Carry Trades and Currency Crashes

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

- “Up by the stairs and down by the elevator”
- Forecasting currency crashes: drivers of conditional FX skewness
- Pricing of currency crashes: option prices
- Co-movements of currencies
- Key drivers:
  - Carry trades
  - Global volatility and/or risk aversion
  - Funding liquidity and unwinding of carry trades
Carry Trade

1. Violation of UIP - “Forward Premium Puzzle”
   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 JPY doesn’t appreciate much (**UIP violation**)

2. Large exchange rate movements without news
   Example: October 7th/8th, 1998
Background: Literature

- Macro: near-random walk of FX
  (Messe & Rogoff 1983, Engel & West)
- Funding liquidity constraints of speculators
  (Brunnermeier and Pedersen 2007; Plantin and Shin 2007)
  - Unwinding of carry trades when funding liquidity dries up
  - Endogenous negative skewness of carry trade returns
  - Excess co-movement of funding currencies (investment currencies)
- Transaction costs (Burnside et al. 2006)
Our Main Results

- FX crash risk increases with
  - interest rate differential (i.e. carry)
  - past FX carry returns
  - speculator carry futures positions
  - and decrease with price of insurance (risk reversals)

- The price of FX crash insurance increases after crash

- An increase in VIX (cf. global risk and risk aversion) leads to unwinding of carry trades

- Investment currencies move together, funding currencies ditto

- Carry trade exposed to – and may lead to – crash risk limits correcting arbitrage ⇒ “Forward premium puzzle”
Data and Definitions

- **FX rates (1986-2006):** $s_t$ (in logs) [Datastream]
  - AUD, CAD, JPY, NZD, NOK, CHF, GBP, EUR per USD
- **Interest rate differentials (1986-2006):** $i^* - i$ (in logs) [Datastream]
  - 3m-LIBOR
- **Foreign currency excess return:** $z_t \equiv \left( i_{t-1}^* - i_{t-1} \right) - \Delta s_t$
  - Return from a carry trade where foreign currency is investment currency
  - UIP: $E_t [z_{t+1}] = 0$
- **Futures positions of non-commercial traders on the CME (1986-2006):** $\text{Futures}_t$ [CFTC]
## Summary Statistics

Table 1: 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>
</tr>
</thead>
<tbody>
<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>(Z_t)</td>
<td>0.009</td>
<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>(i_{t-1}^* - i_{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>
</tr>
<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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<tr>
<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>
</tr>
<tr>
<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>
</tr>
</tbody>
</table>

### Skewness vs. Interest-Rate Differentials

![Skewness vs. Interest-Rate Differentials](image)

**BNP (2008)** Carry Trades & Currency Crashes AEA, Jan 2008 7 / 23
## Summary Statistics

### Table 1: Summary Statistics (cont.)

<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>
</tr>
</thead>
<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>( z_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>( i_{t-1}^* - i_{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 $i_t^* - i_t$ to predict

- FX excess return $z_{t+\tau}$ during quarter $t + \tau$
  - Positive coefficient: carry trade pays off (UIP violation)
- Futures positions at end of quarter $t + \tau$
  - Positive coefficient: consistent with carry trade activity
- Skewness of daily $z_t$ within quarter $t + \tau$
  - Negative coefficient: Carry trades are exposed to crash risk
## Predicting Crash Risk

Table 2: $z$, futures positions, and skewness regressed on $i_t^* - i_t$

<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.
Predicting Crash Risk

Table 2: $z$, futures positions, and skewness regressed on $i_t^* - i_t$

<table>
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<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 $i_t^* - i_t$, $z_t$, Skew$_t$, Futures$_t$
    - 1986-2006, quarterly
    - Impulse responses for shocks to $i_t^* - i_t$ with Choleski decomposition with ordering $i_t^* - i_t$, $z_t$, Skew$_t$, Futures$_t$
    - Bootstrap-after-bootstrap bias-adjusted confidence intervals for impulse response function (Kilian 1998)
Predictable Return and Crash Risk of Carry Trades

Impulse responses for shocks to $i_t^* - i_t$
Predicting 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>$i_t^* - i_t$</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>$Z_t$</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></td>
<td>-0.17</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.05)</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
Positive interest rate differential predicts negatively skewed physical and risk-neutral distributions of FX returns
- Consistent with carry trades being exposed to crash risk

After FX losses, the crash risk is *lower*, but the price of crash insurance is *higher*.

- Price of crash risk insurance is high when future skewness is low.
- The price of insurance goes up after an “earthquake,” although the risk of another “earthquake” is low
- Risk premium may be due to slow moving capital
Unwinding of Carry Trades

- Proxy for global volatility and funding liquidity: CBOE VIX index
  - Prior evidence that funding liquidity “dries up” when VIX spikes

- Carry trade variables
  - $\text{CRet}_t: z_t \times \text{sign}(i_{t-1}^* - i_{t-1})$
    - Negative = Losses on carry trade
  - $\Delta \text{CFut}_t: \Delta \text{Futures}_t \times \text{sign}(i_{t-1}^* - i_{t-1})$
    - Negative = unwinding of carry trades
  - $\Delta \text{CRiskRev}_t: \Delta \text{RiskRev}_t \times \text{sign}(i_{t-1}^* - i_{t-1})$
    - Negative = Insurance against carry trade losses gets more expensive
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>ΔVIX&lt;sub&gt;t&lt;/sub&gt;</th>
<th>ΔCFut&lt;sub&gt;t&lt;/sub&gt;</th>
<th>ΔCFut&lt;sub&gt;t+1&lt;/sub&gt;</th>
<th>ΔCRiskRev&lt;sub&gt;t&lt;/sub&gt;</th>
<th>ΔCRiskRev&lt;sub&gt;t+1&lt;/sub&gt;</th>
<th>CRet&lt;sub&gt;t&lt;/sub&gt;</th>
<th>CRet&lt;sub&gt;t+1&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.55</td>
<td>-1.29</td>
<td>-4.66</td>
<td>-3.48</td>
<td>-0.40</td>
<td>-0.01</td>
<td></td>
</tr>
<tr>
<td>(0.79)</td>
<td>(0.58)</td>
<td>(2.80)</td>
<td>(3.79)</td>
<td>(0.11)</td>
<td>(0.11)</td>
<td></td>
</tr>
<tr>
<td>CFut&lt;sub&gt;t-1&lt;/sub&gt;</td>
<td>-0.09</td>
<td>-0.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.01)</td>
<td>(0.01)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRiskRev&lt;sub&gt;t-1&lt;/sub&gt;</td>
<td></td>
<td>-0.14</td>
<td>-0.10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.02)</td>
<td>(0.01)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&lt;sup&gt;2&lt;/sup&gt;</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. 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<sup>2</sup> is an adjusted R<sup>2</sup> net of the fixed effects.
Unwinding of Carry Trades - VIX

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).

Currency Co-movement

- If FX rates are driven by carry trades, funding currencies move together, and so do investment 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 13-week (non-overlapping) windows mapped to real line by re-scaling and logistic transformation
- $|i_1 - i_2| =$ absolute pairwise interest rate differential at the start of the 13-week period.
- $\rho(i_1, i_2) =$ correlation of 5-day interest rate changes, estimated with overlapping windows, within each 13-week period.
- Average $\rho(\Delta s_1, \Delta s_2)$ is the cross-sectional average of all pairwise correlations of daily FX rate changes within each non-overlapping 13-week periods.
### Currency Co-movement

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>$</td>
<td>i_1 - i_2</td>
<td>$</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>$\rho(i_1, i_2)$</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>
</tbody>
</table>

Time Fixed Effects: Yes, Yes  
Country-Pair Fixed Effects: Yes  
$R^2$: 0.19, 0.36, 0.06, 0.03

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.
Conclusion

- FX crash risk increases with
  - interest rate differential (i.e. carry)
  - past FX carry gains
  - speculator carry futures positions
  - and decrease with price of insurance, risk reversal

- The price of FX crash insurance increases with
  - interest rate differential (i.e. carry)
  - past FX carry losses
  - speculators carry futures positions

- An increase in VIX (cf. global risk or risk aversion) contemporaneously leads to
  - carry unwind
  - carry losses
  - price of insurance increases

- Funding currencies move together, funding currencies ditto
Conclusion, ctd.

- **Carry trade**
  - Exposed to crash risk
  - Payoff resembles that of selling put options
  - Bad payoffs in low liquidity, high volatility states of the world
  - Unwinding of carry trades after losses and in these “bad” states

- Results consistent with idea that speculators
  - trade carry partly “correcting” UIP, but only partly because they
  - face crash risk due to their own funding liquidity constraints and other
    “limits to arbitrage”