Cross-Asset Carry

Summary of findings of *Harvesting Yield from Cross-Asset Carry* note (30 August 2016)

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Carry…

"…is the income you earn if the price stays the same over the holding period"

Koijen, Moskowitz, Pedersen & Vrugt (2015)

Literature

- Academic literature on FX carry is vast
- Literature on multi-asset carry is, instead, scarce

	Universe	Cross-Sectional	Time-Series	Optimised
Burnside, Eichenbaum & Rebelo (2011)	FX		√	
Olszweski & Zhou (2014)	FX	√		
Barroso & Santa-Clara (2015)	FX	√	√	√
Doskov & Swinkels (2015)	FX	√		
Daniel, Hodrick & Lu (2016)	FX	√	√	√
Bekaert & Panayotov (2016)	FX	√		
Ackermann, Pohl & Schmedders (2016)	FX	√		√
Ahmercamp & Grant (2013)	Multi-asset		√	
Koijen, Moskowitz, Pedersen & Vrugt (2015)	Multi-asset	√		
Baz, Granger, Harvey, Le Roux & Rattray (2015)	Multi-asset	√	√	
This Report	Multi-asset	√	√	√

Source: UBS Quantitative Research

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Section 1

The Concept of Carry

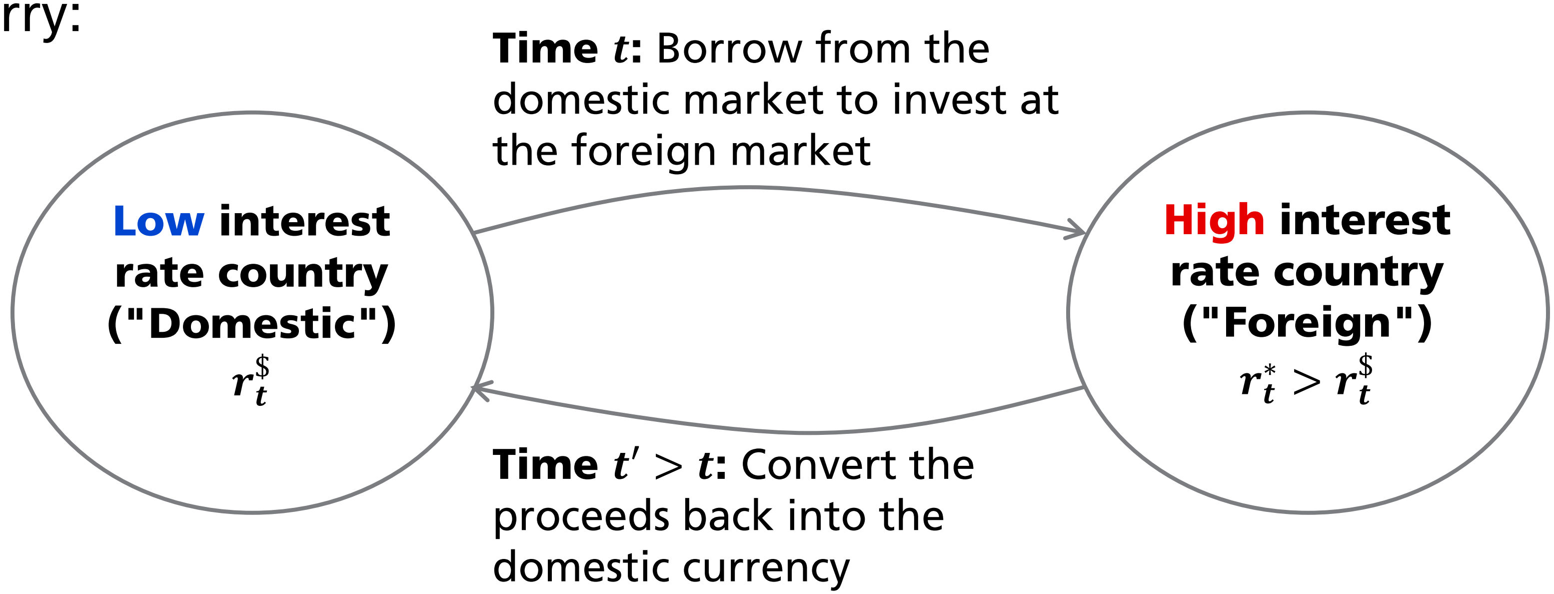
The concept of Carry

- Asset return decomposition (Koijen *et al.* 2015):

$$Return = \underbrace{\color{red}{Carry} + \boldsymbol{E}(price\ appreciation)}_{\boldsymbol{E}(Return)} + unexpected\ price\ shock$$

- Carry is the return obtained if the price does **not** move.

- FX Carry:



- If the FX rate does **not** move, then the return (carry) equals the IR differential:

$$\boxed{Return^{FX\ Carry} = r_t^* - r_t^{\$}, \qquad \text{if} \quad FX_t = FX_{t'}}$$

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Extending FX Carry

- Consider a currency forward/futures contract:

$$F_t = S_t \cdot \frac{1 + r_t^{\$}}{1 + r_t^{*}}$$

$$\Rightarrow r_t^{*} - r_t^{\$} = \left(1 + r_t^{\$}\right) \cdot \frac{S_t - F_t}{F_t}$$

- The $(1 + r_t^{\$})$ is only a proportionality factor, common across all foreign CCYs
- We therefore define carry as follows:

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

- Hence, the fact that $\boldsymbol{r_t^{*} > r_t^{\$}}$ is <u>equivalent to</u>:
  – A positive basis, $S_t - F_t > 0$
  – A downward sloping forward/futures curve → Backwardation
  – The foreign CCY trades at a discount, $F_t - S_t < 0$

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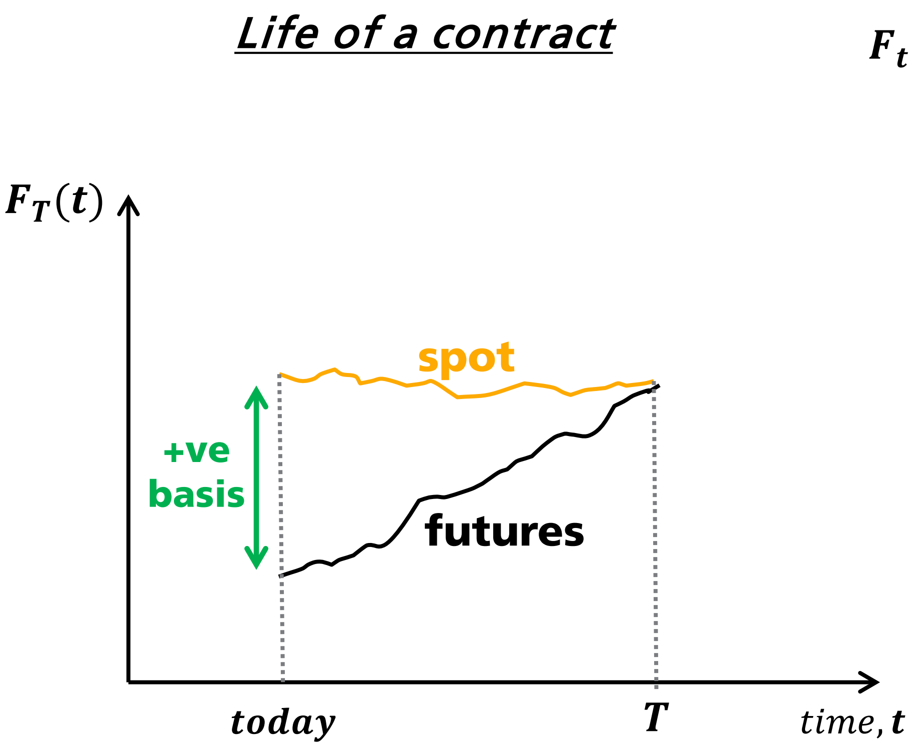
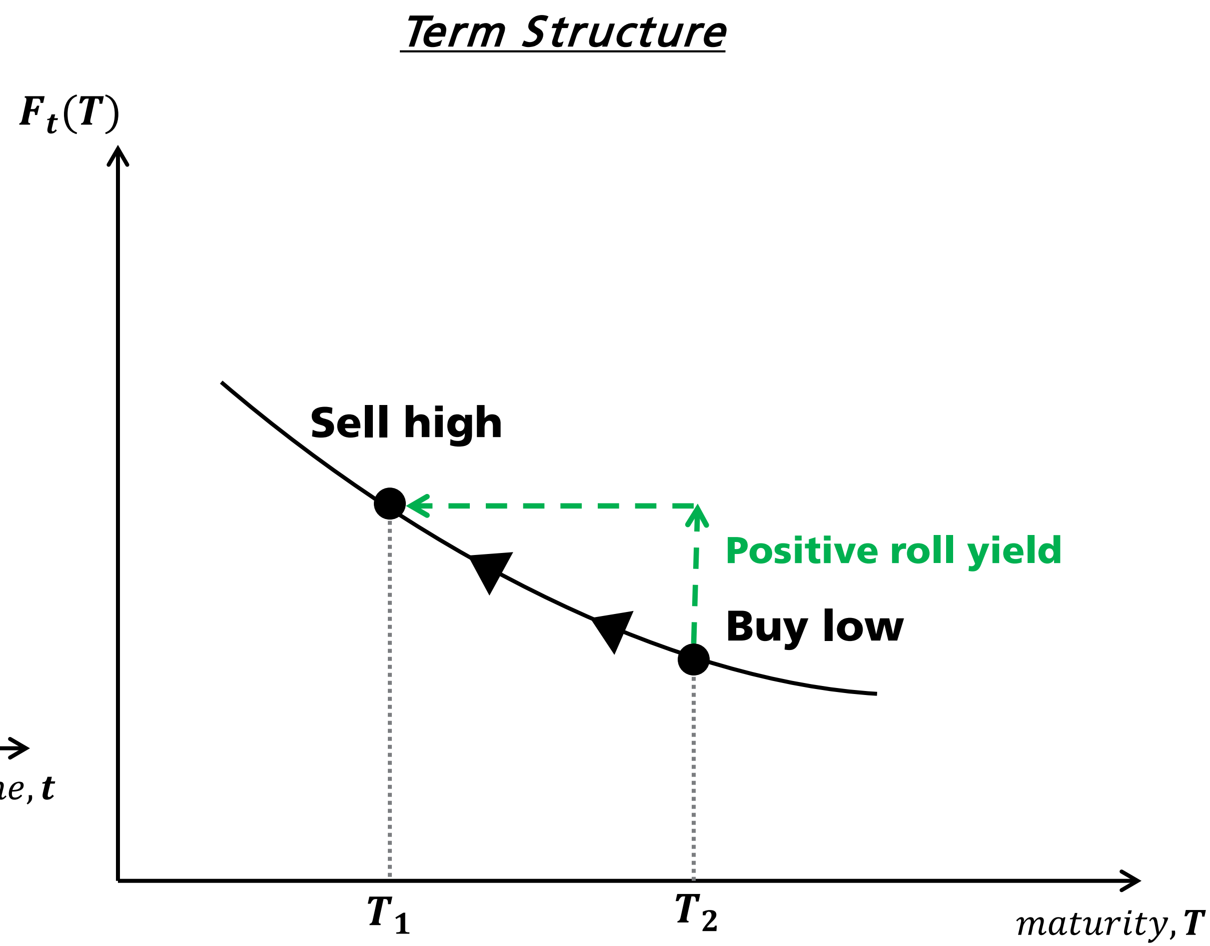
Extending FX Carry

- So, FX Carry:
  - Take long positions in CCYs that trade at a discount ("*backwardated*")
  - Take short positions in CCYs that trade at a premium ("*contangoed*")
- If "*conditions stay the same*" over the holding period…
  - Rolling backwardated futures generates positive rolling yield
  - Rolling contangoed futures generates negative rolling yield
- This allows the extension of the concept of carry to other asset classes using the **futures markets** and measuring the **slope of the futures curve**.

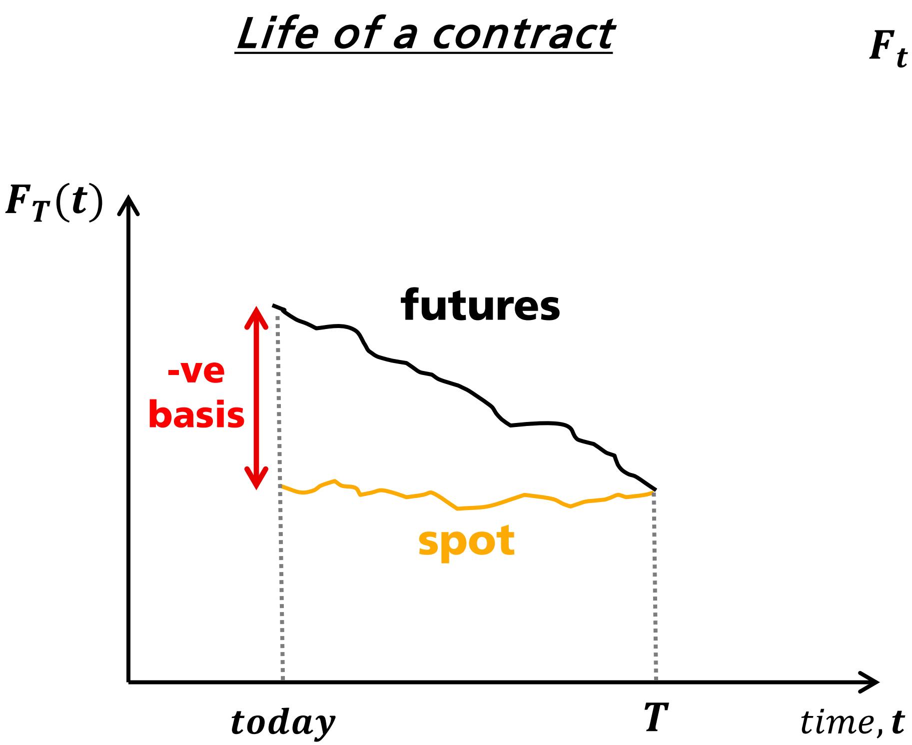
The mechanics of Carry - Backwardation

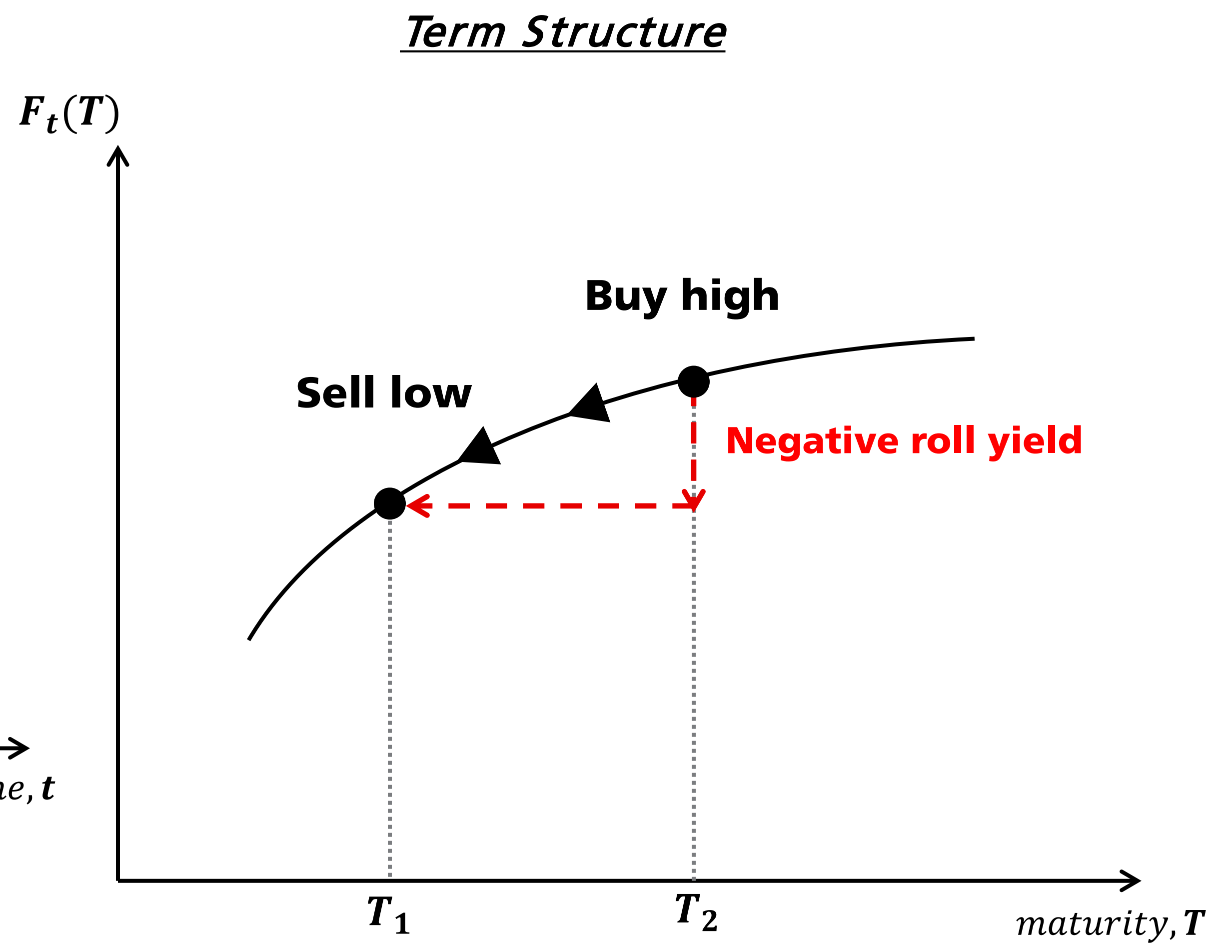




- Typical examples: NZD, AUD, government bonds, commodities in short supply

The mechanics of Carry - Contango





- Typical examples: CHF, JPY, equity indices, most cmdties post-financialisation

Source: UBS Quantitative Research

Carry across asset classes

- To simplify notation, assume time-to-maturity: $T - t = 1\ year$

Asset Class	Futures Price	Carry
FX	$F_t = S_t \cdot \frac{1 + r_t}{1 + r_t^*}$ r_t^*: foreign currency risk-free rate	$C_t \propto r_t^* - r_t$
Equity Indices	$F_t = S_t \cdot (1 + r_t - q_t)$ q_t: dividend yield	$C_t \propto q_t - r_t$
Commodities	$F_t = S_t \cdot (1 + r_t + c_t - y_t)$ c_t: storage costs y_t: convenience yield	$C_t \propto (y_t - c_t) - r_t$
Government Bonds	$F_t = \frac{1 + r_t}{(1 + y_t^{10Y})^{10}}$ $y_t^{9Y},\ y_t^{10Y}$: 9yr, 10yr zero-coupon bond yield	$C_t \propto y_t^{10Y} - D_{mod} \cdot (y_t^{9Y} - y_t^{10Y}) - r_t$ D_{mod}: modified duration

Source: UBS Quantitative Research

Carry signal generation

- Given the idiosyncrasies of each asset class, we capture the slope of the futures curve using different definitions per asset class:

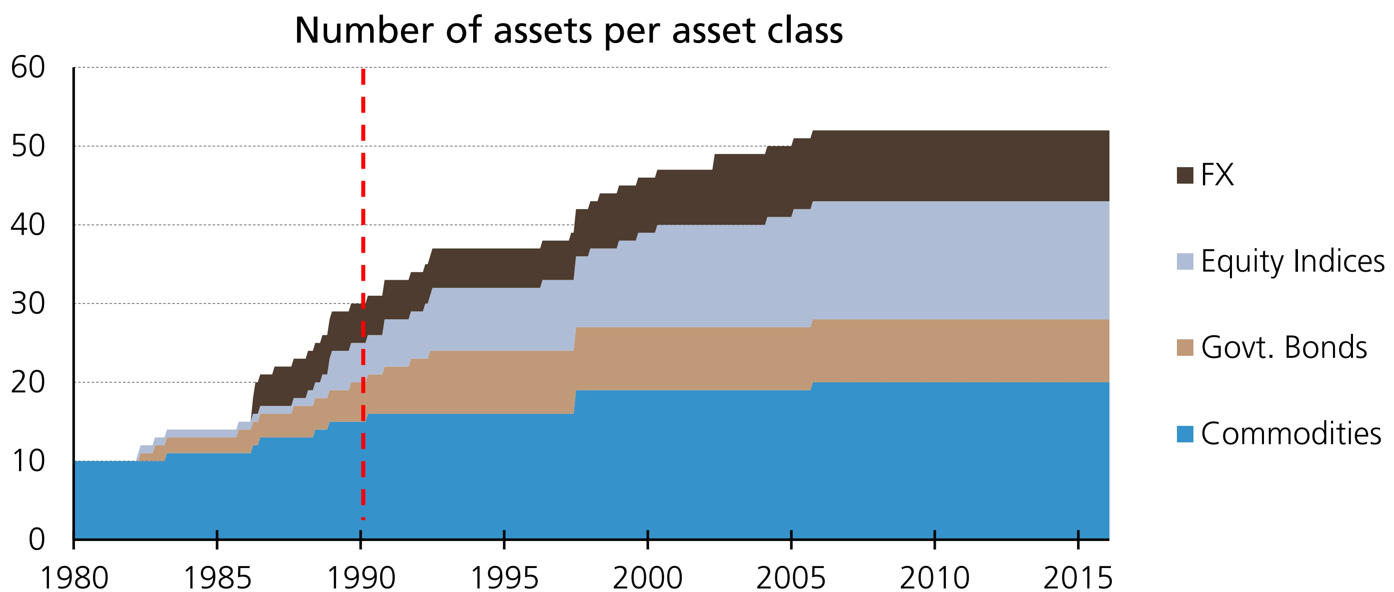
Asset Class	Chosen Metric	Alternatives
FX	$\frac{Spot_t - Fwd_t^{1M}}{Fwd_t^{1M}}$	1. $r_t^* - r_t$ 2. $\frac{1}{T_2-T_1} \cdot \frac{Fut_t^{T_1} - Fut_t^{T_2}}{Fut_t^{T_1}}$
Equity Indices	$\frac{1}{T_2 - T_1} \cdot \frac{Fut_t^{T_1} - Fut_t^{T_2}}{Fut_t^{T_1}}$ Seasonally adjusted (12 months)	$\frac{Spot_t - Fut_t^{1M,intrpl}}{Fut_t^{1M,intrpl}}$ Seasonally adjusted (12 months)
Commodities	$\frac{1}{T_2 - T_1} \cdot \frac{Fut_t^{T_1} - Fut_t^{T_2}}{Fut_t^{T_1}}$ Seasonally adjusted (12 months)	*n/a*
Government Bonds	$\frac{Spot_t^{9Y11M,intrpl} - Fut_t^{1M;10Y,Synth}}{Fut_t^{1M;10Y,Synth}}$	$\frac{1}{T_2 - T_1} \cdot \frac{Fut_t^{T_1} - Fut_t^{T_2}}{Fut_t^{T_1}}$

Note: See examples for the seasonal adjustment at the appendix

Source: UBS Quantitative Research

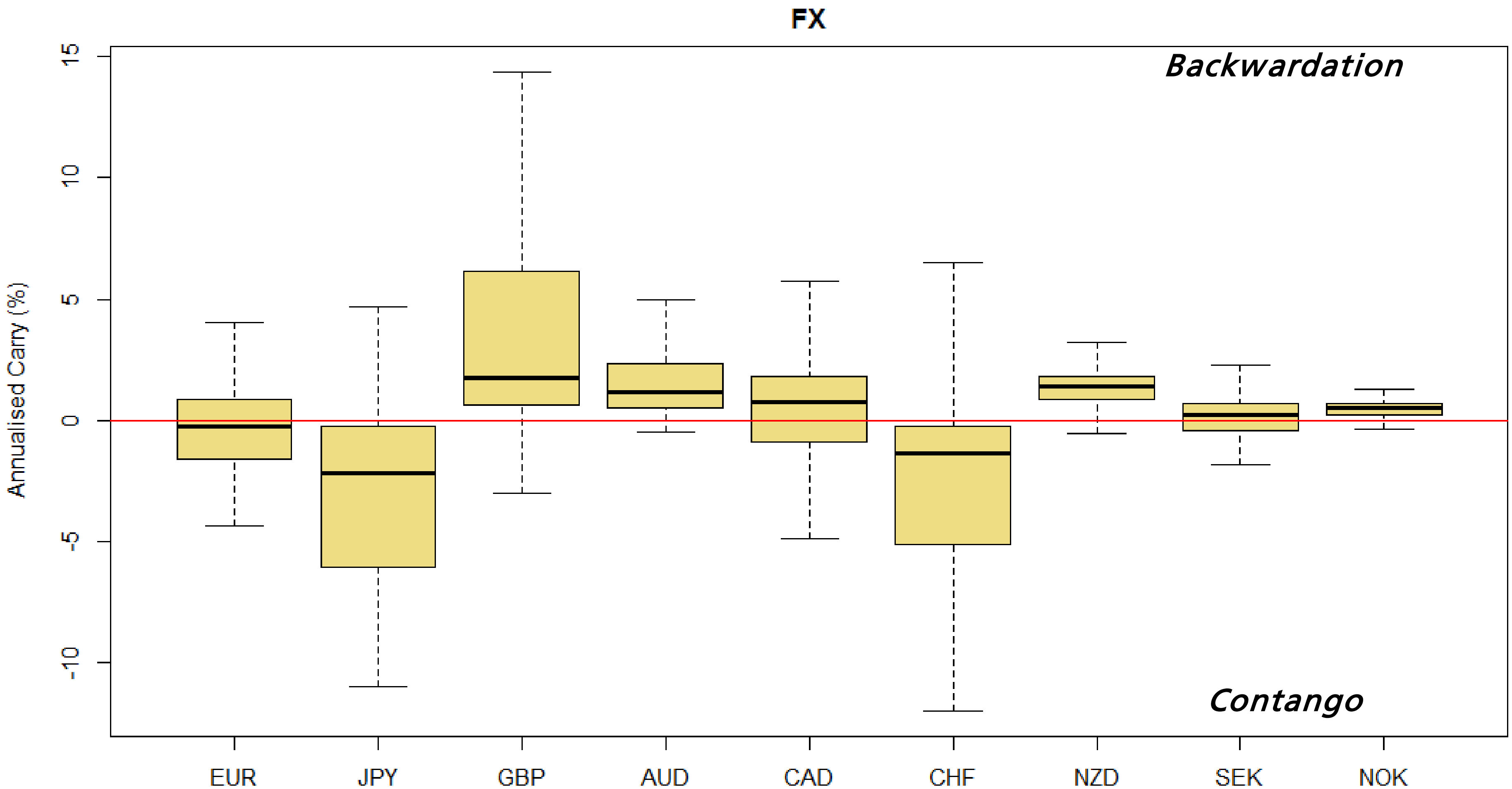
Dataset for back-testing

- Futures Data
  - Source: **Bloomberg**
  - Daily closing futures prices for 52 assets over the period January 1990 – January 2016:
    - 20 Commodities (BCOM constituents ex. precious metals) [15 in January 1990]
    - 8 Government Ten-Year Bonds [5 in January 1990]
    - 9 FX Rates (G10 pairs vs. USD) [5 in January 1990]
    - 15 Country Equity Indices [5 in January 1990]
    - ➢ See the appendix for the full list.



Source: Bloomberg

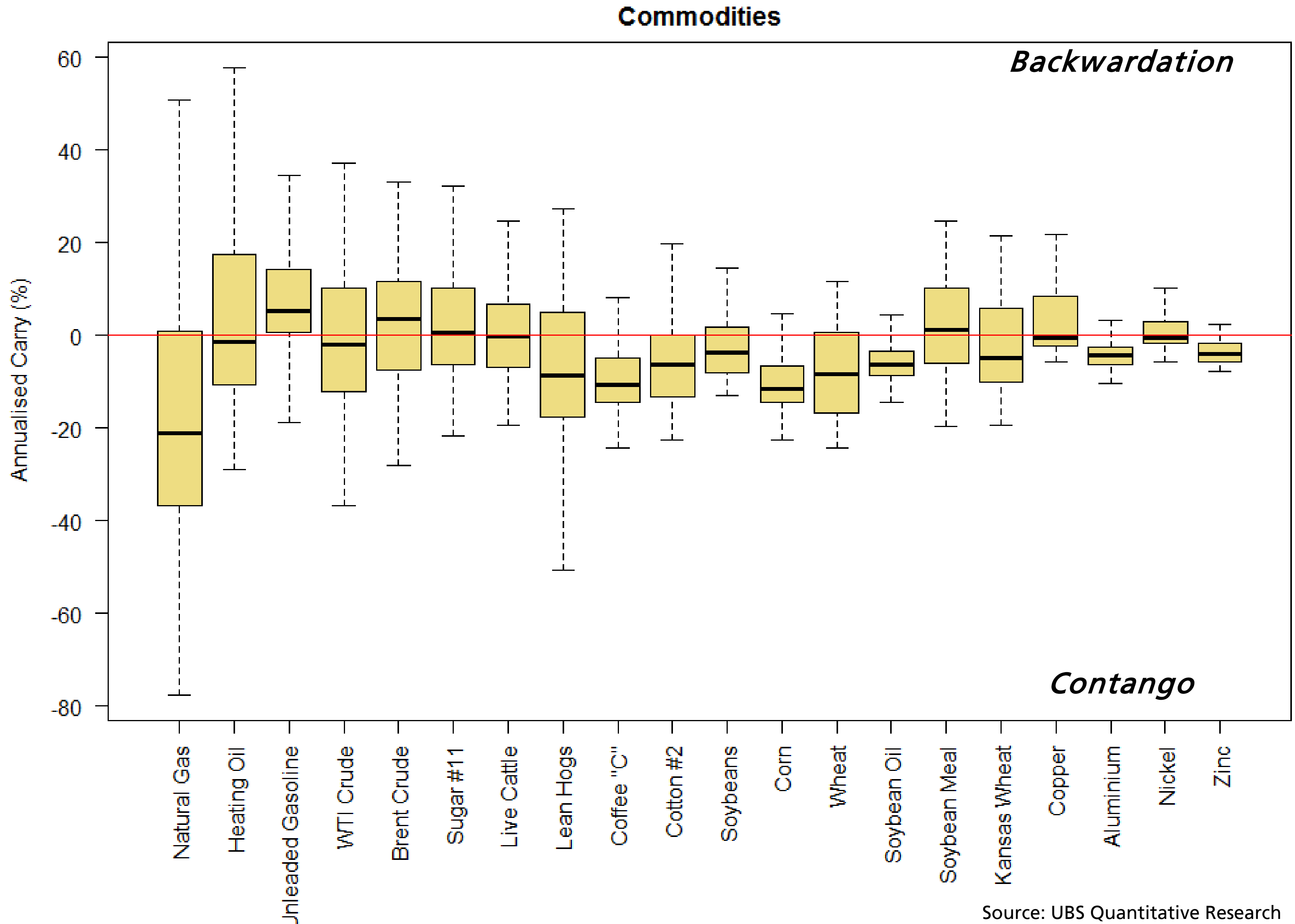
Carry in the cross-section (1990M01 – 2016M01)



Source: UBS Quantitative Research
For illustrative purposes only

* Not all contracts start in January 1990. See Appendix.

Carry in the cross-section (1990M01 – 2016M01)



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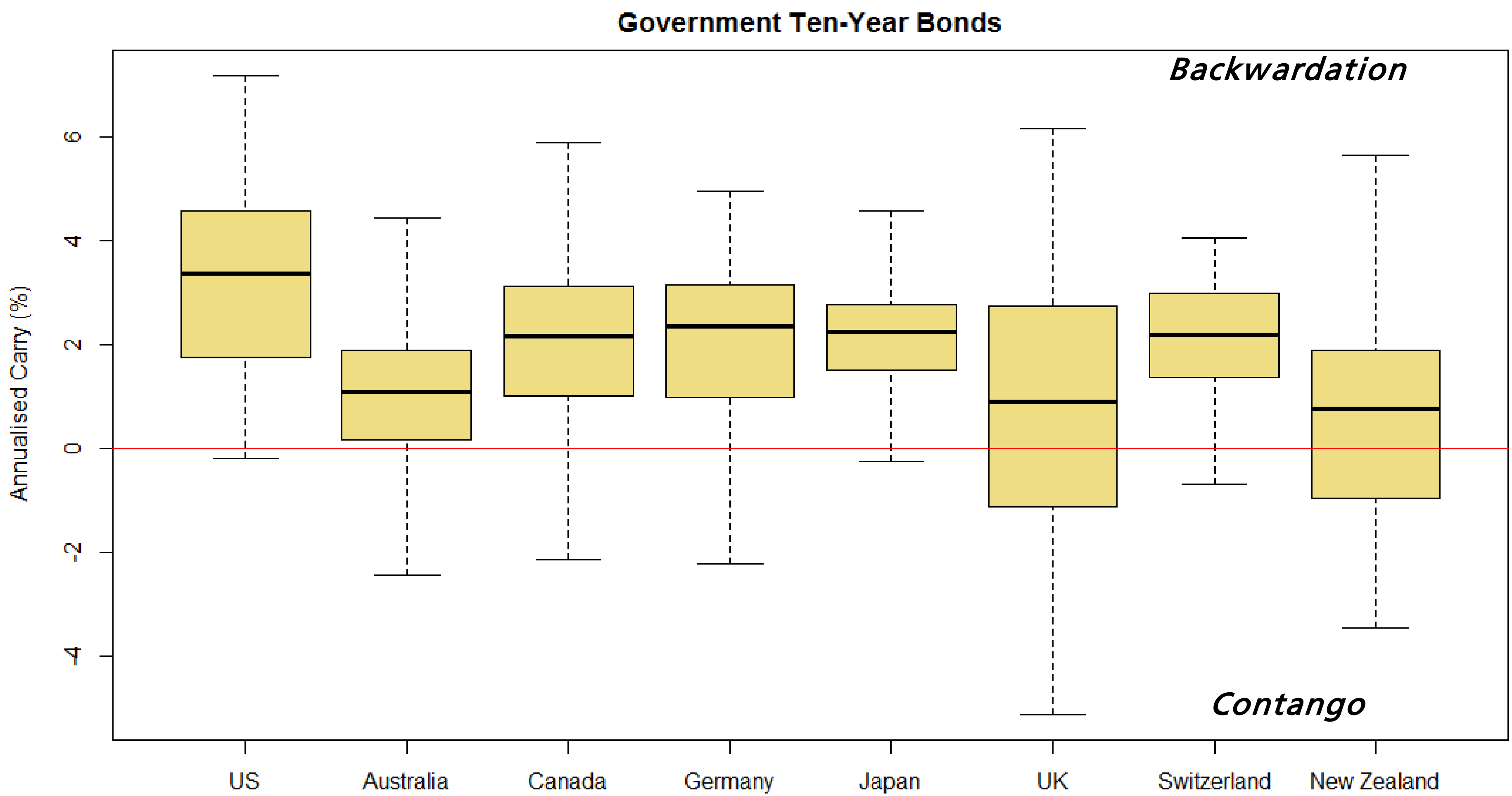
Carry in the cross-section (1990M01 – 2016M01)



Source: UBS Quantitative Research
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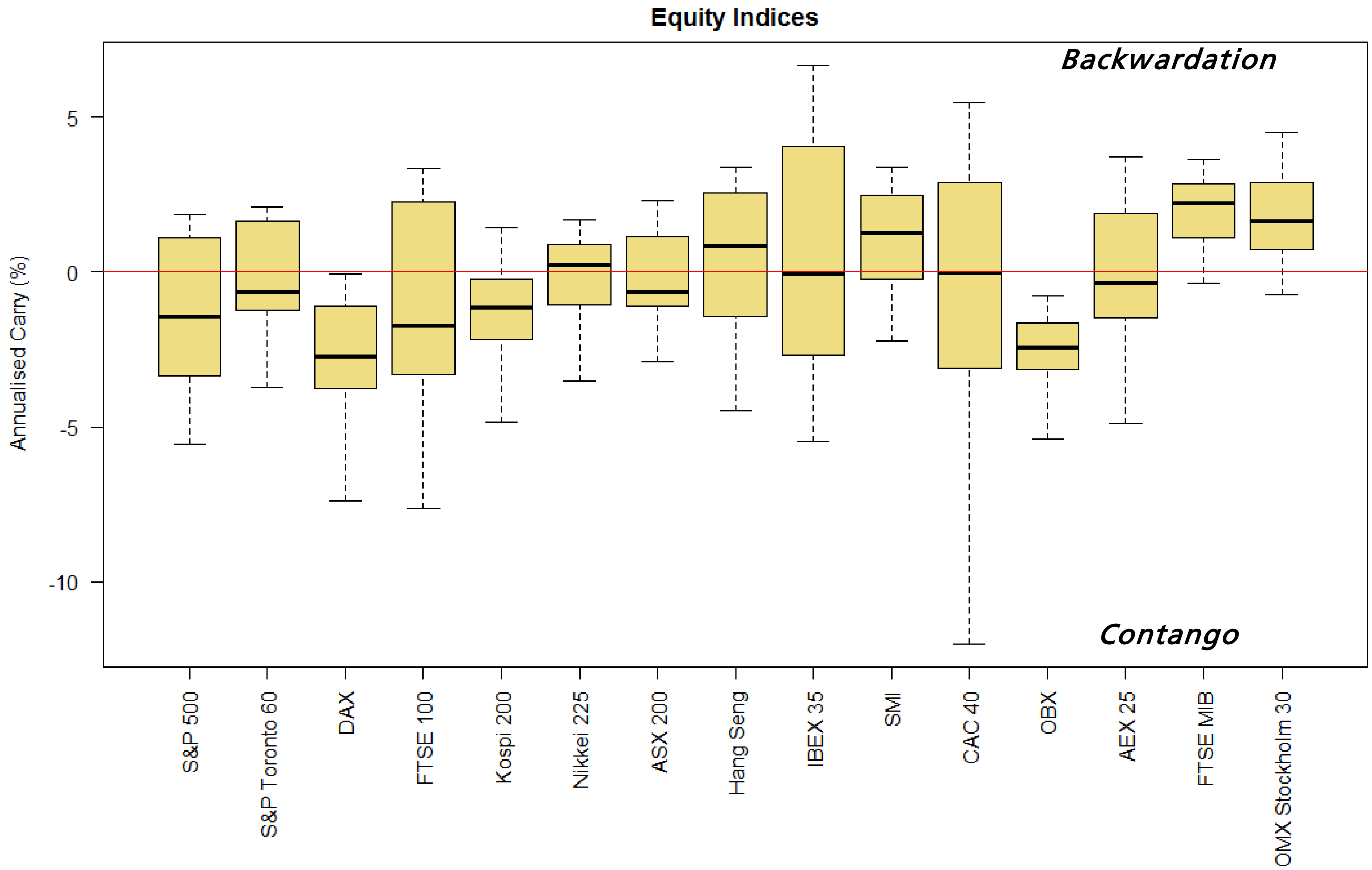
Carry in the cross-section (1990M01 – 2016M01)



* Not all contracts start in January 1990. See Appendix.

Source: UBS Quantitative Research
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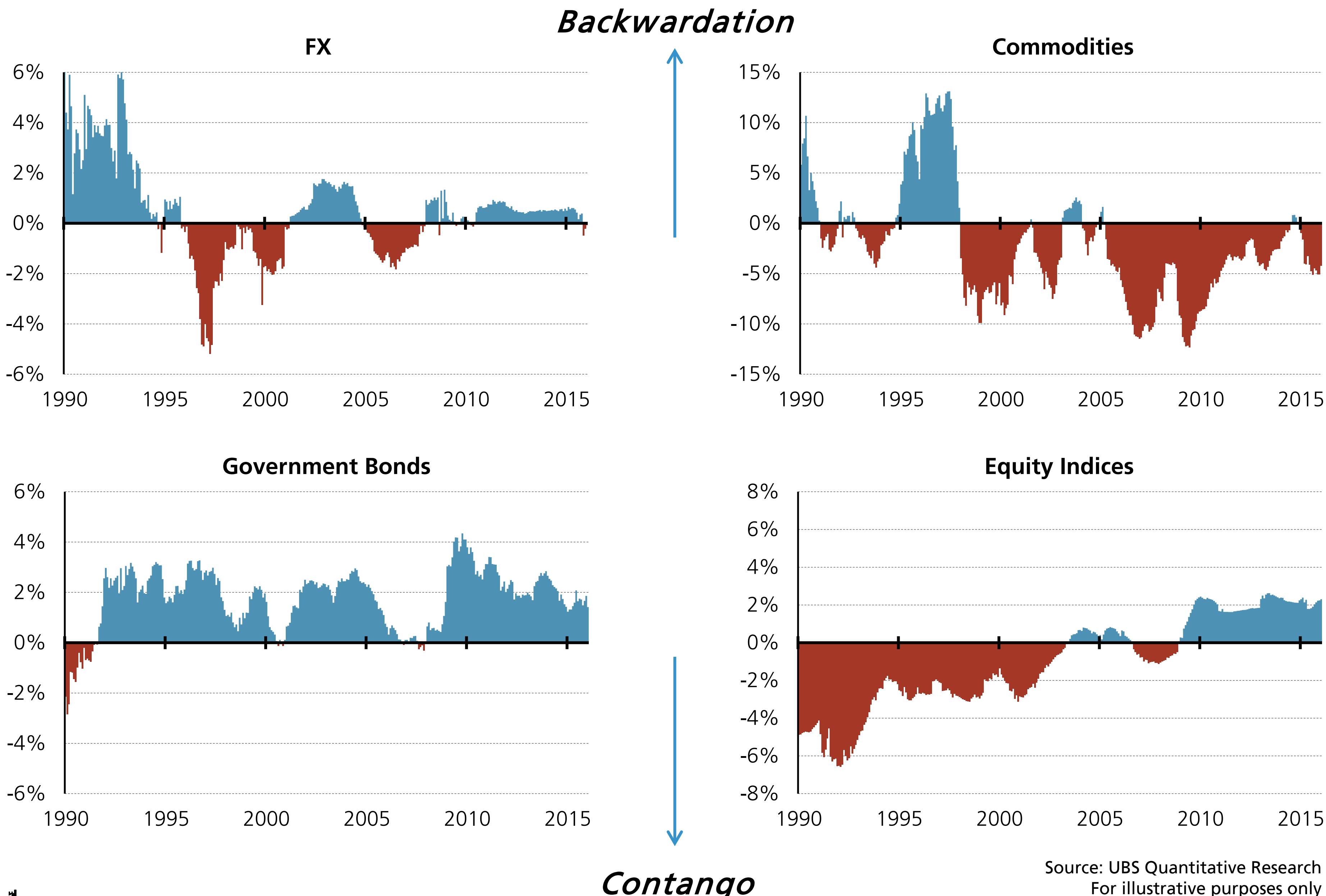
Carry in the time-series (median per asset class)



Source: UBS Quantitative Research
For illustrative purposes only

Constructing Carry Portfolios

- Cross-sectional ("*XS*"):
  - Focus on the **relative strength of carry**
  - Higher carry assets to outperform lower carry assets
  - *Zero net exposure*

- Time-series ("*TS*"):
  - Focus on the **sign of carry** (serial correlation of carry)
  - Positive/negative carry assets to deliver positive/negative returns
  - *Non-zero net exposure → directional*

- Optimised ("*OPT*"):
  - **Combine** the relative strength and the sign of carry
  - Larger/smaller gross weights on assets with higher/lower absolute carry
  - *Non-zero net exposure (unless constrained) → directional*

Section 2

Cross-Sectional Carry

Portfolio weights per asset class

Example: 9 assets, 6 with positive carry, 3 with negative carry

Ranked Carry
>0
>0
>0
>0
>0
>0
<0
<0
<0

Rank assets by carry

Subtract the average rank

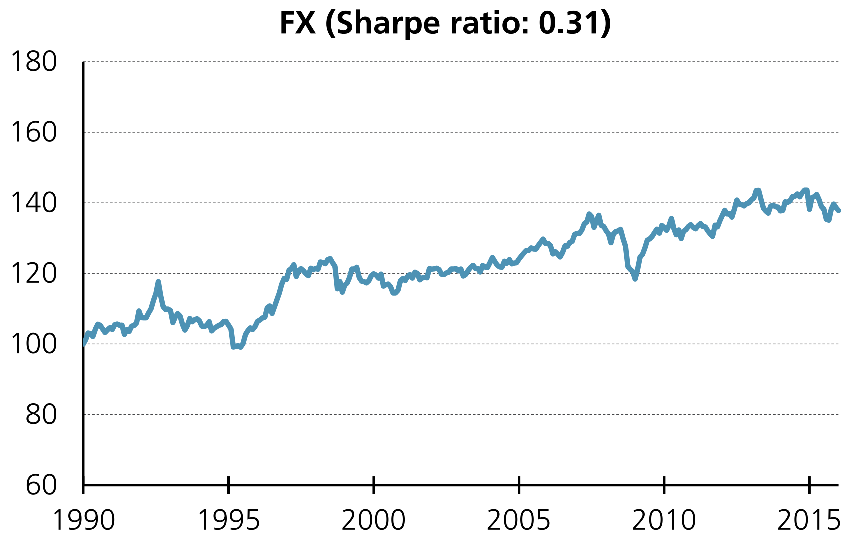
Rescale so that $\sum_i |w_i| = 1$

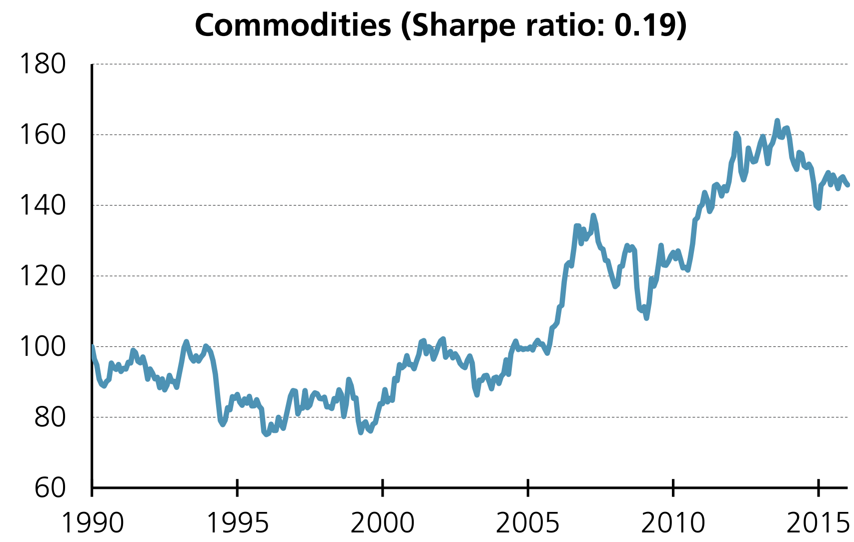
XS weights
+4/20
+3/20
+2/20
+1/20
0
-1/20
-2/20
-3/20
-4/20

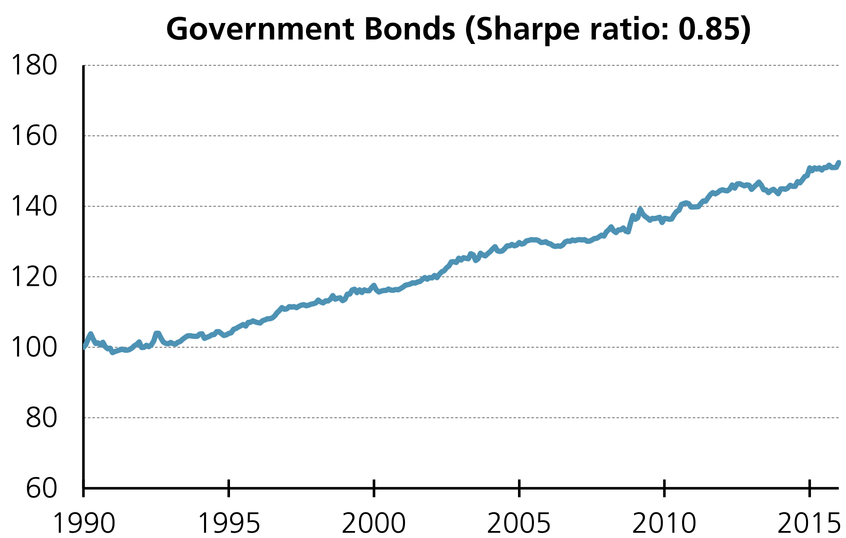
$$\boldsymbol{NET = 0}$$

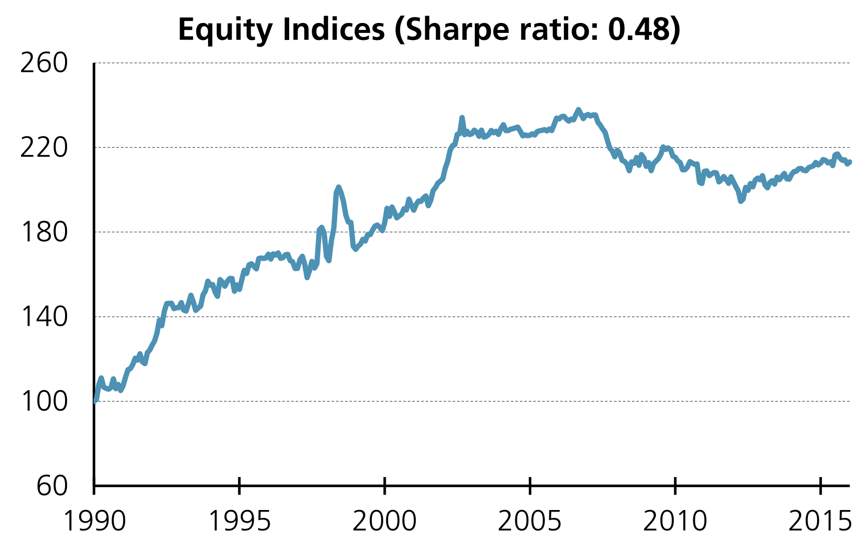
Source: UBS Quantitative Research

Cross-sectional Carry per Asset Class









Source: UBS Quantitative Research
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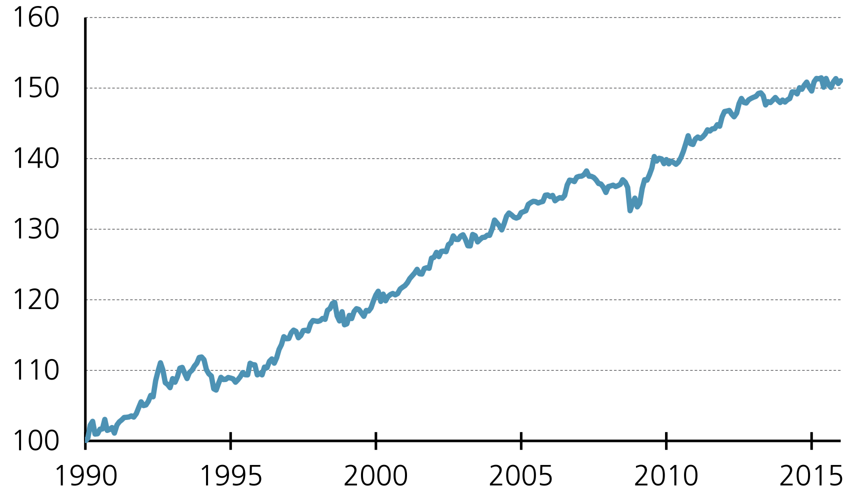
Cross-sectional Carry per Asset Class

Sample: 1990M01 – 2016M01	FX	Commodities	Govt. Bonds	Equity Indices
Average Geometric Return (%)	1.27	1.82	1.62	2.93
Average Excess Return (%)	1.36 (1.58)	1.83 (0.98)	1.63*** (4.32)	3.09** (2.46)
Annualised Volatility (%)	4.39	9.59	1.93	6.43
Skewness	-0.77	-0.19	-0.04	0.80
Kurtosis	4.87	3.48	4.18	7.39
Maximum Drawdown (%)	15.80	26.28	5.15	18.23
Sharpe Ratio (annualised)	0.31	0.19	0.85	0.48
Sortino Ratio (annualised)	0.43	0.28	1.42	0.83
Calmar Ratio	0.08	0.05	0.31	0.16
Correlation Matrix				
- FX	1			
- Commodities	0.01	1		
- Government Bonds	0.06	-0.10	1	
- Equity Indices	0.12	0.00	0.20	1

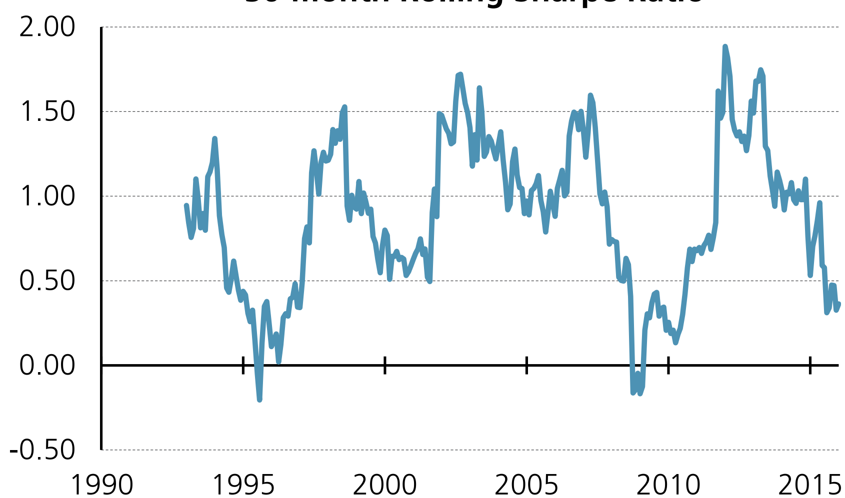
Source: UBS Quantitative Research
For illustrative purposes only

Multi-Asset Cross-sectional Carry

Multi-Asset XS Carry (Sharpe ratio: 0.79)



36-month Rolling Sharpe Ratio



	Unlevered	Levered 7% Target
Average Geometric Return (%)	1.59	5.76
Average Excess Return (%)	1.60*** (4.02)	5.88*** (4.12)
Annualised Volatility (%)	2.04	7.30
Skewness	-0.44	-0.37
Kurtosis	4.99	4.86
Maximum Drawdown (%)	4.19	18.61
Sharpe Ratio (annualised)	0.79	0.81
Sortino Ratio (annualised)	1.25	1.31
Calmar Ratio	0.38	0.31
Average Leverage	1x	4.0x
25^{th} – 75^{th} percentiles	1x to 1x	3.2x to 4.5x

Source: UBS Quantitative Research
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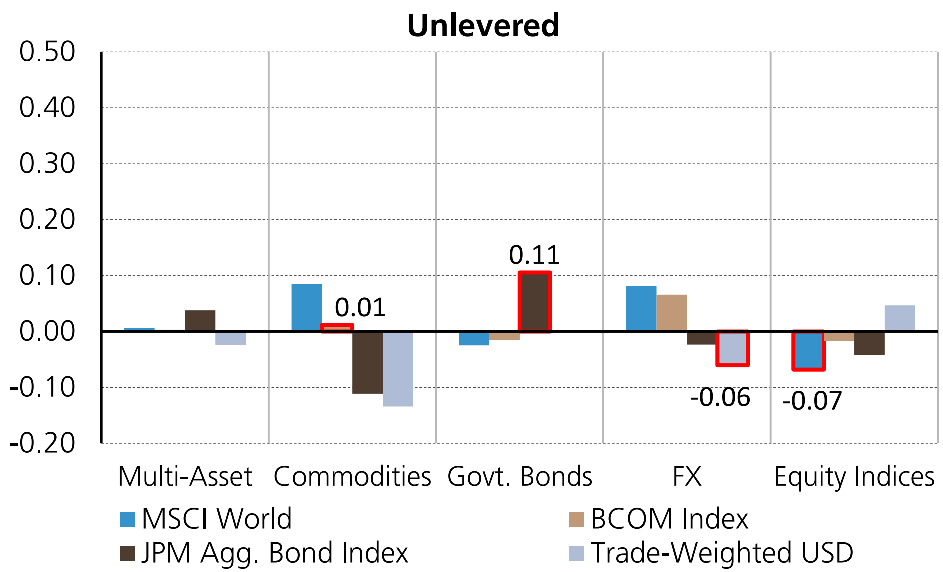
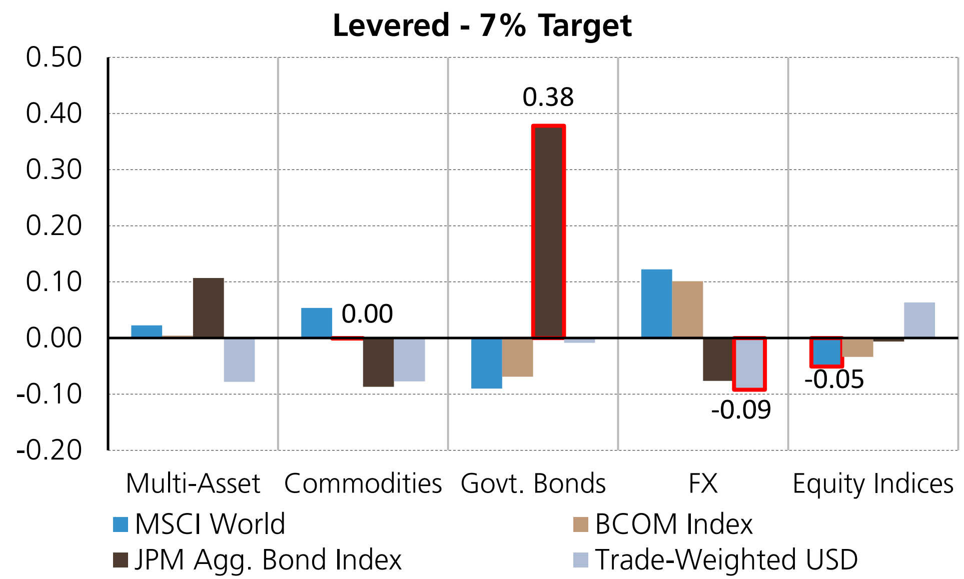
Betas of XS Carry Strategies against Major Indices





Source: UBS Quantitative Research
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Section 3

Time-Series Carry

Portfolio weights per asset class

Example: 9 assets, 6 with positive carry, 3 with negative carry

Positive Carry → Long
Negative Carry → Short
Equal gross weights

Contrast this against XS:

Carry (ranking not necessary)	**TS weights**	**XS weights**
>0	+1/9	+4/20
>0	+1/9	+3/20
>0	+1/9	+2/20
>0	+1/9	+1/20
>0	+1/9	0
>0	+1/9	-1/20
<0	-1/9	-2/20
<0	-1/9	-3/20
<0	-1/9	-4/20

TS: $$NET = \sum_i w_i = +3/9$$

XS: $$NET = 0$$

Source: UBS Quantitative Research

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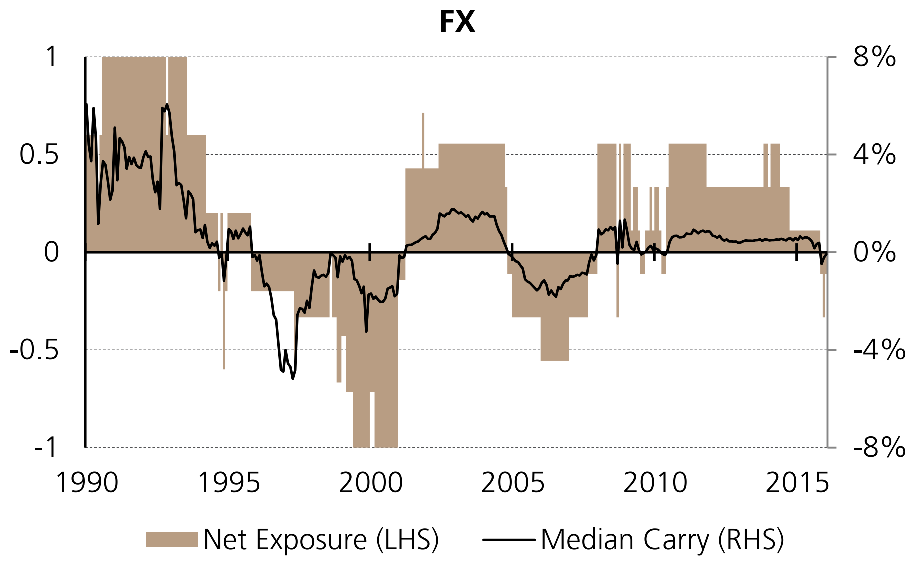
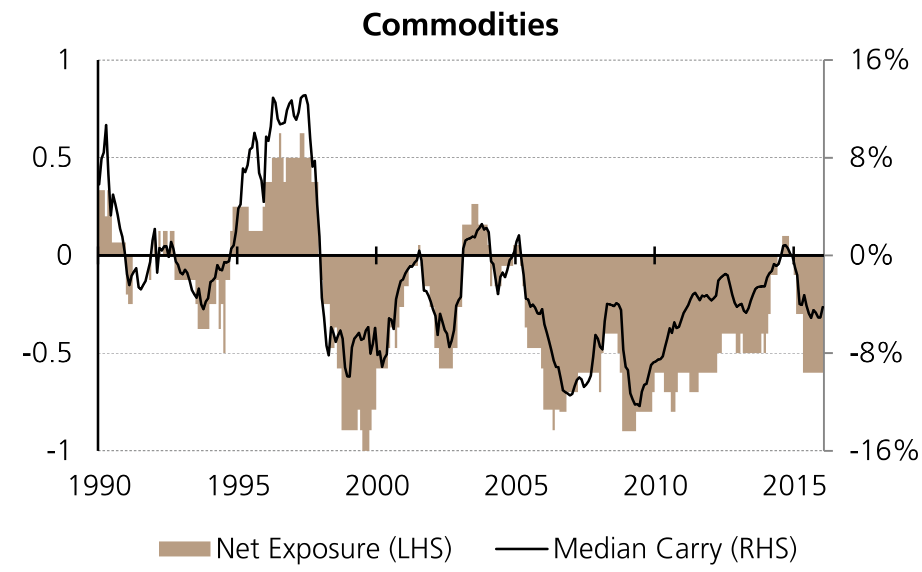
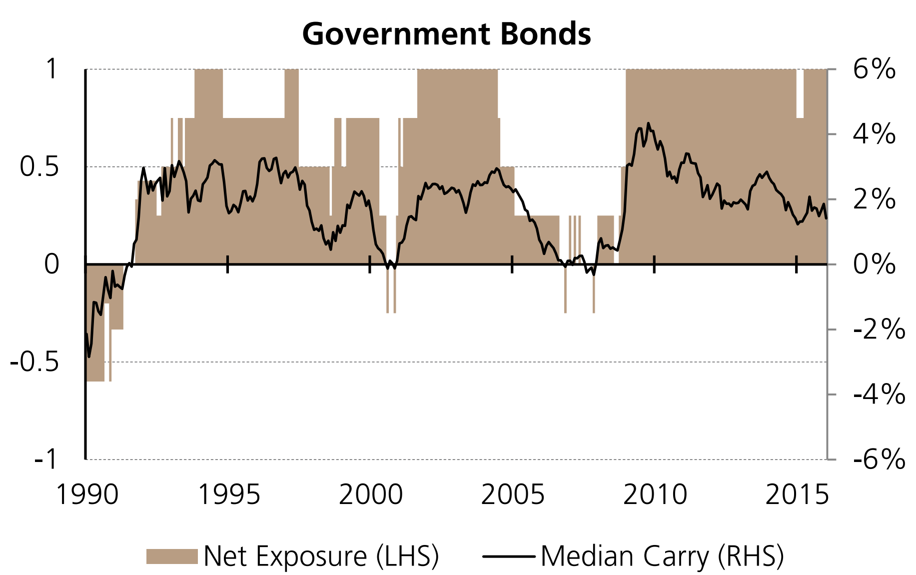
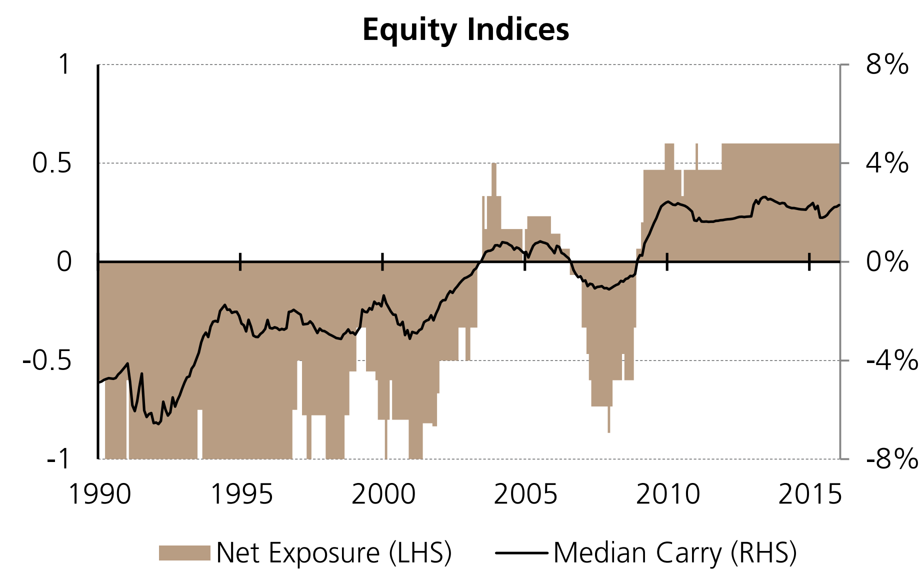
Net exposure per asset class









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Source: UBS Quantitative Research
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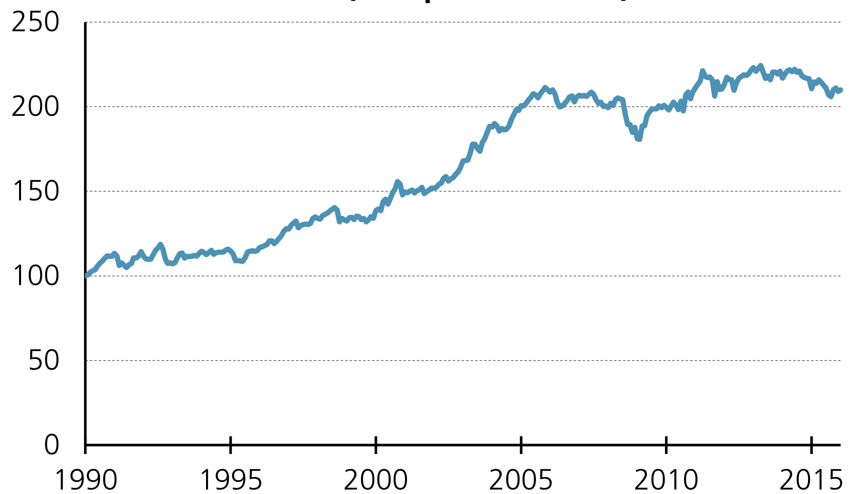
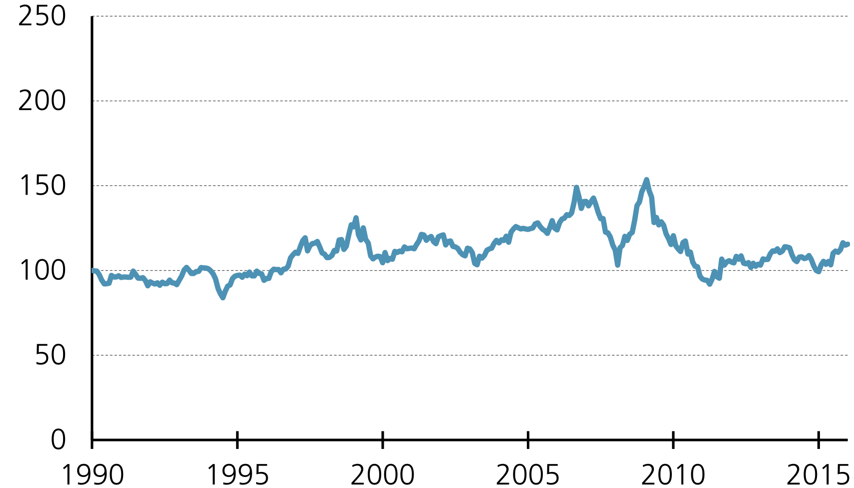
Time-Series Carry per Asset Class

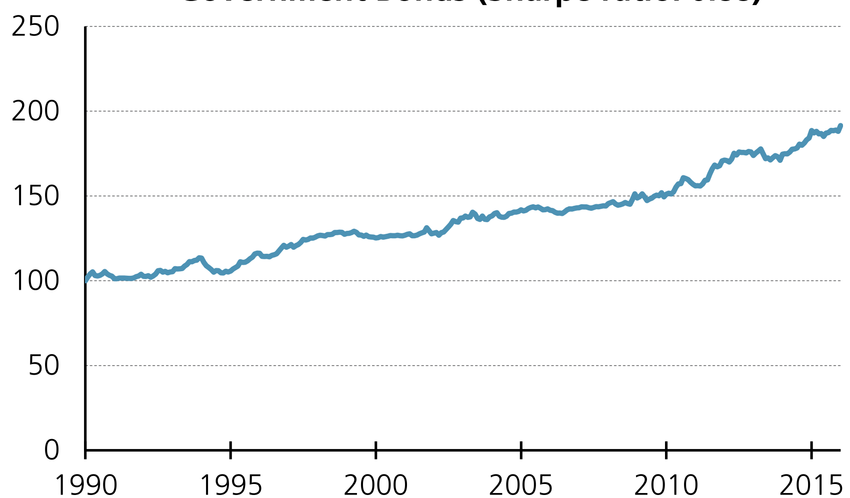
FX (Sharpe ratio: 0.57)



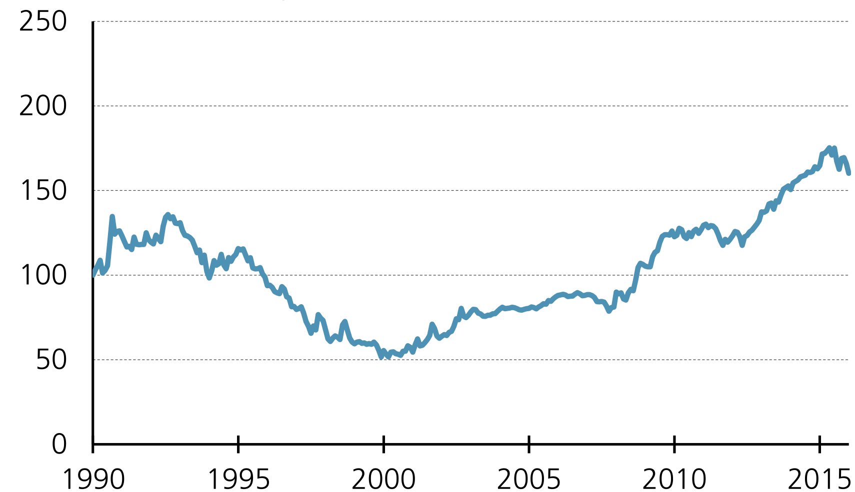
Commodities (Sharpe ratio: 0.10)



Government Bonds (Sharpe ratio: 0.88)



Equity Indices (Sharpe ratio: 0.23)



Source: UBS Quantitative Research
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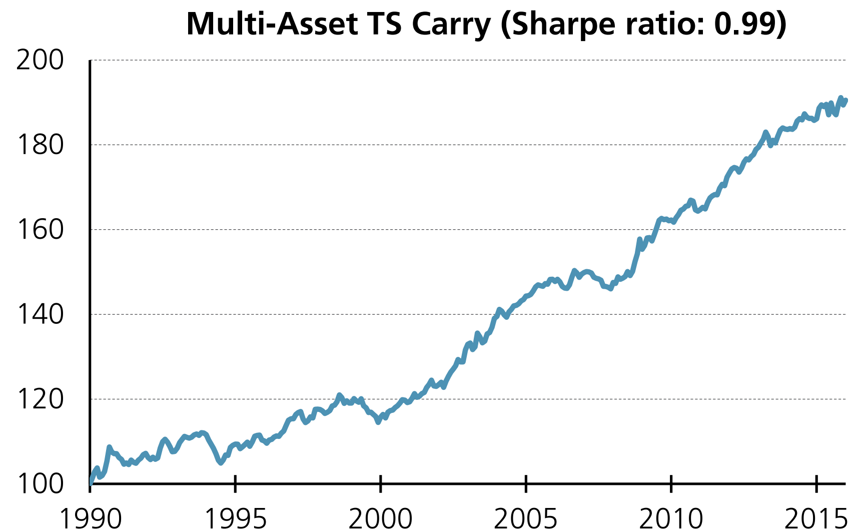
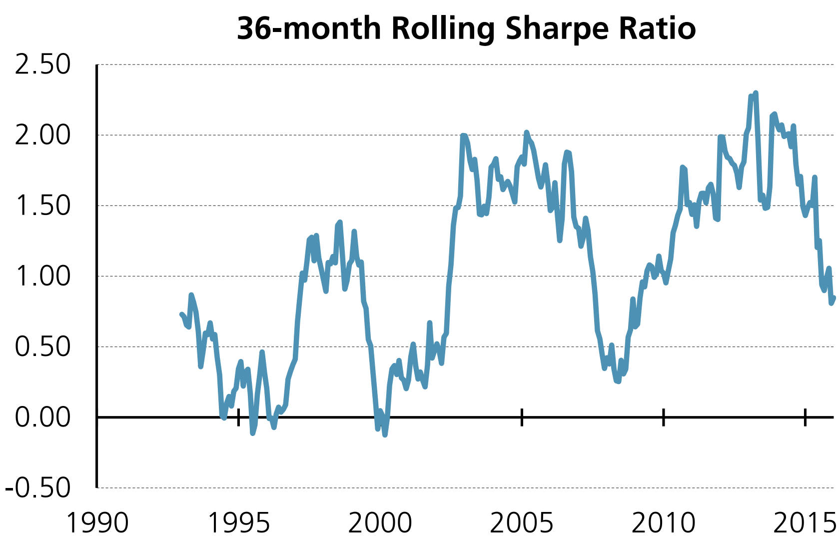
Time-Series Carry per Asset Class

Sample: 1990M01 – 2016M01	FX	Commodities	Govt. Bonds	Equity Indices
Average Geometric Return (%)	2.92	0.49	2.61	2.05
Average Excess Return (%)	3.02*** (2.94)	0.98 (0.51)	2.62*** (4.48)	2.74 (1.17)
Annualised Volatility (%)	5.25	9.87	2.99	12.00
Skewness	-0.58	0.10	-0.01	0.70
Kurtosis	4.45	4.40	3.23	5.26
Maximum Drawdown (%)	14.50	40.21	7.91	61.94
Sharpe Ratio (annualised)	0.57	0.10	0.88	0.23
Sortino Ratio (annualised)	0.85	0.15	1.51	0.37
Calmar Ratio	0.20	0.01	0.33	0.03
Rank Correlation with XS	0.51	0.56	0.68	0.30
Correlation Matrix				
- FX	1			
- Commodities	-0.16	1		
- Government Bonds	0.00	0.11	1	
- Equity Indices	0.09	-0.03	0.01	1

Source: UBS Quantitative Research
For illustrative purposes only

Multi-Asset Time-Series Carry





	Unlevered	Levered 7% Target
Average Geometric Return (%)	2.56	8.12
Average Excess Return (%)	2.57*** (5.05)	8.14*** (5.28)
Annualised Volatility (%)	2.60	7.89
Skewness	0.18	-0.06
Kurtosis	3.78	2.92
Maximum Drawdown (%)	6.40	18.36
Sharpe Ratio (annualised)	0.99	1.03
Sortino Ratio (annualised)	1.79	1.85
Calmar Ratio	0.40	0.44
Average Leverage	1x	3.3x
$25^{th} - 75^{th}$ percentiles	1x to 1x	2.8x to 3.9x

Source: UBS Quantitative Research
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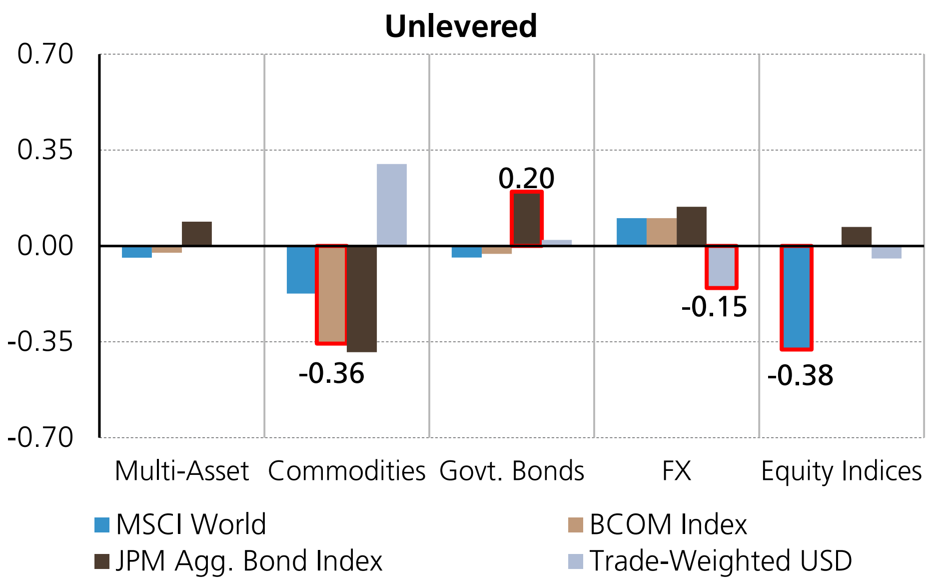
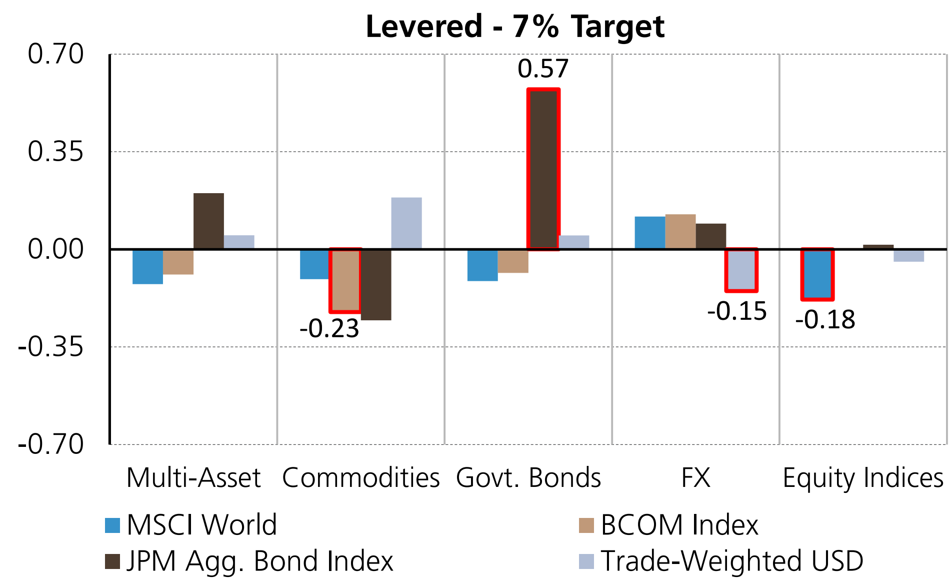
Betas of TS Carry Strategies against Major Indices





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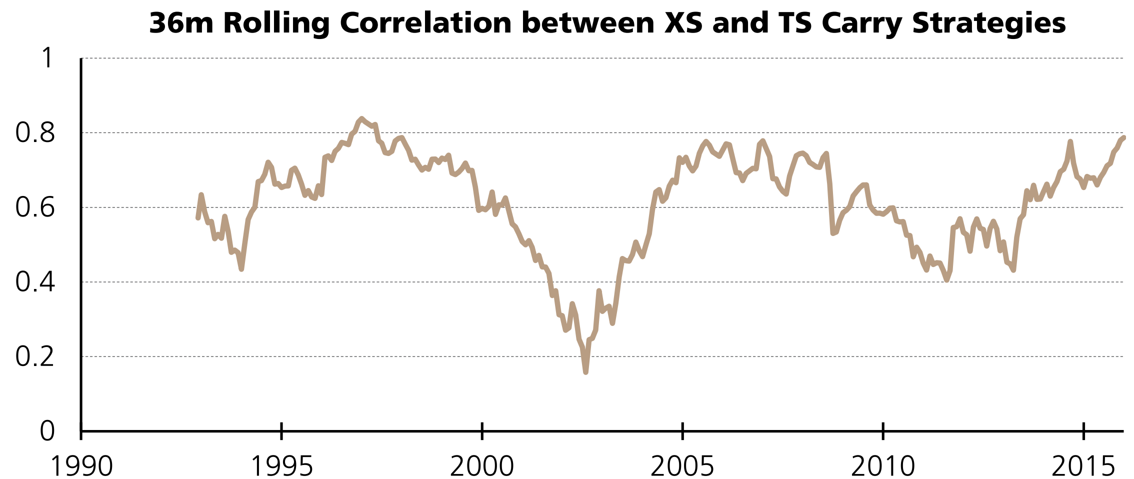
The relationship between XS and TS Carry strategies

	Cross-Sectional Carry				
Time-Series Carry	Commodities	Govt. Bonds	FX	Equity Indices	Multi-Asset
Commodities	0.56	0.06	-0.10	0.10	0.31
Govt. Bonds	-0.12	0.68	-0.02	0.11	0.30
FX	0.06	-0.02	0.51	0.07	0.30
Equity Indices	0.04	0.02	0.02	0.30	0.21
Multi-Asset	0.27	0.38	0.22	0.28	0.61



Source: UBS Quantitative Research
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Section 4

Optimised Carry

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Combining XS and TS Carry Signals

Two ideas:

1. Actively use the covariance structure in the allocation
2. Adjust the exposure to each asset in proportion to their absolute carry:

   – Asset return decomposition:

$$Return = \underbrace{Carry + \boldsymbol{E}(price\ appreciation)}_{\boldsymbol{E}(Return)} + unexpected\ price\ shock$$

$$\Rightarrow \quad \boxed{\boldsymbol{E}(Return) = Carry, \qquad if\ \ \boldsymbol{E}(price\ appreciation) = 0}$$

Introduce a long-short risk-budgeting optimisation:

$$\boldsymbol{w} = argmax \left\{ \sum_{i=1}^{N} \frac{|Carry_t^i|}{N_t^i \cdot \sigma_t^i} \cdot log(|w_i|) \right\}$$

$$s.t. \quad \sigma_P(\boldsymbol{w}) = \sqrt{\boldsymbol{w}' \cdot \boldsymbol{\Sigma} \cdot \boldsymbol{w}} \leq \sigma_{TGT}$$

Number of assets that belong in the same asset class as asset i at time t

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Portfolio weights

Example: 9 assets, 6 with positive carry, 3 with negative carry

Carry
$Carry_1 > 0$
$Carry_2 > 0$
$Carry_3 > 0$
$Carry_4 > 0$
$Carry_5 > 0$
$Carry_6 > 0$
$Carry_7 < 0$
$Carry_8 < 0$
$Carry_9 < 0$

Covariance Matrix

$$\begin{bmatrix} \sigma_1^2 & \sigma_{1,2} & & \sigma_{1,9} \\ \sigma_{1,2} & \sigma_2^2 & & \\ & & \ddots & \\ \sigma_{1,9} & & & \sigma_9^2 \end{bmatrix}$$

Positive Carry → Long

Negative Carry → Short

Long-short risk-budgeting optimisation

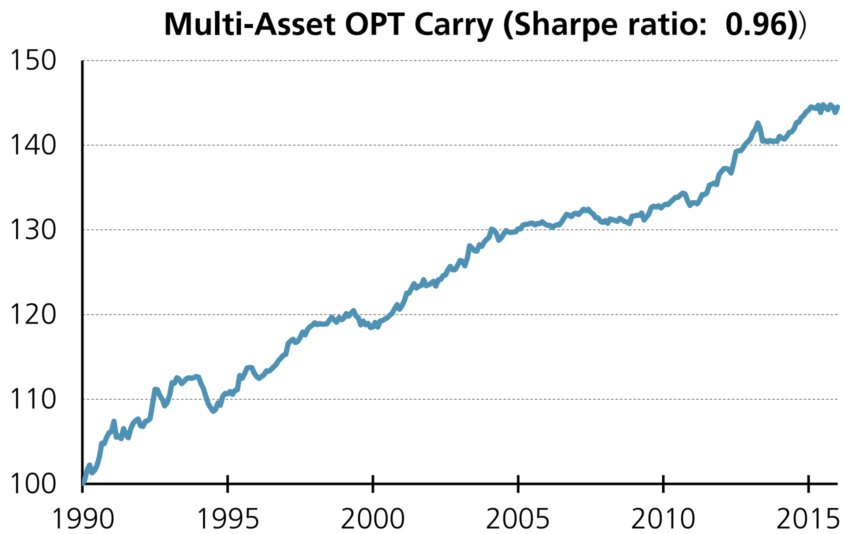
Contrast this against TS, XS:

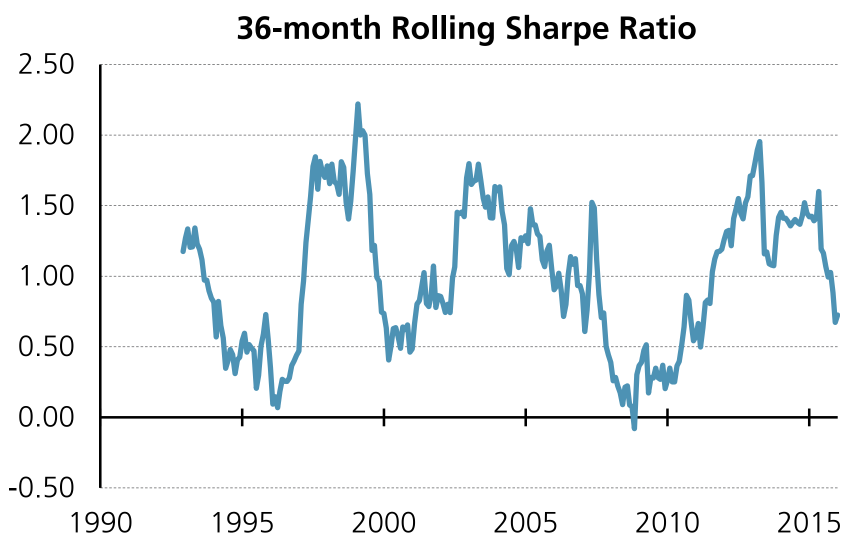
OPT weights	TS weights	XS weights
$w_1 > 0$	+1/9	+4/20
$w_2 > 0$	+1/9	+3/20
$w_3 > 0$	+1/9	+2/20
$w_4 > 0$	+1/9	+1/20
$w_5 > 0$	+1/9	0
$w_6 > 0$	+1/9	-1/20
$w_7 < 0$	-1/9	-2/20
$w_8 < 0$	-1/9	-3/20
$w_9 < 0$	-1/9	-4/20

	OPT	TS	XS
$Net = \sum_i w_i$	$\neq 0$	$+3/9$	0
$Gross = \sum_i \lvert w_i \rvert$	1	1	1

Source: UBS Quantitative Research

Multi-Asset Optimised Carry





	Unlevered	Levered 7% Target
Average Geometric Return (%)	1.42	9.15
Average Excess Return (%)	1.42*** (4.93)	9.16*** (5.34)
Annualised Volatility (%)	1.48	8.77
Skewness	0.26	0.30
Kurtosis	5.32	4.42
Maximum Drawdown (%)	3.66	18.86
Sharpe Ratio (annualised)	0.96	1.04
Sortino Ratio (annualised)	1.76	1.96
Calmar Ratio	0.39	0.49
Average Leverage	1x	7.1x
25^{th} – 75^{th} percentiles	1x to 1x	5.1x to 9.1x

Source: UBS Quantitative Research
For illustrative purposes only

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Robustness Results

- Do simple combinations of the multi-asset XS and TS portfolios outperform the optimised carry strategy?

		Simple Combinations of XS & TS Portfolios	
	Optimised Carry	Equal Weights	Inv. Volatility Weights
Average Geometric Return (%)	9.15	7.53	7.86
Average Excess Return (%)	9.16*** (5.34)	7.58*** (5.07)	7.89*** (5.17)
Annualised Volatility (%)	8.77	7.64	7.81
Skewness	0.30	-0.15	-0.13
Kurtosis	4.42	3.50	3.36
Maximum Drawdown (%)	18.86	15.50	17.53
Sharpe Ratio (annualised)	1.04	0.99	1.01
Sortino Ratio (annualised)	1.96	1.70	1.76
Calmar Ratio	0.49	0.49	0.45
Average Leverage	7.1x	2.8x	3.0x
25^{th} – 75^{th} percentiles	5.1x to 9.1x	2.3x to 3.2x	2.5x to 3.5x

Source: UBS Quantitative Research
For illustrative purposes only

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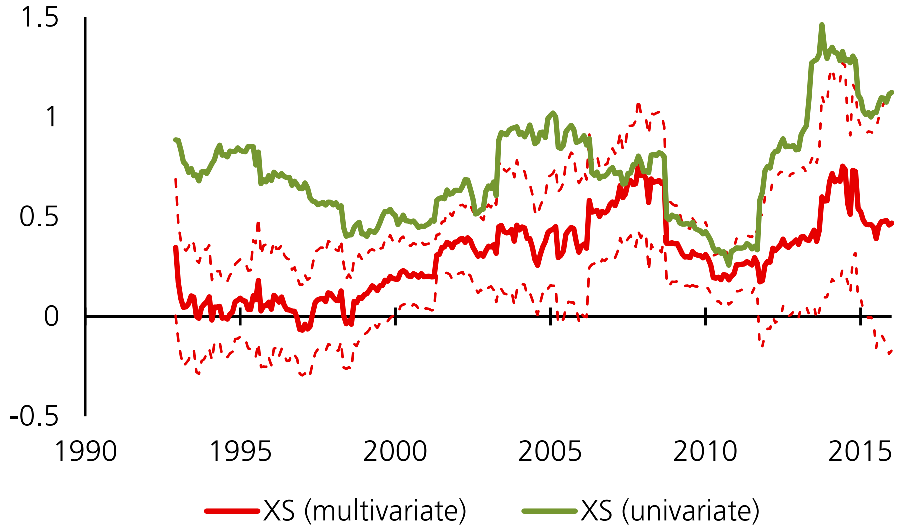
Exposure on XS and TS Carry Strategies

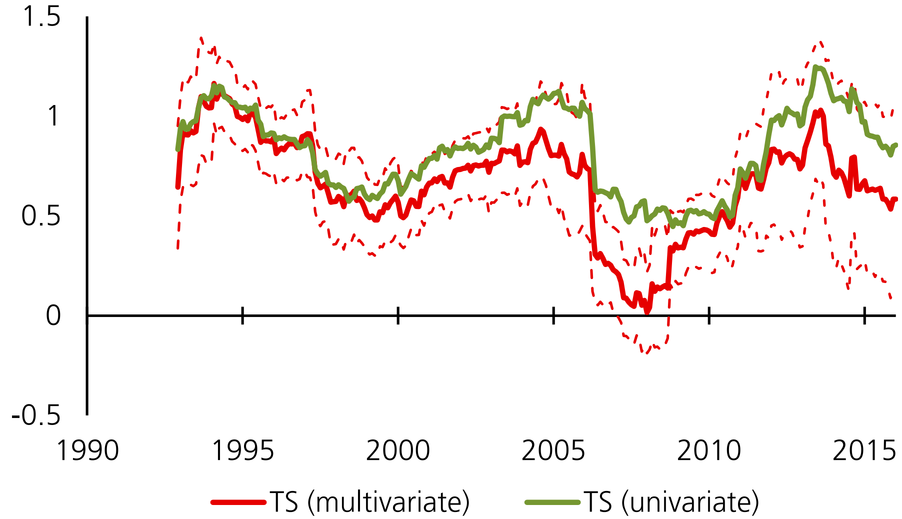
$$r_t^{OPT(7\%)} = \alpha + \beta^{XS} \cdot r_t^{XS(7\%)} + \beta^{TS} \cdot r_t^{TS(7\%)} + \epsilon_t$$

Ann. alpha (%)	Cross-Sectional (7%)	Time-Series (7%)	adjusted R^2
5.08*** (3.10)	0.69*** (9.30)		33.3%
2.73** (1.96)		0.79*** (14.97)	50.4%
2.33* (1.75)	0.29*** (5.88)	0.63*** (11.25)	53.8%

36m Rolling Exposure to XS Multi-Asset Carry (7%)



36m Rolling Exposure to TS Multi-Asset Carry (7%)



Source: UBS Quantitative Research
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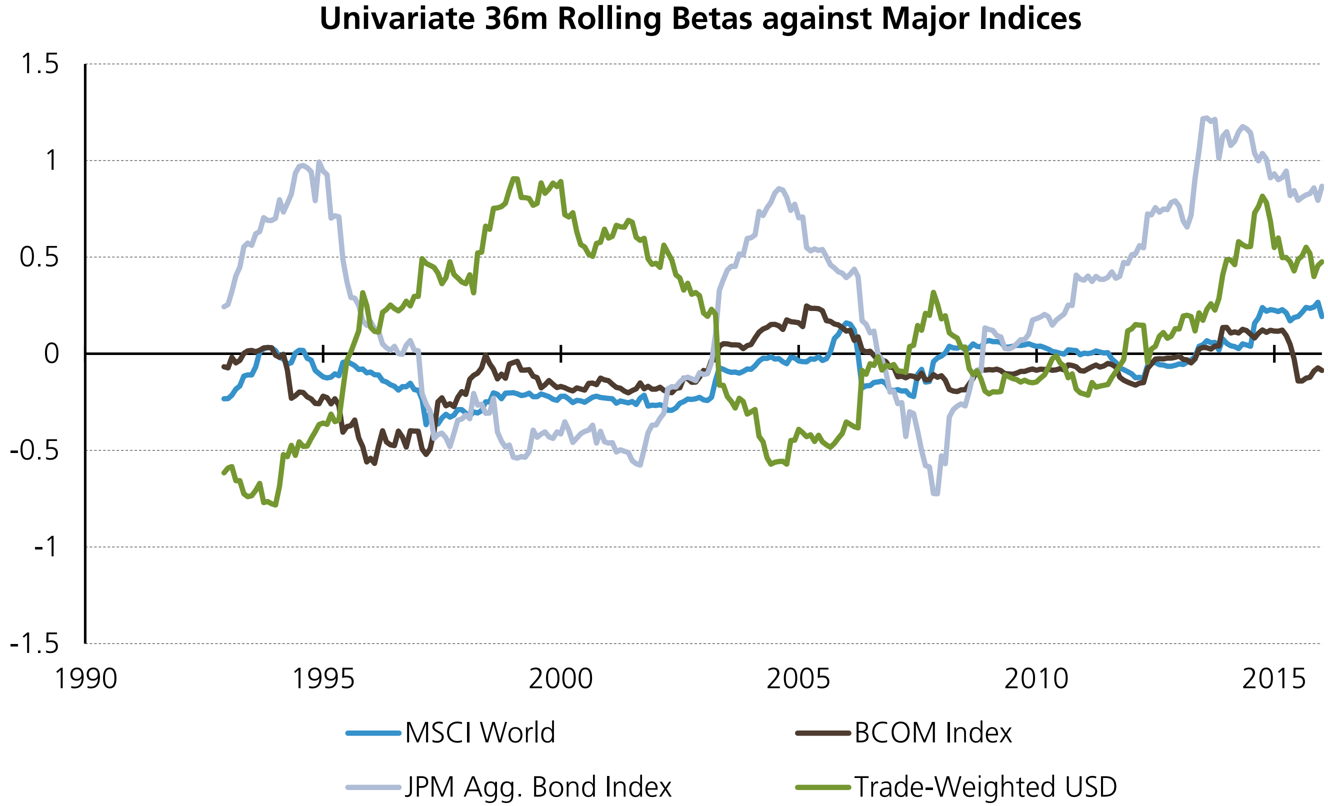
Exposure on Major Indices



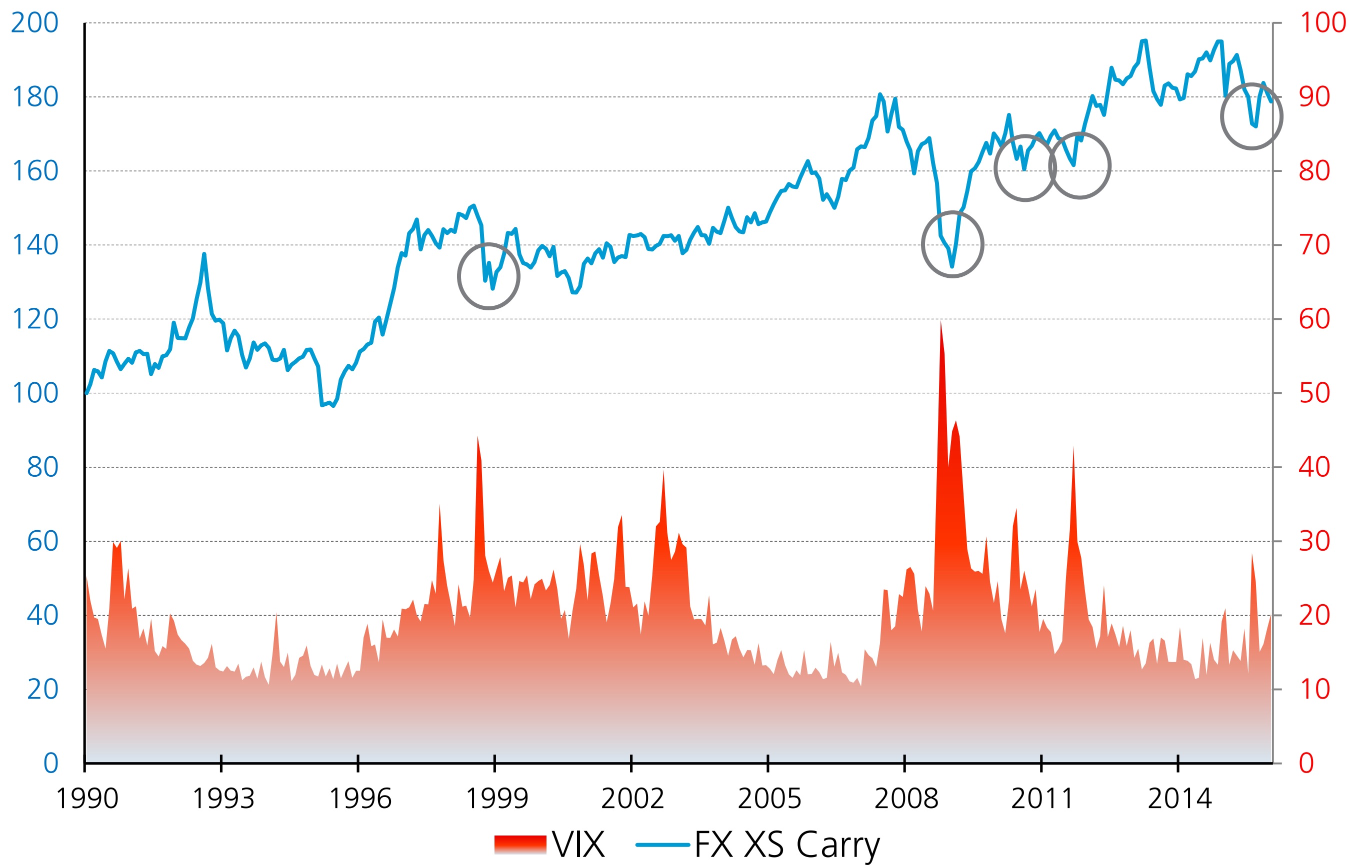
Source: UBS Quantitative Research
For illustrative purposes only

Section 5

Is it Crash Risk?

Is it Crash Risk?

- FX cross-sectional carry bears negative skewness, and the literature has associated the premium to currency crash risk, funding liquidity risk, FX volatility risk, consumption growth risk, a "peso problem" or equity downside risk.



Source: UBS Quantitative Research
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Is it Crash Risk?

- We regress levered carry strategies (target volatility at 7%) across asset classes as well as at the multi-asset level against a number of factors $\boldsymbol{F}$:

$$r_{Carry,t} = const. + \boldsymbol{\beta}' \cdot \boldsymbol{F}_t + \epsilon_t$$

- Crash-risk proxies:
  - **Market squared:**

$$r_{MKT,t,squared} = \left(r_{MKT,t}\right)^2$$

  - **Henrikson and Merton (1981) downside risk variable:**

$$r_{MKT,t,down} = -r_{MKT,t} \cdot \mathbb{I}\left\{r_{MKT,t} < 0\right\}$$

  - **Lettau, Maggiori and Weber (2014) tail risk variable:**

$$r_{MKT,t,tail} = -r_{MKT,t} \cdot \mathbb{I}\left\{r_{MKT,t} < -\sigma_{MKT}\right\}$$

  - **Changes in VIX:**

$$\Delta VIX_t = VIT_t - VIX_{t-1}$$

- For MKT, we consider MSCI World or a broad asset-class-specific index.

Analysis using the underlying mkt of each asset class

Cross-Sectional Carry Strategies						Time-Series Carry Strategies					
$const.$	MKT	MKT^2	MKT_{down}	MKT_{tail}	$adj.R^2$	$const.$	MKT	MKT^2	MKT_{down}	MKT_{tail}	$adj.R^2$
Commodities (market: BCOM Index)											
0.10	0.00				0.00%	0.12	-0.22***				18.64%
0.27**	-0.02	-0.95***			1.92%	0.13	-0.22***	-0.04			18.10%
0.41**	-0.11*		-0.20**		1.01%	0.18	-0.24***		-0.04		18.16%
0.26**	-0.07			-0.16**	1.16%	0.16	-0.24***			-0.04	18.21%
Government Bonds (market: JPM Aggregate Bond Index)											
0.46***	0.38***				9.57%	0.48***	0.57***				15.34%
0.53***	0.40***	-2.76			9.33%	0.52***	0.59***	-1.55			14.87%
0.66***	0.24*		-0.32		9.60%	0.63***	0.48***		-0.22		15.00%
0.55***	0.31***			-0.24	9.57%	0.51***	0.55***			-0.07	14.83%
FX (market: Trade-Weighted USD)											
0.16	-0.09				0.55%	0.31**	-0.15				1.37%
0.50***	-0.11	-11.87***			6.95%	0.55***	-0.16*	-8.37**			4.01%
0.75***	-0.58***		-0.89***		4.90%	0.84***	-0.59***		-0.81***		4.57%
0.34***	-0.30**			-0.47**	2.85%	0.47***	-0.34***			-0.42**	2.95%
Equity Indices (market: MSCI World Index)											
0.18*	-0.05**				1.45%	0.21*	-0.18***				12.07%
0.22*	-0.05**	-0.17			0.91%	-0.01	-0.16***	1.14**			14.04%
0.15	-0.04		0.02		0.84%	-0.26*	-0.03		0.28***		14.23%
0.11	-0.02			0.06	1.25%	-0.06	-0.07			0.25***	15.64%

Source: UBS Quantitative Research. For illustrative purposes only.
All strategies are levered at 7% target volatility. The constant of each regression is multiplied by 100.
The regressions are conducted using monthly returns between January 1990 and January 2016.

Analysis using MSCI World as the market

Cross-Sectional Carry Strategies						Time-Series Carry Strategies					
$const.$	$MSCI$	$MSCI^2$	$MSCI_{down}$	$MSCI_{tail}$	$adj.R^2$	$const.$	$MSCI$	$MSCI^2$	$MSCI_{down}$	$MSCI_{tail}$	$adj.R^2$
Commodities											
0.07	0.06**				1.25%	0.11	-0.10***				4.24%
0.11	0.05*	-0.21			0.71%	0.08	-0.10***	0.19			3.70%
0.05	0.06		0.01		0.61%	0.11	-0.10***		0.00		3.62%
0.12	0.03			-0.05	0.79%	0.11	-0.10***			0.00	3.62%
Government Bonds											
0.58***	-0.09***				3.69%	0.68***	-0.12***				4.51%
0.60***	-0.09***	-0.14			3.12%	0.74***	-0.13***	-0.30			4.05%
0.60***	-0.09***		-0.01		3.07%	0.71***	-0.13***		-0.02		3.91%
0.58***	-0.09***			0.00	3.07%	0.64***	-0.10***			0.04	3.98%
FX											
0.16	0.12***				6.30%	0.32***	0.12***				5.49%
0.28**	0.11***	-0.63			6.65%	0.26**	0.12***	0.35			5.14%
0.31	0.07		-0.09		6.04%	0.22	0.15***		0.06		5.02%
0.17	0.12***			-0.01	5.70%	0.21	0.17***			0.11	5.78%
Equity Indices											
0.18*	-0.05**				1.45%	0.21*	-0.18***				12.07%
0.22*	-0.05**	-0.17			0.91%	-0.01	-0.16***	1.14**			14.04%
0.15	-0.04		0.02		0.84%	-0.26*	-0.03		0.28***		14.23%
0.11	-0.02			0.06	1.25%	-0.06	-0.07			0.25***	15.64%

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Source: UBS Quantitative Research. For illustrative purposes only.
All strategies are levered at 7% target volatility. The constant of each regression is multiplied by 100.
The regressions are conducted using monthly returns between January 1990 and January 2016.

Analysis using changes in VIX

	Cross-Sectional Carry Strategies				Time-Series Carry Strategies			
	const.	***MSCI***	ΔVIX	$adj. R^2$	***const.***	***MSCI***	ΔVIX	$adj. R^2$
Commodities								
	0.08		-0.06**	1.37%	0.10		0.08**	2.35%
	0.08	0.03	-0.04	0.91%	0.12	-0.10***	0.01	3.86%
Government Bonds								
	0.57***		0.07**	2.12%	0.64***		0.07**	1.72%
	0.58***	-0.08**	0.01	3.22%	0.66***	-0.12***	0.00	3.60%
FX								
	0.18		-0.12***	6.11%	0.34***		-0.10***	4.17%
	0.16	0.08**	-0.07*	7.01%	0.32***	0.09**	-0.04	5.43%
Equity Indices								
	0.17*		0.01	0.03%	0.16		0.09**	2.81%
	0.19*	-0.08***	-0.05	1.53%	0.20*	-0.22***	-0.06	11.74%

Source: UBS Quantitative Research. For illustrative purposes only.
All strategies are levered at 7% target volatility. The constant of each regression and the exposure to ΔVIX are multiplied by 100. The regressions are conducted using monthly returns between January 1990 and January 2016.

Analysis for the Multi-Asset Carry Strategies

$const.$	$MSCI$	$MSCI^2$	$MSCI_{down}$	$MSCI_{tail}$	ΔVIX	$adj. R^2$
XS Multi-Asset						
0.49***	0.02					0.23%
0.63***	0.01	-0.76				0.94%
0.59**	-0.01		-0.06			-0.26%
0.50***	0.02			-0.01		-0.39%
0.49***					-0.06	1.46%
0.50***	-0.03				-0.08*	1.01%
TS Multi-Asset						
0.70***	-0.13***					6.13%
0.57***	-0.11***	0.68*				6.45%
0.43**	-0.04		0.16*			6.46%
0.49***	-0.04			0.20***		8.22%
0.66***					0.05	1.03%
0.69***	-0.16***				-0.05	5.78%
OPT Multi-Asset						
0.78***	-0.08**					1.80%
0.81***	-0.08**	-0.15				1.20%
0.80***	-0.09		-0.01			1.17%
0.74***	-0.06			0.04		1.25%
0.77***					0.03	0.33%
0.79***	-0.10**				-0.03	1.39%

Source: UBS Quantitative Research. For illustrative purposes only.
All strategies are levered at 7% target volatility. The constant of each regression and the exposure to ΔVIX are multiplied by 100. The regressions are conducted using monthly returns between January 1990 and January 2016.

Concluding Remarks

- Carry is a model-free characteristic and readily available via the slope of the futures/forwards curve.
- We provide a unifying framework across asset classes (commodities, government bonds, currencies, equity indices) and portfolio methodologies (cross-sectional, time-series, optimised).
- Apart from FX, there is no strong evidence in favour of crash/volatility risk.
- The optimised multi-asset carry portfolio has an attractive risk-return profile, with a positive skewness and a small and negative exposure to the broad equity market, without being exposed to any downside risk.

Source: Wikipedia

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Section 6

Appendix & References

Dataset

- Starting month for each asset per asset class; this is the first month that a carry signal becomes available

Commodities

Natural Gas	Feb-91
Heating Oil	May-87
Unl. Gasoline	Aug-06
WTI Crude	Jan-84
Brent Crude	Apr-89
Sugar #11	Dec-70
Live Cattle	Dec-70
Lean Hogs	Mar-87
Coffee C	Jun-73
Cotton #2	Dec-70
Soybeans	Jan-71
Corn	Dec-70
Wheat	Dec-70
Soybean Oil	Dec-70
Soybean Meal	Dec-70
Kansas Wheat	Dec-70
Copper	Oct-89
Aluminium	May-98
Nickel	May-98
Zinc	May-98

Govt. (10y) Bonds

US	Jun-82
Australia	Oct-87
Canada	Oct-89
Germany	Dec-90
Japan	Nov-85
UK	Dec-82
Switzerland	Jul-92
New Zealand	Nov-91

Currencies

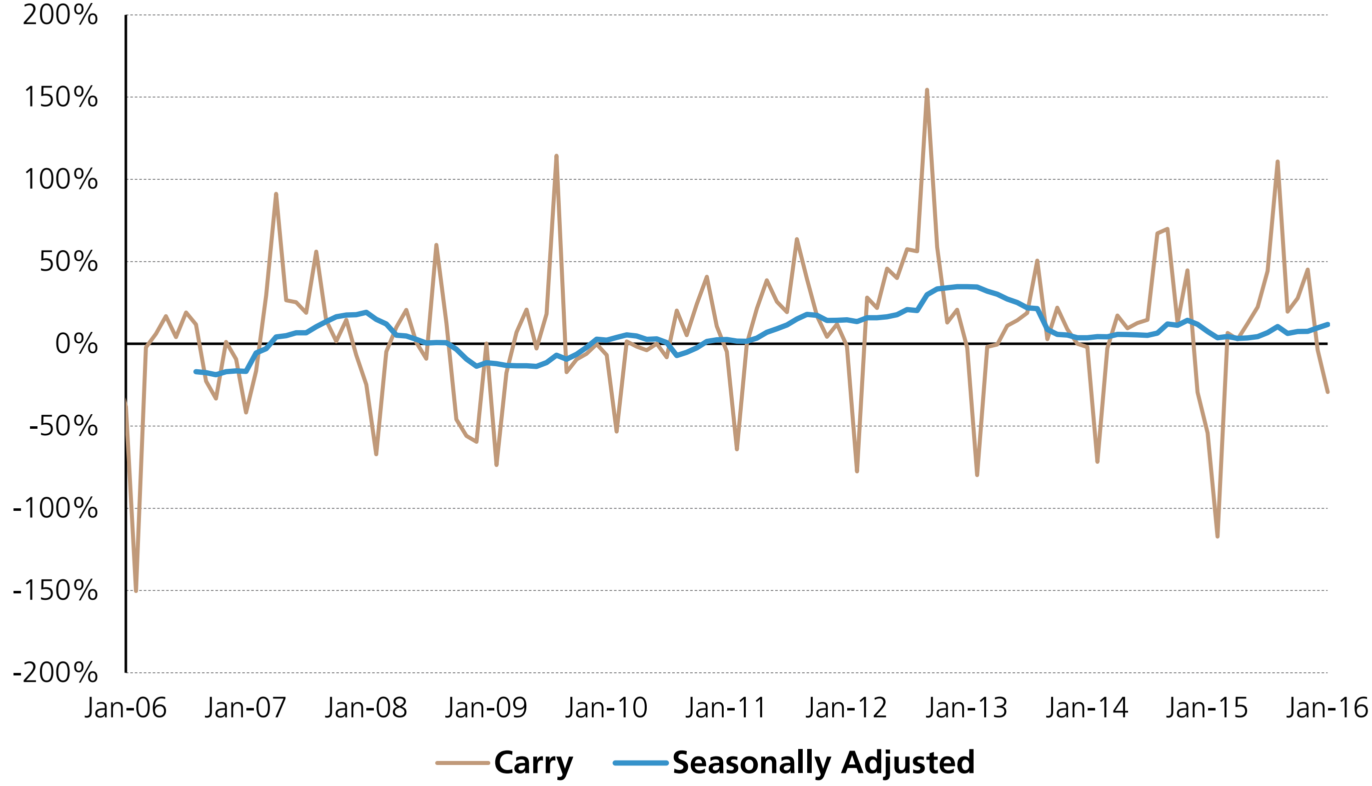
EUR	Jan-99
JPY	Jan-89
GBP	Jan-89
AUD	Feb-87
CAD	Jan-89
CHF	Jan-89
NZD	Jun-97
SEK	Jun-02
NOK	Jun-02

Equity Indices

S&P 500	Apr-83
S&P TSX 60	Oct-01
Dax	Jun-92
FTSE 100	Feb-89
Kospi 200	Mar-97
Nikkei 225	Jul-89
ASX 200	Mar-01
Hang Seng	Feb-93
IBEX 35	May-93
SMI	Oct-99
CAC 40	Nov-89
OBX	Apr-06
AEX	Dec-89
FTSE MIB	Feb-05
OMX 30	Dec-05

Source: UBS Quantitative Research

Seasonal adjustment example – Unleaded Gasoline



Source: UBS Quantitative Research
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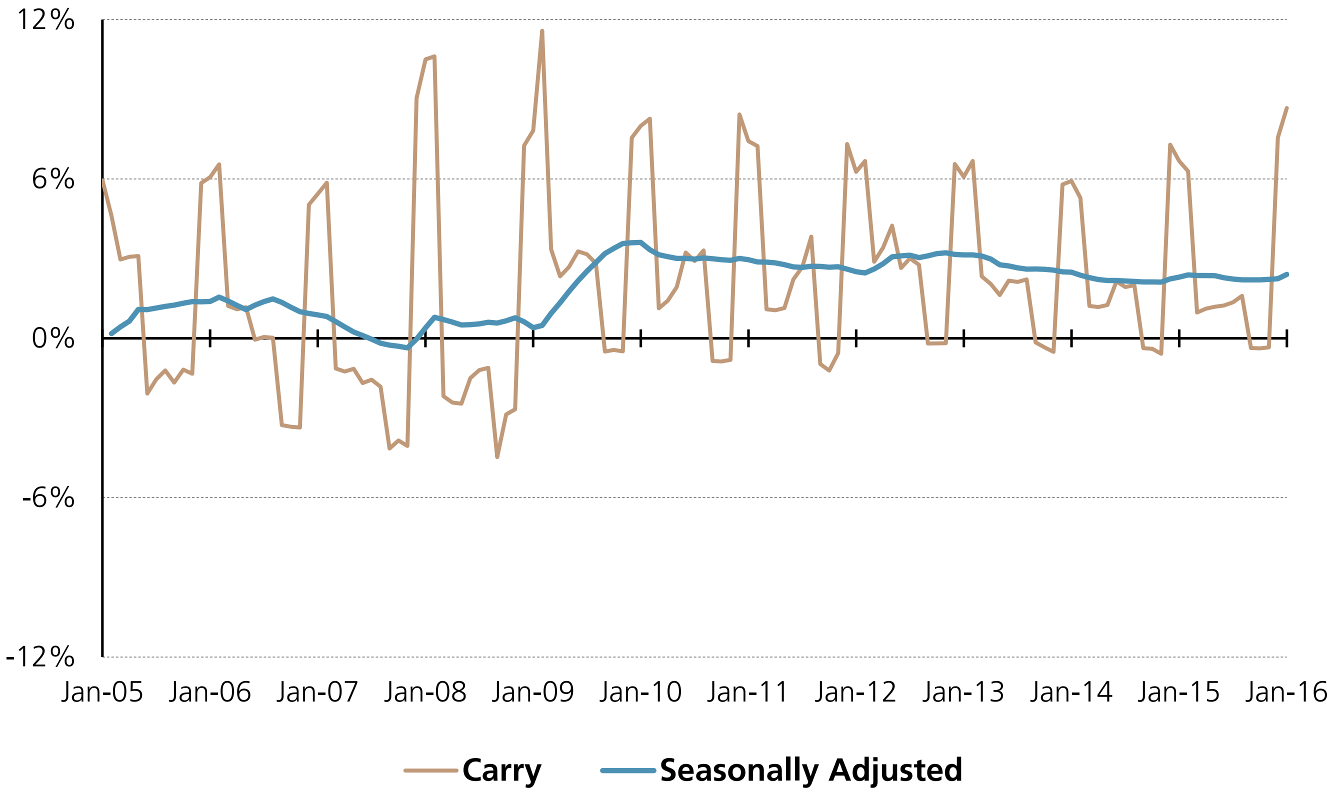
Seasonal adjustment example – FTSE MIB (Italy)



Source: UBS Quantitative Research
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Section 7

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Sell	FSR is > 6% below the MRA.	15%	21%
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