>
<td>(3.80)</td>
</tr>
<tr>
<td>$t+2$</td>
<td>2.24</td>
<td>8.09</td>
<td>-23.22</td>
</tr>
<tr>
<td></td>
<td>(0.69)</td>
<td>(5.09)</td>
<td>(3.65)</td>
</tr>
<tr>
<td>$t+3$</td>
<td>2.24</td>
<td>6.07</td>
<td>-23.59</td>
</tr>
<tr>
<td></td>
<td>(0.69)</td>
<td>(4.69)</td>
<td>(3.82)</td>
</tr>
<tr>
<td>$t+4$</td>
<td>1.50</td>
<td>6.47</td>
<td>-23.26</td>
</tr>
<tr>
<td></td>
<td>(0.62)</td>
<td>(4.47)</td>
<td>(4.60)</td>
</tr>
<tr>
<td>$t+5$</td>
<td>1.11</td>
<td>5.92</td>
<td>-23.40</td>
</tr>
<tr>
<td></td>
<td>(0.52)</td>
<td>(3.47)</td>
<td>(5.04)</td>
</tr>
</tbody>
</table>

Notes: Panel regressions (1986-2006) with country-fixed effects and quarterly data. Standard errors in parentheses are robust to within-time period correlation of residuals and are adjusted for serial correlation with a Newey-West covariance matrix with 10 lags.
Table 2: Future FX excess returns, futures positions, and skewness regressed on $r_{f,t} - r_{d,t}$

<table>
<thead>
<tr>
<th></th>
<th>FX excess return</th>
<th>Futures</th>
<th>Skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t + 6$</td>
<td>0.76</td>
<td>4.75</td>
<td>-22.10</td>
</tr>
<tr>
<td></td>
<td>(0.48)</td>
<td>(2.50)</td>
<td>(4.97)</td>
</tr>
<tr>
<td>$t + 7$</td>
<td>0.68</td>
<td>4.15</td>
<td>-21.20</td>
</tr>
<tr>
<td></td>
<td>(0.48)</td>
<td>(1.83)</td>
<td>(4.05)</td>
</tr>
<tr>
<td>$t + 8$</td>
<td>0.44</td>
<td>2.74</td>
<td>-16.95</td>
</tr>
<tr>
<td></td>
<td>(0.55)</td>
<td>(2.04)</td>
<td>(4.02)</td>
</tr>
<tr>
<td>$t + 9$</td>
<td>0.27</td>
<td>0.44</td>
<td>-12.88</td>
</tr>
<tr>
<td></td>
<td>(0.63)</td>
<td>(2.35)</td>
<td>(3.44)</td>
</tr>
<tr>
<td>$t + 10$</td>
<td>-0.04</td>
<td>-0.90</td>
<td>-11.08</td>
</tr>
<tr>
<td></td>
<td>(0.77)</td>
<td>(3.21)</td>
<td>(3.72)</td>
</tr>
</tbody>
</table>

Notes: Panel regressions (1986-2006) with country-fixed effects and quarterly data. Standard errors in parentheses are robust to within-time period correlation of residuals and are adjusted for serial correlation with a Newey-West covariance matrix with 10 lags.
Predicting Crash Risk

Consider dynamic relationships between FX excess returns, futures positions, skewness, and interest rate differentials:

Vector-Autoregressions

VAR(3) with $R_t^F - R_t^d, x_t, Skew_t, \text{Futures}_t$

Impulse responses for shocks to $R_t^F - R_t^d, x_t, Skew_t, \text{Futures}_t$

Bootstrap-after-bootstrap bias-adjusted confidence intervals for impulse response function (Kilian 1998)

Bootstrap-after-bootstrap bias-adjusted confidence intervals for impulse response function (Kilian 1998)

VAR(3) with $R_t^F - R_t^d, x_t, Skew_t, \text{Futures}_t$

Consider dynamic relationships between FX excess returns, futures positions, skewness, and interest rate differentials:
Predicting Crash Risk

Impulse responses for shocks to $r_{f,t} - r_{d,t}$

- Interest rate differential
- Cumulated excess return
- Futures position
- Skewness
Crash Risk

Figure 1: Kernel density estimates of distribution of foreign exchange excess returns conditional on interest rate differential. Interest rate differential groups quarterly: < -0.005 (red), -0.005 to 0.005 (magenta), > 0.005 (blue); weekly: < -0.01 (red), -0.01 to 0.01 (magenta), > 0.01 (blue).
Table 3: Forecasting crashes and the price of crash risk

<table>
<thead>
<tr>
<th></th>
<th>Skewness_{t+1}</th>
<th>Skewness_{t+1}</th>
<th>RiskRev_t</th>
</tr>
</thead>
<tbody>
<tr>
<td>( r_{f,t} - r_{d,t} )</td>
<td>-24.74</td>
<td>-29.33</td>
<td>-25.49</td>
</tr>
<tr>
<td></td>
<td>(11.47)</td>
<td>(11.87)</td>
<td>(28.21)</td>
</tr>
<tr>
<td>( x_t )</td>
<td>-2.98</td>
<td>-1.57</td>
<td>8.47</td>
</tr>
<tr>
<td></td>
<td>(0.79)</td>
<td>(0.73)</td>
<td>(1.62)</td>
</tr>
<tr>
<td>Futures_t</td>
<td>0.08</td>
<td>0.14</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>(0.11)</td>
<td>(0.11)</td>
<td>(0.16)</td>
</tr>
<tr>
<td>Skewness_t</td>
<td>0.20</td>
<td>0.21</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>(0.12)</td>
</tr>
<tr>
<td>RiskRev_t</td>
<td>-0.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.21</td>
<td>0.24</td>
<td>0.43</td>
</tr>
</tbody>
</table>

Notes: Panel regressions (1998-2006) with country-fixed effects and quarterly data. Standard errors in parentheses are robust to within-time period correlation of residuals and are adjusted for serial correlation with a Newey-West covariance matrix with 10 lags.
Rival premium may be due to slow moving capital.

Risk of another "earthquake" is low, although the price of insurance goes up after an "earthquake." After FX losses, the crash risk is lower, but the price of crash insurance is higher when future skewness is low.

Price of crash risk insurance is higher, consistent with carry trades being exposed (lead to?) to crash risk and risk-neutral distributions of FX returns. Positive interest rate differential predicts negatively skewed physical.

Brunnermeier, Nagel, Pedersen () November 2007 Preliminary 20 / 27
Unwinding of Carry Trades

Proxy for global volatility and funding liquidity: CBOE VIX index

Prior evidence that funding liquidity “dries up” when VIX spikes

Unwinding of carry trade losses gets more expensive

\[ \text{ACRISKREV}_t = \text{ACRISKREV}_t \times \text{sign}(\text{RISKREV}_t) \times (r_f^t - r_d^t - 1 - 1) \]

Negative = Insurance against carry trade losses gets more expensive

\[ \text{ACFUT}_t = \text{ACFUT}_t \times \text{sign}(\text{FUT}_t) \times (r_f^t - r_d^t - 1 - 1) \]

Negative = unwinding of carry trades

\[ \text{CRiskRev}_t = \text{CRiskRev}_t \times \text{sign}(\text{RISKREV}_t) \times (r_f^t - r_d^t - 1 - 1) \]

Negative = Losses on carry trade

Carry trade variables

Positive evidence that funding liquidity “dries up” when VIX spikes

Proxy for global volatility and funding liquidity: CBOE VIX index
Unwinding of Carry Trades

Table 4: Sensitivity of weekly carry trade positions, price of skewness insurance, and carry trade returns to changes in VIX

<table>
<thead>
<tr>
<th></th>
<th>(\Delta CF_{ut_t})</th>
<th>(\Delta CF_{ut_{t+1}})</th>
<th>(\Delta CR_{iskRev_t})</th>
<th>(\Delta CR_{iskRev_{t+1}})</th>
<th>(CR_{et_t})</th>
<th>(CR_{et_{t+1}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Delta VIX_t)</td>
<td>-1.55</td>
<td>-1.29</td>
<td>-4.66</td>
<td>-3.48</td>
<td>-0.40</td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td>(0.79)</td>
<td>(0.58)</td>
<td>(2.80)</td>
<td>(3.79)</td>
<td>(0.11)</td>
<td>(0.11)</td>
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<tr>
<td>(CF_{ut_{t-1}})</td>
<td>-0.09</td>
<td>-0.11</td>
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<td></td>
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<tr>
<td></td>
<td>(0.01)</td>
<td>(0.01)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>(CR_{iskRev_{t-1}})</td>
<td></td>
<td></td>
<td>-0.14</td>
<td>-0.10</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.02)</td>
<td>(0.01)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.05</td>
<td>0.06</td>
<td>0.07</td>
<td>0.03</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Notes: Panel regressions with country-fixed effects and weekly data (1990. CAD, JPY, CHF, GBP, and EUR only (only currencies for which we have positions data since 1986). Standard errors in parentheses are robust to within-time period correlation of residuals and are adjusted for serial correlation with a Newey-West covariance matrix with 6 lags. The reported \(R^2\) is an adjusted \(R^2\) net of the fixed effects.
Figure 2: Kernel density estimates of distribution of carry trade returns conditional on contemporaneous change in VIX. Change in VIX groups quarterly: \(< -0.25\) (red), \(-0.25\) to 0.25 (magenta), \(0.25\) (blue); weekly: \(< -0.1\) (red), \(-0.1\) to 0.1 (magenta), \(0.1\) (blue).
If FX rates are driven by carry trades, investment currencies should move with investment currencies and funding currencies with funding currencies, i.e., the lower the interest rate differential between a pair of currencies, the more their FX rates (relative to USD) should co-move.

Variables

- **Dependent variable** is the pairwise correlation of daily log FX rate changes within each 13-week period.
- **Average $d(\Delta s_1, \Delta s_2)$** is the cross-sectional average of all pairwise overlapping windows, within each 13-week period.
- **Average $r_D(s_1, s_2)$** = correlation of 5-day interest rate changes, estimated within each 13-week period.
- **Average $r_D(\Delta s_1, \Delta s_2)$** is the pairwise correlation of daily log FX rate changes within each 13-week period.
- **Average $|\Delta r_1 - \Delta r_2|$** = absolute pairwise interest rate differential at the start of the 13-week period.

By re-scaling and logistic transformation, the absolute pairwise interest rate differential is mapped to the real line.

13-week periods:

- Correlations of daily FX rate changes within each non-overlapping 13-week period. The more their FX rates (relative to USD) should co-move, the lower the interest rate differential between a pair of currencies, i.e., the lower the interest rate differential, the more their FX rates should co-move with investment currencies and funding currencies with funding currencies.
Table 5: Correlation of FX rate changes and magnitude of interest rate differentials

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(</td>
<td>r_1 - r_2</td>
<td>)</td>
<td>-10.49</td>
<td>-6.70</td>
</tr>
<tr>
<td></td>
<td>(3.69)</td>
<td>(3.54)</td>
<td>(3.90)</td>
<td>(6.34)</td>
</tr>
<tr>
<td>( \rho(r_1, r_2) )</td>
<td>0.80</td>
<td>0.28</td>
<td>0.87</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>(0.15)</td>
<td>(0.07)</td>
<td>(0.16)</td>
<td>(0.07)</td>
</tr>
<tr>
<td>( \rho(\Delta s_1, \Delta s_2) )</td>
<td>2.53</td>
<td>2.55</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.07)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time Fixed Effects</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country-Pair Fixed Effects</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.19</td>
<td>0.36</td>
<td>0.06</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Note: The dependent variable is the pairwise correlation of daily FX rate changes, estimated within non-overlapping 13-week periods. The reported \( R^2 \) is an adjusted \( R^2 \) net of the fixed effects.
Investment currencies move together, funding currencies ditto.

Price of insurance increases
Carry losses
Carry unwind, i.e., reduced speculator futures positions

An increase in VIX (cf. global risk or risk aversion) contemporaneous with
Speculator carry futures positions
Past FX carry losses
Interest rate differential (i.e., carry)

The price of FX crash insurance increases with
and decreases with price of insurance, risk reversal
Speculator carry futures positions
Past FX carry gains
Interest rate differential (i.e., carry)

FX crash risk increases with

Conclusion
Conclusion, continued

Carry trade exposure to crash risk due to their own funding liquidity constraints and other

“limits to arbitrage”

Trade carry partly “correcting” UIP, but only partly because they

Unwinding of carry trades after losses and in these “bad” states

Results consistent with idea that speculators

Bad payoffs in low liquidity, high volatility states of the world

Payoff resembles that of selling put options

Exposed to crash risk

Carry trade