Carry Trades and Currency Crashes

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Motivation

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

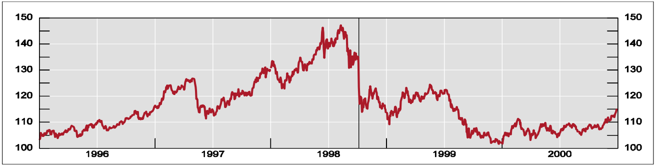
- Interest-rate differential an important driver of currency crash risk, i.e. conditional FX skewness
- “Up by the stairs and down by the elevator”
- Pricing of currency crashes: option prices
- Co-movements of currencies
- Examine the importance of
  - Carry trades
  - Global volatility and/or risk aversion
  - Funding liquidity and unwinding of carry trades

Motivation: The Carry Trade

1. 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

   Violation of UIP - "Forward Premium Puzzle"

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, 2007)
- Rare disasters (Farhi and Gabaix (2008))
- Consumption growth risk (Lustig and Verdelhan (2007))

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 or TED (cf. global risk and risk aversion) associated with unwinding of carry trades
- Investment currencies move together, funding currencies ditto
- Carry trade exposed to – and may lead to – crash risk, this limits arbitrage, contributing to the "forward premium puzzle"

Data and Definitions

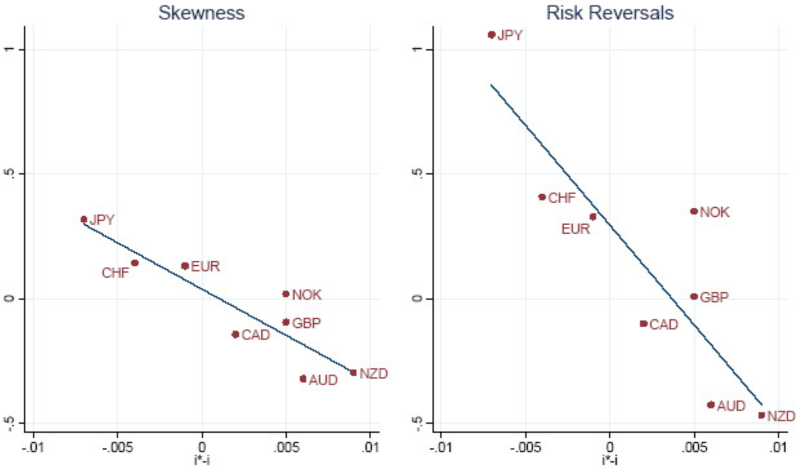
- FX rates (1986-2006): s_t (in logs) [Datastream]
  - AUD, CAD, JPY, NZD, NOK, CHF, GBP, EUR per USD
- Interest rate differentials (1986-2006): $i^* - i$ (in logs) [Datastream] 3m-LIBOR
- Foreign currency excess return: $z_t \equiv \left(i^*_{t-1} - i_{t-1}\right) - \Delta s_t$
  - Return from a carry trade where foreign currency is investment currency
  - UIP: $E_t\left[z_{t+1}\right] = 0$
- Futures positions of non-commercial traders on the CME (1986-2006): Futures_t [CFTC]
- Risk Reversals (1998-2006): RiskRev_t [JP Morgan]

Summary Statistics

Table 1: Summary Statistics

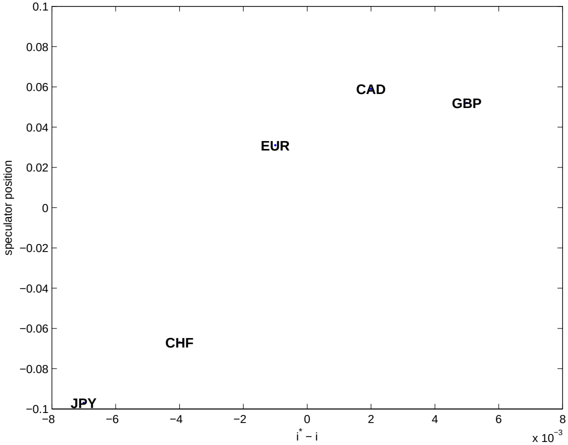
	AUD	CAD	JPY	NZD	NOK	CHF	GBP	EUR
Panel A: Means								
Δs_t	-0.003	-0.002	-0.003	-0.005	-0.002	-0.004	-0.004	-0.004
z_t	0.009	0.004	-0.004	0.013	0.007	-0.001	0.009	0.003
$i^*_{t-1} - i_{t-1}$	0.006	0.002	-0.007	0.009	0.005	-0.004	0.005	-0.001
Futures pos	-	0.059	-0.097	-	-	-0.067	0.052	0.031
Skewness	-0.322	-0.143	0.318	-0.297	-0.019	0.144	-0.094	0.131
Risk rev	-0.426	-0.099	1.059	-0.467	0.350	0.409	0.009	0.329

Summary Statistics, Graphically



Summary Statistics, Graphically

Speculator positions and interest-rate differentials



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

Qtr	z	Futures	Skewness
$t+1$	2.17	8.26	-23.92
	(0.78)	(5.06)	(3.87)
$t+2$	2.24	8.06	-23.20
	(0.70)	(5.08)	(3.71)
$t+3$	1.87	5.96	-23.65
	(0.66)	(4.68)	(3.87)
$t+4$	1.50	6.41	-23.28
	(0.63)	(4.44)	(4.65)
$t+5$	1.11	5.87	-23.49
	(0.52)	(3.47)	(5.05)
$t+6$	0.76	4.72	-22.24
	(0.48)	(2.52)	(5.00)
$t+7$	0.68	4.27	-21.23
	(0.49)	(1.91)	(4.09)
$t+8$	0.44	2.81	-16.96
	(0.55)	(2.12)	(4.03)
$t+9$	0.27	0.46	-12.90
	(0.63)	(2.41)	(3.45)
$t+10$	-0.04	-0.96	-11.14
	(0.78)	(3.26)	(3.74)

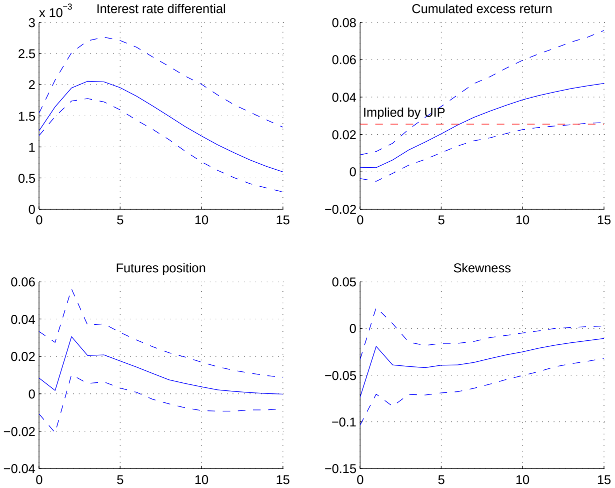
Notes: Panel regressions (1986-2006) with country-fixed effects and quarterly data. Standard errors in parentheses are robust to within-time period correlation and are NW adjusted.

Predicting Crash Risk

- We confirm these findings in a VAR
- 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)
  - The usual caveats apply (sensitivity to specification etc.)

Predictable Return and Crash Risk of Carry Trades

Impulse responses for shocks to $i_t^* - i_t$



Predicting Crash Risk

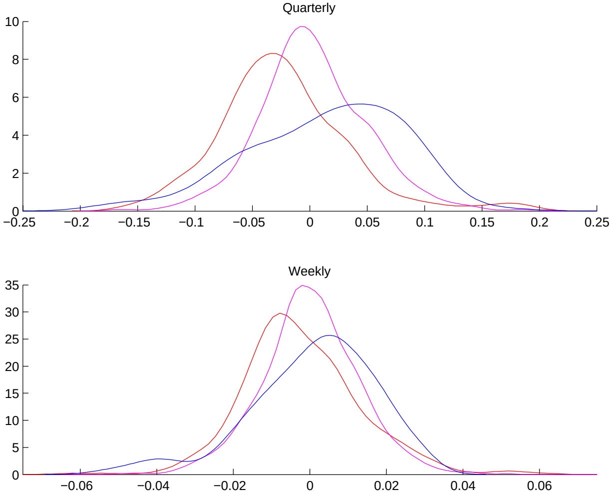


Figure 1: Kernel density estimates of distribution of foreign exchange excess returns conditional on interest rate differential. Interest rate differential groups quarterly: $<$ -0.005 (red), -0.005 to 0.005 (magenta), $>$ 0.005 (blue);

Price of Crash Risk

Table 3: Forecasting crashes and the price of crash risk

	Skewness_{t+1}	Skewness_{t+1}	Skewness_{t+1}	RiskRev_t	RiskRev_t
$i_t^* - i_t$	-28.51	-22.18	-27.34	-15.51	-30.70
	(11.59)	(12.59)	(11.52)	(29.20)	(25.91)
z_t		-3.34	-2.11		7.87
		(0.60)	(0.69)		(1.39)
Futures_t	-0.26	0.13	0.18	1.16	0.27
	(0.12)	(0.15)	(0.14)	(0.19)	(0.12)
Skewness_t	0.12	0.18	0.17	0.10	-0.02
	(0.05)	(0.05)	(0.05)	(0.09)	(0.10)
RiskRev_t			-0.16		
			(0.04)		
R^2	0.12	0.18	0.21	0.20	0.41

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.

Price of Crash Risk

- 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

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

	ΔFut$_t$	ΔFut$_{t+1}$	ΔRiskR$_t$	ΔRiskR$_{t+1}$	z_t	z_{t+1}
$\Delta VIX_t \times sign(i^*_{t-1} - i_{t-1})$	-1.47	-1.29	-5.33	-2.74	-0.43	-0.03
	(0.77)	(0.57)	(2.64)	(3.39)	(0.11)	(0.11)
Futures$_{t-1}$	-0.09	-0.10				
	(0.01)	(0.01)				
RiskRev$_{t-1}$			-0.16	-0.11		
			(0.02)	(0.02)		
R^2	0.04	0.06	0.08	0.04	0.00	-0.00

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^2 is an adjusted R^2 net of the fixed effects.

- CBOE VIX index and TED spread:
  Proxies for global volatility and funding liquidity:
  Prior evidence that funding liquidity "dries up" when VIX / TED spikes

Unwinding of Carry Trades

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

	ΔFut$_t$	ΔFut$_{t+1}$	ΔRiskR$_t$	ΔRiskR$_{t+1}$	z_t	z_{t+1}
$\Delta TED_t \times sign(i^*_{t-1} - i_{t-1})$	-0.48	-1.92	-0.71	-25.05	-0.27	-0.57
	(2.27)	(1.85)	(10.02)	(13.89)	(0.35)	(0.31)
Futures$_{t-1}$	-0.09	-0.10				
	(0.01)	(0.01)				
RiskRev$_{t-1}$			-0.16	-0.11		
			(0.02)	(0.02)		
R^2	0.04	0.06	0.08	0.04	0.00	0.00

Funding Liquidity and Violations of UIP

Table 6: Future excess FX return regressed on $i_t^* - i_t$ and its interaction

	Forecast with VIX		Forecast with TED	
Qtr	$i_t^* - i_t$	$\text{VIX}_t \times \text{sign}(i_{t-1}^* - i_{t-1})$	$i_t^* - i_t$	$\text{TED}_t \times \text{sign}(i_{t-1}^* - i_{t-1})$
$t+1$	1.35	0.29	2.58	-0.62
	(1.36)	(0.26)	(1.01)	(0.45)
$t+2$	1.37	0.35	2.27	-0.04
	(1.17)	(0.18)	(0.91)	(0.50)
$t+3$	0.75	0.53	1.40	0.72
	(1.20)	(0.23)	(0.90)	(0.58)
$t+4$	0.63	0.53	0.96	0.84
	(1.22)	(0.23)	(0.90)	(0.59)
$t+5$	0.93	0.31	1.04	0.11
	(0.82)	(0.16)	(0.58)	(0.29)
$t+6$	0.63	0.29	0.18	0.88
	(0.65)	(0.11)	(0.48)	(0.30)
$t+7$	0.23	0.34	0.23	0.70
	(0.90)	(0.16)	(0.57)	(0.28)
$t+8$	0.05	0.31	0.46	-0.03
	(0.83)	(0.17)	(0.64)	(0.40)
$t+9$	0.28	0.09	0.41	-0.21
	(0.79)	(0.18)	(0.68)	(0.34)
$t+10$	0.30	0.02	-0.25	0.33
	(0.87)	(0.17)	(0.77)	(0.40)

Currency Co-movement

- If carry trades affect FX, it should also affect covariance matrix:
  - funding currencies move together, and so do investment currencies
  - i.e., the lower the interest rate differential, the more their FX rates co-move
- Variables
  - Dependent variable: pairwise correlation of daily log FX changes within 13-week (non-overlapping) windows, mapped to real line by 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 $\rho(\Delta s_1, \Delta s_2)$ = 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

	(1)	(2)	(3)	(4)
$\lvert i_1^* - i_2^* \rvert$	-10.89	-6.62	-16.39	-13.41
	(3.81)	(3.62)	(4.05)	(6.41)
$\rho(i_1^*, i_2^*)$	0.63	0.28	0.70	0.32
	(0.16)	(0.08)	(0.17)	(0.08)
Average $\rho(\Delta s_1, \Delta s_2)$	2.54	2.56		
	(0.08)	(0.08)		
Time Fixed Effects			Yes	Yes
Country-Pair Fixed Effects				Yes
	0.18	0.36	0.05	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

- 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"
- 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
- An increase in VIX associated with
  - carry losses, carry unwind (lower speculator positions)
  - price of insurance increases
- Funding currencies move together, funding currencies ditto

Carry

Ralph S.J. Koijen, LBS
Tobias J. Moskowitz, Chicago Booth and NBER
Lasse H. Pedersen, NYU, CBS, AQR, CEPR, NBER
Evert B. Vrugt, VU University Amsterdam, PGO-IM

The Concept of Carry

- Concept of carry almost exclusively applied to currencies
    - Carry = interest rate differential
    - Main findings:
        - Uncovered interest-rate parity (UIP) fails
        - Carry trade earns significant risk-adjusted returns
        - Negative skewness reflecting large sudden crashes
        - Substantial exposure to liquidity and volatility risks
- We generalize the concept of carry to any asset

Carry = "Return you earn if market conditions stay constant"

Carry and Returns: Key Questions

- Carry = "Return you earn if market conditions stay constant"
- Carry and returns:

$$\text{return} = \underbrace{\text{carry} + \text{E(price appreciation)}}_{\text{expected return}} + \text{unexpected price shock.}$$

  Carry is a characteristic of any asset that is *directly observable*

- Key research questions
  1. Does a generalized pan-asset-class version of UIP/EH hold?
  2. Do expected returns vary over time and across assets?
  3. How can expected returns be estimated ex ante?
  4. What drives expected returns?

What We Do

- Apply the general definition of carry across asset classes
- We test the key research questions in global markets
  - Global equities
  - Global bonds
  - Global slope trades
  - Commodities
  - US Treasuries across maturities
  - Credit markets
  - Options
- Methodology
  - Regression tests
  - Portfolio tests: carry trades
- Study the source of risk: crash, macro, liquidity, and volatility risks

Main Results: Caring About Carry

1. Carry predicts returns in each major asset class we study
   - Significant regressions; coefficient $\lessgtr 1$ depending on asset class
   - Sharpe ratio of Diversified Carry Factor $= 1.1$
   - Strong rejection of generalized UIP/EH in favor of models of varying risk premia
2. Potential underlying drivers
   - Not crash risk: limited skewness and kurtosis
   - Some exposure to liquidity risk
   - Some exposure to volatility risk
   - Drawdowns during recessions
3. Carry unifies and extends
   - Unified framework related to known predictors studied separately, one asset class at a time
   - Generates new predictors not studied before

$\Rightarrow$ Most finance models have direct implications for carry strategies and hence a useful new set of moments to calibrate models to

Defining Carry in Futures Markets

- The (excess) return on a fully-collateralized futures contract equals:

$$r_{t+1} = \frac{S_{t+1} - F_t}{F_t}$$

where S_t is the spot price and F_t the one-month futures price

- Carry is the return you earn if prices stay constant, i.e., $S_{t+1} = S_t$:

$$C_t = \frac{S_t - F_t}{F_t}$$

- We can write the (excess) return as:

$$r_{t+1} = \frac{S_{t+1} - F_t}{F_t} = \underbrace{C_t + \frac{E_t\left(\Delta S_{t+1}\right)}{F_t}}_{E_t(r_{t+1})} + u_{t+1}$$

- We apply this definition in every asset class

Carry in Currencies: Familiar Territory

- The currency carry equals, using $F_t = S_t(1 + r_t^f)/(1 + r_t^{f*})$:

$$C_t := \frac{S_t - F_t}{F_t} \propto r_t^{f*} - r_t^f$$

- The difference between the foreign and domestic interest rate – as usual

Carry in Equities

- The equity carry equals, using $F_t = S_t(1 + r_t^f) - E_t^Q(D_{t+1})$,:

$$C_t \propto \frac{E_t^{\mathbb{Q}}(D_{t+1})}{S_t} - r_t^f,$$

- The difference between the exp. dividend yield and the local r^f
- Consider the Gordon Growth Model for equity prices S_t:

$$S = \frac{D}{E(R) - g}$$

suggesting a link between expected excess returns and carry

$$E(R) - r^f = \frac{D}{S} - r^f + g$$

Carry in Commodities

- Commodity futures prices depend on δ_t the convenience yield, $F_t = S_t(1 + r_t^f - \delta_t)$

- The commodity carry equals:

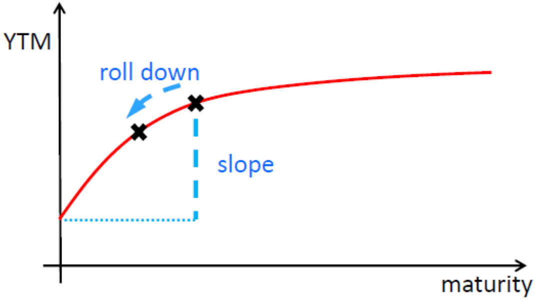
$$C_t \propto \delta - r_t^f,$$

the difference between the convenience yield and the risk-free rate

Carry in Fixed Income

- The carry of a T-year bond with $S_t = P_t^{T-1} = 1/(1+y_t^{T-1})^{T-1}$ and $F_t = (1+r_t^f)P_t^T$ is:

$$
\begin{aligned}
C_t^T &= \frac{P_t^{T-1}}{(1+r_t^f)P_t^T} - 1 \\
&\simeq \underbrace{y_t^T - r_t^f}_{\text{Slope}} \quad \underbrace{-D^{Modified}\left(y_t^{T-1} - y_t^T\right)}_{\text{Roll down}},
\end{aligned}
$$



Carry in Slope Trades

- The carry of a T-year bond with $S_t = P_t^{T-1} = 1/(1+y_t^{T-1})^{T-1}$ and $F_t = (1+r_t^f)P_t^T$ is:

$$\begin{aligned} C_t^T &= \frac{P_t^{T-1}}{(1+r_t^f)P_t^T} - 1 \\ &\simeq \underbrace{y_t^T - r_t^f}_{\text{Slope}} \quad \underbrace{-D^{Modified}\left(y_t^{T-1} - y_t^T\right)}_{\text{Roll down}}, \end{aligned}$$

- We also apply the same concept to the slope of the the term structure across markets:

$$C_t = C_t^{T_1} - C_t^{T_2},$$

where $T_1 > T_2$. Carry determined by two roll-down components and the yield difference between T_1 and T_2

Carry in Treasury and Credit Markets

- We can apply this definition to both Treasuries and corporate bonds
- Carry of longer maturities "mechanically" higher and more volatile due to differences in duration
- We adjust the carry definition to make it duration neutral:

$$C_t^{\text{duration-adjusted},i} = \frac{C_t^i}{D_t^i}$$

- Strategies also work for non-adjusted carry

Carry in Options Markets

- Start from the price of an option, $F_t^j(S_{it}, K, T, \sigma_T)$, $j = \text{Call}, \text{Put}$
- The option carry is defined as before:

$$C_{it}^j(K, T, \sigma_T) = \frac{F_t^j(S_{it}, K, T-1, \sigma_{T-1})}{F_t^j(S_{it}, K, T, \sigma_T)} - 1$$

- Using linear approximations, we get:

$$C_{it}^j(K, T, \sigma_T) \simeq \frac{-\theta_t^j(S_{it}, K, T, \sigma_T) + \nu_t^j(S_{it}, K, T, \sigma_T)(\sigma_{T-1} - \sigma_T)}{F_t^j(S_{it}, K, T, \sigma_T)}$$

$\Rightarrow$ Carry depends on the option's

- theta $\theta_t^j = -\frac{\partial F}{\partial \tau}$ and
- volatility "roll-down" $\sigma_{T-1} - \sigma_T$ scaled by vega $\nu_t^j = \frac{\partial F}{\partial \sigma}$

Data Overview: Global Markets

- Equity index data from 13 countries

  US, Canada, UK, France, Germany, Spain, Italy, Netherlands, Norway, Switzerland, Japan, Hong Kong, Australia

- Currency data for 20 countries

  Australia, Austria, Belgium, Canada, Denmark, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, UK, Euro, US

- Data on 24 commodities

  Aluminium, Copper, Nickel, Zinc, Lead, Gold, Silver, Crude Oil, Gasoil, WTI Crude, Unleaded Gasoline, Heating Oil, Natural Gas, Cotton, Coffee, Cocoa, Sugar, Soybeans, Kansas Wheat, Corn, Wheat, Lean Hogs, Feeder Cattle, Live Cattle

- Fixed income data for 10 countries

  Australia, Canada, Germany, UK, Japan, New Zealand, Norway, Sweden, Switzerland, US

$\Rightarrow$ For all asset classes, we have more than 20 years of data

Data Overview: Global Markets, Continued

- Treasuries:
  - 6 portfolios of US Treasuries sorted by maturity starting in 1971
  - Maturities: 1-12, 13-24, 25-36, 37-48, 49-60, and 61-120 months
- Credit portfolios:
  - 8 portfolios of corporate bonds from Barclays that vary by credit quality (AAA, AA, A, and BAA) and maturity (int. and long)
  - Sample starts in 1973
- Index options
  - Dow Jones Industrial Average, NASDAQ 100 Index, CBOE Mini-NDX Index, AMEX Major Market Index, S&P500 Index, S&P100 Index, S&P Midcap 400 Index, S&P Smallcap 600 Index, Russell 2000 Index, PSE Wilshire Smallcap Index
  - Consider two delta groups, $|\Delta| \in [0.2\text{-}0.4]$ or $|\Delta| \in [0.4\text{-}0.6]$, and maturities between 1 and 2 months starting in 1996
  - Implement the carry strategies separately for call and put options

Data Sources

- Bloomberg: Futures and spot prices for
  - Global equities
  - Global fixed income (Jonathan Wright for earlier sample)
  - Commodities
- Datastream:
  - Currency forward and spot exchange rates
  - Duration, yields, and returns for credit portfolios
- OptionMetrics:
  - Index options and implied volatilities by maturity and moneyness
- CRSP:
  - Maturity and returns for Treasuries portfolios
- Gürkaynak, Sack, and Wright:
  - Yields for Treasuries portfolios
- ECRI:
  - Business cycle data following the NBER methodology

Carry Predictability: Portfolio Tests

- Our carry trade portfolio weights

$$w_t^i = z_t \left(\text{rank}(C_t^i) - \frac{N_t + 1}{2} \right),$$

  - Linear in the rank of the carry
  - Invests a dollar long and short each period

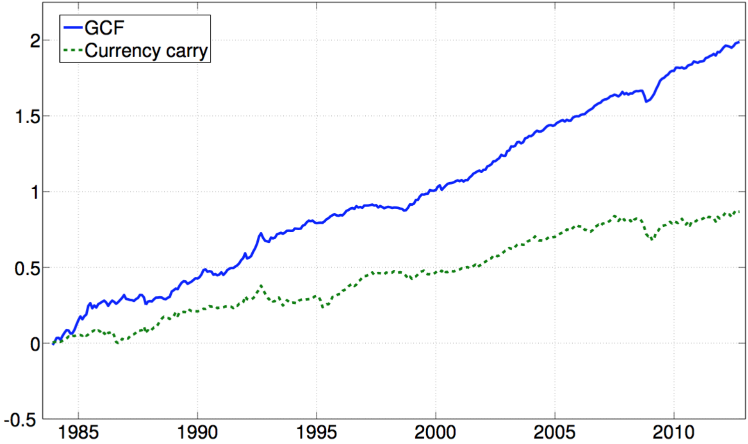
- We consider two versions of the carry strategy:
  - "Current carry": uses the current, 1-month carry
  - "Carry1-12": uses the 12-month moving average of the current carry to remove seasonal effects

Global Carry Trade Returns

Asset class	Strategy	Mean	Stdev	Skewness	Kurtosis	Sharpe ratio
Global equities	Carry	9.14	10.42	0.22	4.74	0.88
	EW	5.00	15.72	-0.63	3.91	0.32
Fixed income 10Y global	Carry	3.85	7.45	-0.43	6.66	0.52
	EW	5.04	6.85	-0.11	3.70	0.74
Fixed income 10Y–2Y global	Carry	3.77	5.72	-0.22	5.49	0.66
	EW	4.04	5.73	-0.05	3.67	0.71
US Treasuries	Carry	0.46	0.67	0.47	10.46	0.68
	EW	0.69	1.22	0.58	12.38	0.57
Commodities	Carry	11.22	18.78	-0.40	4.55	0.60
	EW	1.05	13.45	-0.71	6.32	0.08
Currencies	Carry	5.29	7.80	-0.68	4.46	0.68
	EW	2.88	8.10	-0.16	3.44	0.36
Credit	Carry	0.24	0.52	1.32	18.19	0.47
	EW	0.37	1.09	-0.03	7.09	0.34
Options calls	Carry	64	172	-2.82	14.49	0.37
	EW	-73	313	1.15	3.88	-0.23
Options puts	Carry	179	99	-1.75	10.12	1.80
	EW	-299	296	1.94	7.11	-1.01
All asset classes (global carry factor)	Carry	6.75	6.12	-0.02	5.24	1.10
	EW	3.46	7.34	-0.38	7.94	0.47

Global Carry Factor: Cumulative Returns

- Strong performance of the global carry factor:



Static and Dynamic Components of Carry Returns

Decompose expected return into static and dynamic components:

$$
\begin{aligned}
E\left(r_{t+1}^{\text{carry trade}}\right) &= E\left(\sum_i w_t^i r_{t+1}^i\right) \\
&= \sum_i E\left(w_t^i\right) E\left(r_{t+1}^i\right) \\
&\quad + \sum_i E\left[\left(w_t^i - E\left(w_t^i\right)\right)\left(r_{t+1}^i - E\left(r_{t+1}^i\right)\right)\right]
\end{aligned}
$$

Static and Dynamic Components of Carry Returns

Individual securities	Static	Dynamic	% Dynamic
Equities global	-0.1%	9.3%	101%
Fixed income - 10Y global	0.6%	3.3%	86%
Fixed income - 10Y−2Y global	0.1%	3.7%	99%
US Treasuries	0.3%	0.2%	42%
Commodities	4.1%	7.1%	64%
Currencies	2.2%	3.1%	58%
Credit	0.2%	0.1%	30%
Options calls	-7.2%	70.8%	111%
Options puts	-0.4%	179.3%	100%

Regions and groups	Static	Dynamic	% Dynamic
Equities global	-0.6%	6.6%	111%
Fixed income - 10Y global	0.5%	3.3%	87%
Fixed income - 10Y−2Y global	0.2%	3.9%	96%
Commodities	-0.4%	15.4%	103%
Currencies	2.3%	2.4%	51%

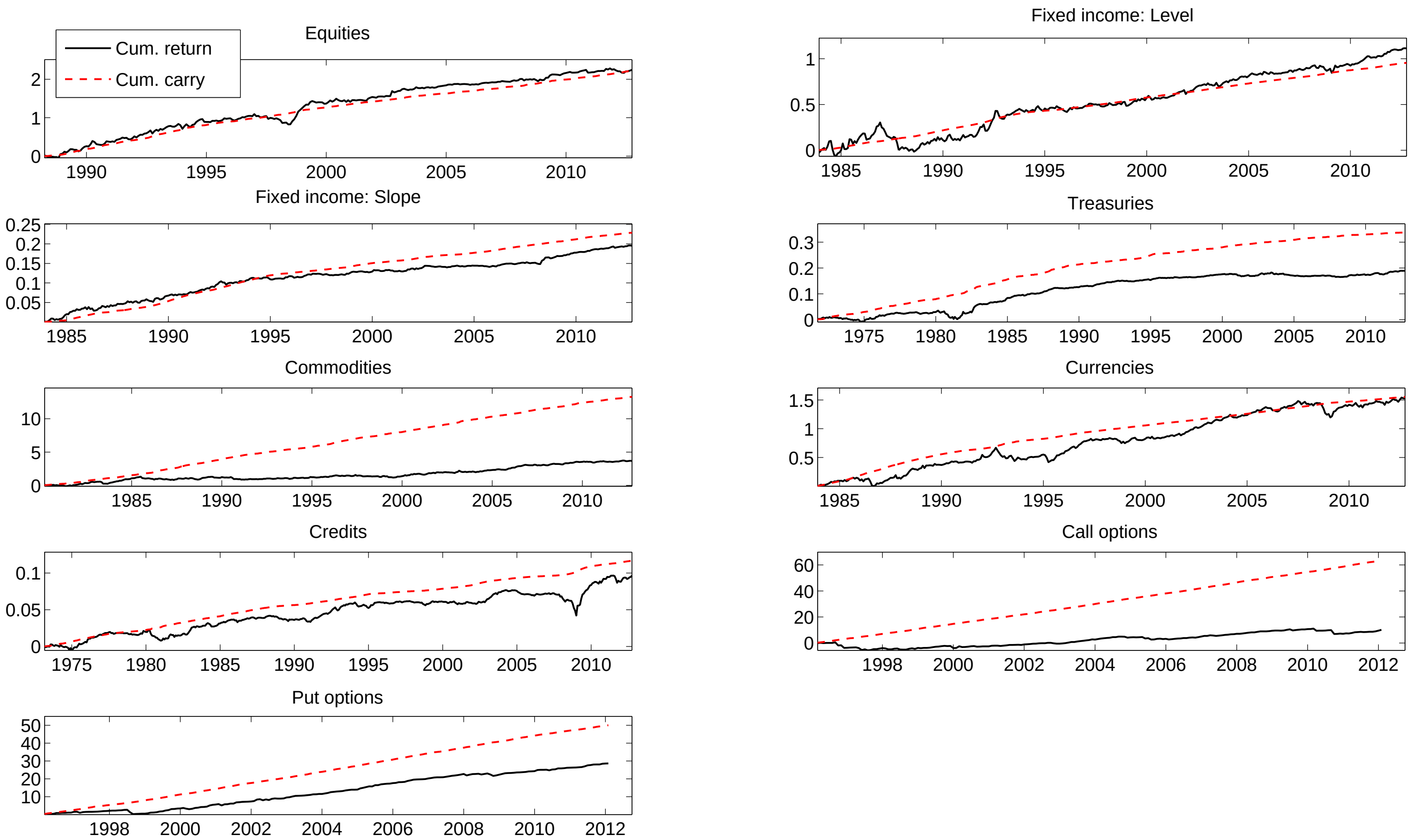


Figure 2: **Global Carry Strategies: Cumulative Return and Cumulative Carry.** The figure shows, for each asset class, the cumulative sum of the excess returns of the long-short carry portfolio. Also, the figure shows the cumulative carry (that is, cumulative return if prices stay the same over each month) of the carry trade. The difference between the return and the carry is the realized price appreciation of the long versus short positions. A cumulative return below the cumulative carry indicates that the market "takes back" part of the carry, otherwise the carry investor earns capital appreciation in addition to the carry. The sample period is 1972 to September 2012.

Risk Exposures

Common carry structure across markets

- Correlations across carry trade

What are the risk exposures that could help explain the return premium?

- Value and momentum?
- Liquidity or volatility risk?
- Prolonged drawdowns during bad times

Table V: **Correlation of Global Carry Strategies vs. Traditional Predictors**

Panel A reports the monthly return correlations between carry strategies (using carry1-12) for each asset class where carry trades are performed using individual securities within each asset class. Bootstrapped standard errors from 10,000 random long-short strategies created for each asset class are in parentheses. Panel B reports monthly correlations across asset classes of their long-only equal weighted index of all securities within each asset class. Panel C reports monthly correlations in carry trades across broader asset class groups, Panel D reports monthly correlations of the standard predictor of returns in each asset class for the same broad asset class groups, Panel E reports the correlations of value and Panel F the correlations of momentum returns across the same asset class groups.

Panel A: Correlations of Carry Trade Returns Across Asset Classes

	EQ	FI 10Y	FI 10Y−2Y	Treasuries	COMM	FX	Credit	Calls	Puts
EQ		0.17	0.16	0.12	0.03	0.14	0.09	-0.08	-0.07
FI 10Y	(0.08)		-0.07	0.06	0.06	0.06	-0.03	0.09	-0.03
FI 10Y−2Y	(0.07)	(0.08)		0.13	0.02	-0.10	0.14	0.12	0.02
Treasuries	(0.06)	(0.06)	(0.07)		0.11	0.07	0.05	0.05	0.12
COMM	(0.06)	(0.06)	(0.06)	(0.08)		0.10	0.14	-0.14	0.15
FX	(0.06)	(0.07)	(0.07)	(0.07)	(0.06)		0.31	0.06	0.11
Credit	(0.06)	(0.05)	(0.06)	(0.11)	(0.06)	(0.10)		-0.01	-0.02
Calls	(0.09)	(0.08)	(0.07)	(0.05)	(0.07)	(0.07)	(0.04)		-0.02
Puts	(0.08)	(0.07)	(0.08)	(0.09)	(0.07)	(0.07)	(0.10)	(0.07)	

Panel B: Correlation of Long-Only Equal-Weighted Benchmark Across Asset Classes

	EQ	FI 10Y	FI 10Y−2Y	Treasuries	COMM	FX	Credit	Calls	Puts
EQ		0.03	0.09	-0.18	0.29	0.12	0.17	0.71	-0.82
FI 10Y			0.21	0.68	-0.15	0.05	0.65	-0.08	0.17
FI 10Y−2Y				-0.04	0.02	-0.08	0.22	0.08	-0.12
Treasuries					-0.11	0.13	0.81	-0.19	0.35
COMM						0.47	0.05	0.30	-0.33
FX							0.22	0.20	-0.23
Credit								0.07	-0.16
Calls									-0.61

Correlation of Factors Across Broad Asset Classes

	Panel C: Carry				Panel D: Standard Predictor			
	EQ	FI	COMM	FX	EQ	FI	COMM	FX
EQ		0.24	0.03	0.14		-0.03	-0.08	-0.20
FI			0.16	0.26			0.06	0.12
COMM				0.10				0.02
	Panel E: Value				**Panel F: Momentum**			
	EQ	FI	COMM	FX	EQ	FI	COMM	FX
EQ		-0.07	0.02	0.02		0.14	0.21	0.19
FI			-0.06	0.02			0.11	0.14
COMM				0.14				0.06

Table VI: **Individual Carry Strategy Exposure to the Global Carry Factor**

The table reports the result of regressing each carry portfolio on the global carry factor (GCF). We consider two versions of each regression: one in which the GCF is an equal-risk-weighted average of all carry strategies ("own asset included") and one in which the GCF excludes the asset class being evaluated ("own asset excluded"). The intercepts or alphas (in percent) from these regressions as well as the betas on the GCF (that includes or excludes the own asset class) are reported along with their t-statistics (in parentheses) and the R^2 from the regression. The mean return and t-statistic of each strategy is also reported.

	Equities global		**FI level**		**FI slope**	
Own asset	Included	Excluded	Included	Excluded	Included	Excluded
mean	0.76	0.76	0.32	0.32	0.06	0.06
	(4.36)	(4.36)	(2.78)	(2.78)	(5.53)	(5.53)
α	0.04	0.57	-0.19	0.20	0.01	0.04
	(0.18)	(2.64)	(-1.43)	(1.61)	(0.99)	(3.77)
GCF	1.22	0.34	0.82	0.18	0.07	0.02
	(6.79)	(1.92)	(6.85)	(1.78)	(7.89)	(2.06)
R^2	20.0	1.7	20.3	1.1	21.2	1.7
	Treasuries		**Commodities**		**FX**	
Own asset	Including	Excluding	Including	Excluding	Including	Excluding
mean	0.04	0.04	0.93	0.93	0.44	0.44
	(4.39)	(4.39)	(3.42)	(3.42)	(3.65)	(3.65)
α	-0.01	0.02	0.02	0.68	-0.06	0.31
	(-1.13)	(2.24)	(0.06)	(2.38)	(-0.45)	(2.10)
GCF	0.08	0.03	1.47	0.38	0.81	0.21
	(12.62)	(3.93)	(8.04)	(2.66)	(7.38)	(1.75)
R^2	47.9	5.3	17.3	1.6	18.2	1.3
	Credit		**Calls**		**Puts**	
Own asset	Including	Excluding	Including	Excluding	Including	Excluding
mean	0.02	0.02	5.30	5.30	14.91	14.91
	(2.93)	(2.93)	(1.49)	(1.49)	(7.23)	(7.23)
α	-0.01	0.01	-2.71	6.33	7.61	13.11
	-(0.88)	(1.72)	(-0.58)	(1.87)	(2.88)	(5.35)
GCF	0.04	0.01	13.68	-1.67	12.46	3.83
	(8.87)	(3.15)	(4.24)	(-0.47)	(5.11)	(1.63)
R^2	22.8	2.9	7.9	0.1	19.5	1.9

Carry vs. Value and Momentum

Carry different from value and momentum

- Momentum: One-year past returns
- Value: Current price relative to fundamental value (or 5-year past returns)
- Carry: Forward-looking return, assuming market conditions stay constant

Risk-adjustment Performance and Exposures

	Equities global		FI Level		FI Slope		Treasuries		Commodities	
α	0.79	0.77	0.35	0.33	0.34	0.29	0.03	0.02	0.93	0.64
	(4.51)	(4.51)	(3.06)	(3.08)	(4.00)	(3.63)	(3.38)	(2.74)	(3.43)	(2.57)
Passive long	-0.06	-0.06	-0.07	-0.18	-0.07	-0.23	0.16	0.12	0.01	-0.02
	(-1.10)	(-1.16)	(-0.94)	(-2.10)	(-0.91)	(-3.03)	(2.57)	(3.51)	(0.12)	(-0.31)
Value		0.17		0.07		0.07		0.00		-0.21
		(1.84)		(0.51)		(0.64)		(-0.67)		(-2.96)
Momentum		0.06		0.56		0.43		0.00		0.29
		(0.74)		(4.26)		(4.37)		(0.04)		(3.81)
TSMOM		-0.04		0.03		0.04		0.00		-0.04
		(-1.69)		(1.82)		(3.12)		(0.80)		(-0.45)
R^2	0.01	0.03	0.00	0.16	0.00	0.20	0.08	0.07	0.00	0.20
IR	0.91	0.90	0.57	0.61	0.71	0.70	0.54	0.64	0.60	0.47

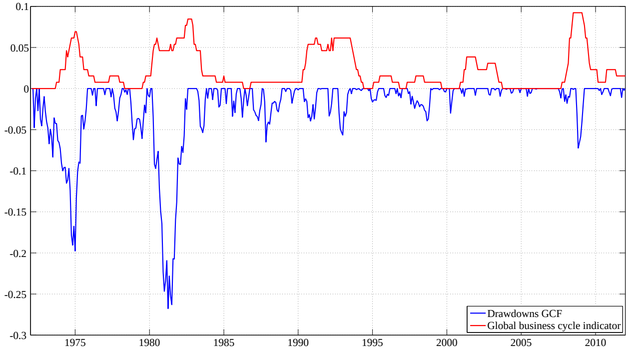
	FX		Credits		Calls		Puts		*GCF*	
α	0.40	0.30	0.02	0.02	3.21	6.93	13.02	12.55	0.53	0.44
	(3.31)	(2.31)	(2.85)	(1.70)	(1.07)	(2.15)	(4.74)	(4.55)	(6.52)	(5.51)
Passive long	0.17	0.22	0.02	0.14	-0.34	-0.35	-0.08	-0.09	0.10	0.14
	(2.47)	(3.46)	(0.50)	(2.31)	(-5.90)	(-6.07)	(-1.85)	(-2.10)	(1.34)	(1.78)
Value		0.11		0.01		-5.96		2.82		0.08
		(1.08)		(0.81)		(-2.14)		(0.98)		(1.00)
Momentum		0.03		0.00		-4.32		2.14		0.10
		(0.31)		(-0.21)		(-2.54)		(1.01)		(1.45)
TSMOM		0.01		0.00		-0.92		-0.77		-0.01
		(0.25)		(-1.42)		(-1.00)		(-1.07)		(-0.22)
R^2	0.03	0.05	0.00	0.07	0.39	0.43	0.05	0.07	0.02	0.04
IR	0.63	0.47	0.45	0.39	0.29	0.64	1.61	1.56	1.05	1.24

Exposures to Global Liquidity and Volatility Shocks

Asset class	Exposure liquidity shocks	T-stat.	Exposure volatility changes	T-stat.
Equities	0.22	1.65	-0.12	-0.49
FI 10Y	0.28	1.44	-0.54	-2.25
FI 10Y−2Y	0.32	1.65	-0.31	-1.19
Treasuries	-0.21	-0.80	0.54	2.92
Commodities	0.26	2.36	-0.42	-2.74
Currencies	0.88	3.62	-1.03	-6.46
Credit	1.24	3.78	-0.58	-2.05
Options calls	-0.03	-0.33	-0.10	-0.84
Options puts	0.57	2.48	-0.62	-2.00

Carry Drawdowns and Recession Risk

Carry drawdowns: $D_t = \sum_{s=1}^{t} r_s - \max_{u \in \{1,\dots,t\}} \sum_{s=1}^{u} r_s$



Three major carry drawdowns:

- 1972.8 - 1975.9 (DD = -19.6%)
- 1980.3 - 1982.6 (DD = -26.8%)
- 2008.8 - 2009.2 (DD = -7.2%)

Carry Drawdowns: Returns per Asset Class

		Carry expansions		Carry drawdowns	
Asset class	Strategy	Mean	Stdev	Mean	Stdev
Equities	Carry	15.03	9.71	-6.15	10.95
	EW	8.31	13.73	-3.62	19.87
FI global, 10Y	Carry	10.84	6.19	-13.90	7.93
	EW	3.75	6.53	8.33	7.55
FI global, 10Y−2Y	Carry	8.10	5.10	-7.25	5.98
	EW	2.94	5.45	6.85	6.34
Treasuries	Carry	0.97	0.64	-0.57	0.65
	EW	0.98	1.14	0.10	1.34
Commodities	Carry	21.49	17.33	-13.23	20.24
	EW	4.54	11.73	-7.24	16.68
Currencies	Carry	10.06	7.29	-6.81	8.00
	EW	5.17	7.68	-2.95	8.89
Credit	Carry	0.60	0.52	-0.50	0.45
	EW	0.84	1.03	-0.61	1.15
Options calls	Carry	152	138	-161	225
	EW	195	272	-237	389
Options puts	Carry	258	77	-22	124
	EW	364	238	132	409

Carry in the Time Series: Timing Strategies

Timing carry by going long/short based on carry (relative to zero)

Individual securities	mean	stdev	skewness	kurtosis	Sharpe ratio
Equities	7.40	18.55	0.39	4.49	0.40
FI global, 10Y	7.09	10.93	-0.16	4.05	0.65
FI global, 10Y–2Y	6.90	9.62	-0.15	4.29	0.72
Treasuries	1.36	2.28	-0.48	14.51	0.60
Commodities	8.28	20.78	0.13	5.56	0.40
Currencies	7.86	10.08	-0.72	5.63	0.78
Credit	1.27	2.00	-0.24	8.00	0.64
Options calls	146.45	626.92	-1.15	3.88	0.23
Options puts	597.76	592.72	-1.94	7.11	1.01

Conclusion

- Carry is an important characteristic which is directly observable
- Carry predicts returns in every asset class
  - Broad rejection of UIP/EH
  - E(R) varies over time and across assets as captured by carry
  - Strong performance of our Global Carry Factor
- Carry captures varying E(R) driven by
  - Recession risk in carry drawdowns
  - Liquidity risk
  - Volatility risk
  - Limited arbitrage and other effects – future research