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Connecting Markets East & West

Getting paid for “making markets”

A liquidity premium that *really* is one

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Quantitative Strategy
Global Markets

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Table of contents

Overview: what liquidity provision really is

Why market-making helps a portfolio

Key points

- Many so-called “liquidity premia” are just **beta in disguise**
- A robust, genuinely different risk premium for providing liquidity does exist
  - **Providing liquidity earns this risk premium**, much like market makers do
  - It is **equivalent to mean reversion** positioning as is well documented in academic work
  - It is **different from beta and other risk premia**, such as carry, value, and momentum
- This “market-making” risk premium can enhance portfolio returns and diversification
  - **Superior returns**, especially as regulation restricts traditional market makers
  - **Genuine diversification**, particularly in crisis, as the strategy tends to benefit from illiquidity

Despite talk of "liquidity premia", the usual alternatives show no evidence of earning any premia but beta

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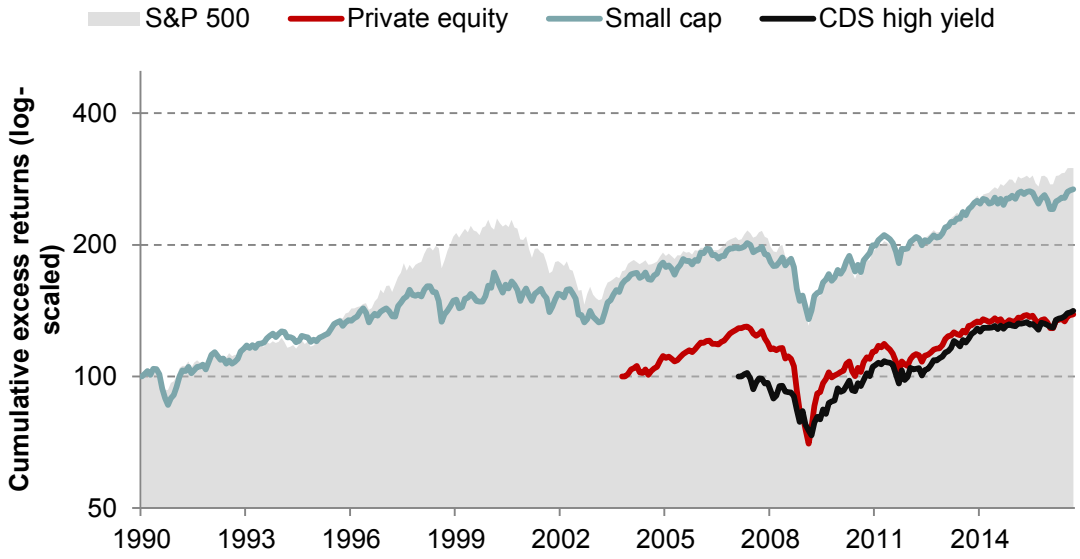
Large and significant betas, small and insignificant alphas

Singing from the same hymn-sheet - Illiquid long-only products (normalized) vs S&P 500



- Beta to S&P 500 is highly significant
  - T-stats above 10
  - Coefficients from 0.5 to 1.6
- Non-beta exposure is insignificant
  - T-stats close to zero
  - Intercept (alpha) terms close to zero

	Pvt equity	Small cap	High-yield
beta	**1.6**	**1.1**	**0.5**
t-stat	22.4	24.8	13.3
alpha	**-0.27%**	**0.06%**	**0.07%**
t-stat	-0.9	0.3	0.4

Source: Bloomberg, S&P, Nomura. Note: Listed private equity data starts in 2003, small cap in 1990 and CDX HY in 2007., Small Cap = Ruseell 2000, High Yield is CDX high yield, Beta = Beta to S&P 500

Liquidity provision premium = mean-reversion returns

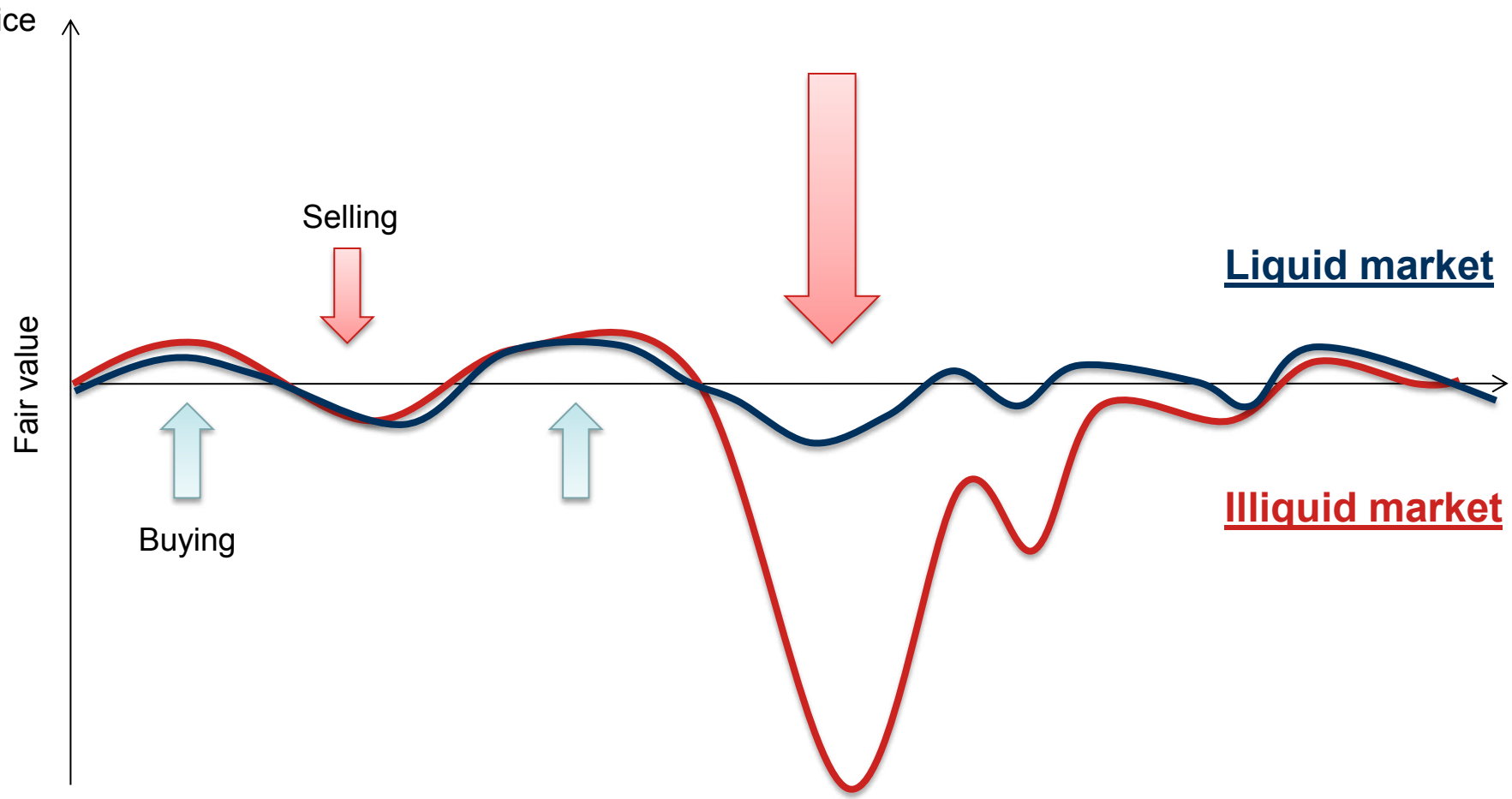
Market makers earn more in illiquid markets, as mean reversion opportunities are more extreme

Many studies show liquidity provision leads to mean-reversion returns

- Liquidity provision is a risk premium.
- Mean-reversion returns are linked to illiquidity.
- Market-makers make higher profits in illiquid markets.
- In general, empirical studies show liquidity has decreased in recent years.

Illiquid market = mean-reverting prices

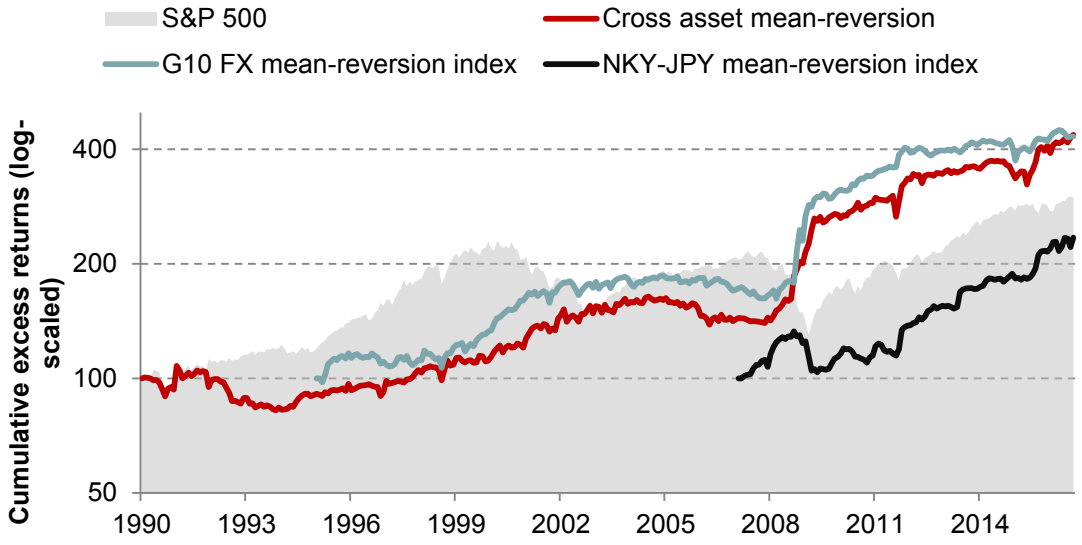
Liquid market: Large orders can be absorbed by market-makers, making mean-reversion returns negligible
Illiquid market: Large orders make market deviate from "fair value", increasing mean-reversion returns



Mean-reversion may offer *true* liquidity premia

Consistent with academic research, a "market maker" strategy earns significant non-beta risk premia

Mean-reversion captures a risk premium truly different from typical beta exposure



- Beta to S&P 500 is
  - modestly negative
  - only significant at the 10% level
- Non-beta exposure is significant
  - t-stats significant at the 1% confidence
  - intercept (alpha) is positive and decent at 86bp per annum

	Pvt equity	Small cap	High-yield	G10 FX mean-rev	NKY-JPY mean-rev	Cross asset mean-rev
beta	**1.6**	**1.1**	**0.5**	**-0.1**	**0.0**	**0.0**
t-stat	22.4	24.8	13.3	-2.3	0.8	0.7
alpha	**-0.27%**	**0.06%**	**0.07%**	**0.86%**	**0.55%**	**0.21%**
t-stat	-0.9	0.3	0.4	3.8	2.7	2.9

Source: Bloomberg, S&P, Nomura. Note: Listed private equity data starts in 2003, small cap in 1990, CDX HY in 2007. Mean-reversion strategies: FX mean-reversion in 1995., NKY-JPY mean-rev in 2007, Aggregate mean-reversion in 1990. Small Cap = Ruseell 2000, High Yield is CDX high yield, G10 FX mean-reversion is the Nomura FX mean-reversion strategy. Beta = Beta to S&P 500

G10 FX Mean Reversion

Nomura G10 FX Mean Reversion Index (Bloomberg: NMSYGRNU Index <GO>)

Style / Risk

Volatility | Momentum | Carry | **Value** | Left Tail | **Right Tail**

Instruments

- The strategy trades the following currencies:
  - GBP, AUD, NZD, CAD, NOK, SEK and CHF.
  - It trades only the less liquid pairs (excluding USD, EUR and JPY crosses)
  - Equally-weighted across the **21 less liquid G10 crosses**

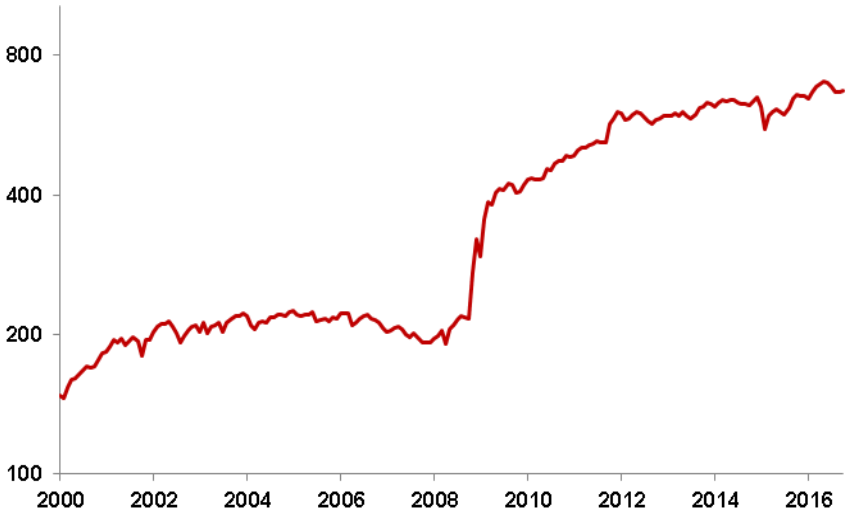
Methodology

- **Signal**: determined from the movements and volatility of the market over daily vs. six weekly time periods.
  - The size of the signal is determined by the strength of deviation from the mean
  - The overall signal is aggregated per currency
  - The individual currency delta is capped at 6% (before leverage); the global delta is capped at 10%
  - Leverage of 50x is applied to the capped signals
- **Index returns** reflects instrument positions and independent price data and are net of all charges

Key Advantages

- **Diversification across instrument for risk control** achieved through equal weight, instrument risk scaling and caps on positions
- Only **less liquid pairs**: improves performance as mean-reverting behaviour is strongest in less liquid crosses
- **Continuous signals:** avoids whipsaw trading as it can take neutral positions. Also easier implementation for large portfolios

Returns and Risk Characteristics (net of all charges)*



G10 FX Mean Reversion	Since Jan-2000	5Y	3Y	1Y
Annualised Return	9.8%	3.6%	3.0%	2.1%
Volatility	12.9%	8.5%	9.8%	6.4%
Sharpe Ratio	**0.76**	**0.43**	**0.31**	**0.33**
Max Drawdown	14.8%	14.4%	14.4%	5.2%
Calmar ratio	**0.66**	**0.25**	**0.21**	**0.41**

Skew since Jan-2000 : +2.60

** 0.50% per annum index charge is included in the performance statistics.*
Source: Nomura, Bloomberg, October 2016. Past performance is no guarantee of future results. Sharpe ratio = annualised return/standard deviation. Calmar ratio = annualised return/maximum drawdown, maximum drawdown = absolute value of the largest peak-to-valley return of the Index during the observed period. Skew is calculated based on monthly return of the index. Index returns are reconstructed using both back-tested and historical data

NKYJPY Spread Reversion A Index

Nomura NKYJPY Spread Reversion A Index (Bloomberg: NMISVNJA Index <GO>)

Style / Risk

Volatility | Momentum | Carry | **Value** | Left Tail | Right Tail

Rationale

- Historically, Nikkei 225 (NKY) and USDJPY exhibit strong co-movements
- NKY has heavy weightings in export-oriented companies
- In recent years, this co-movement between NKY and USDJPY has been further reinforced by Bank of Japan's unconventional easing policies and the FX hedging of Japanese equities positions by foreign investors

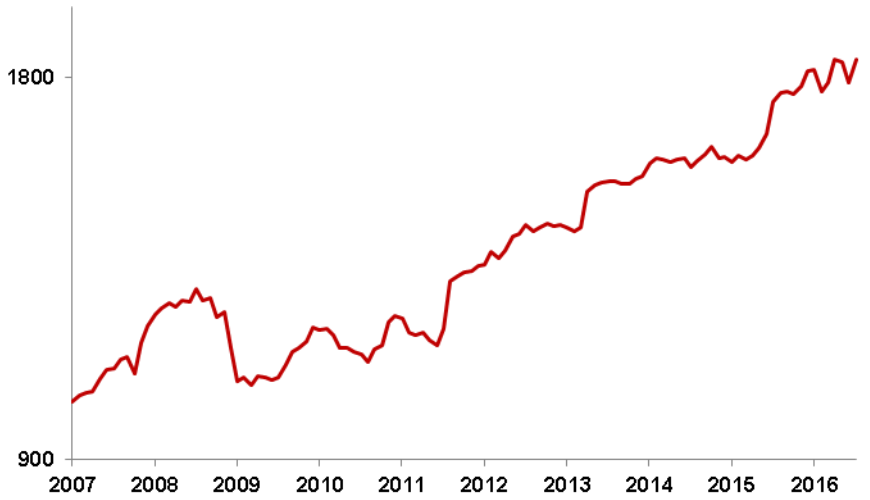
Methodology

- Nomura NKYJPY Spread Reversion Strategy enters concurrent positions in NKY futures contract and USDJPY spot to generate profit from the close relationship between the two instruments
- If NKY / USDJPY level > historical average, short NKY futures and long USD spot against JPY; else long NKY futures and short USD spot against JPY
- The notional exposure on these two instruments is based on two signals:
  - The degree of the deviation from the trailing average of the ratio (NKY/ USDJPY): Larger deviation → Bigger position
  - The historical realized volatility of the ratio: Higher volatility → Smaller position for risk control

Academic / Nomura Research

- Lo and MacKinlay 1988, *Stock Market Prices Do Not Follow Random Walks: Evidence from a Simple Specification Test*
- Goto, Ikeda and Nordvig 2013, *Bullish Equity Flows can be Bearish Yen*
- Goto and Ikeda 2016, *FX hedging flows amid volatile equity movements*

Historical Index Performance



NKYJPY Spread Reversion A	Since Inception	5Y	3Y	1Y
Annualised Return	6.8%	10.1%	7.6%	8.0%
Volatility	7.3%	7.2%	6.7%	9.0%
Sharpe Ratio	**0.92**	**1.39**	**1.13**	**0.89**
Max Drawdown	16.1%	4.0%	4.0%	4.0%
Calmar ratio	**0.42**	**2.50**	**1.89**	**1.98**

Skew since Inception : +0.36

Source: Nomura, Bloomberg; Data as of 30 September 2016 based on monthly returns

Past performance is no guarantee of future results. Sharpe Ratio = Average Return/Volatility. Maximum Drawdown = Absolute value of the largest peak-to-valley return of the Index during the observed period. For further details, please see the full presentations and documentation from Nomura. Always refer to the full documentation before investing in any product

Liquidity – What is it?

And why is there so little of it?

Liquidity - What is it?

Liquidity is a broad and elusive concept that generally denotes the ability to trade large quantities quickly, at low cost, and without moving the price.

-Pástor-Stambaugh (JPE 2003)

Market making – providing liquidity

Market makers make money when investors require immediate execution more than tight pricing

When large institutional trades come to the market, I am supposed to take them down and warehouse them. I wait for the price to move back to fair value, which is how I make money….

-Anonymous Sovereign Bond Trader

- Market makers profit by **executing and warehousing large trades**
- Earn returns from the **mean-reversion** between their bid (offer) prices and where they offload the trade.
- **Providing liquidity** is taking advantage of the price slippage in an illiquid market

Mean-reversion is a measure of the liquidity risk premium

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Academic studies propose mean-reversion as a measure of liquidity-provision returns

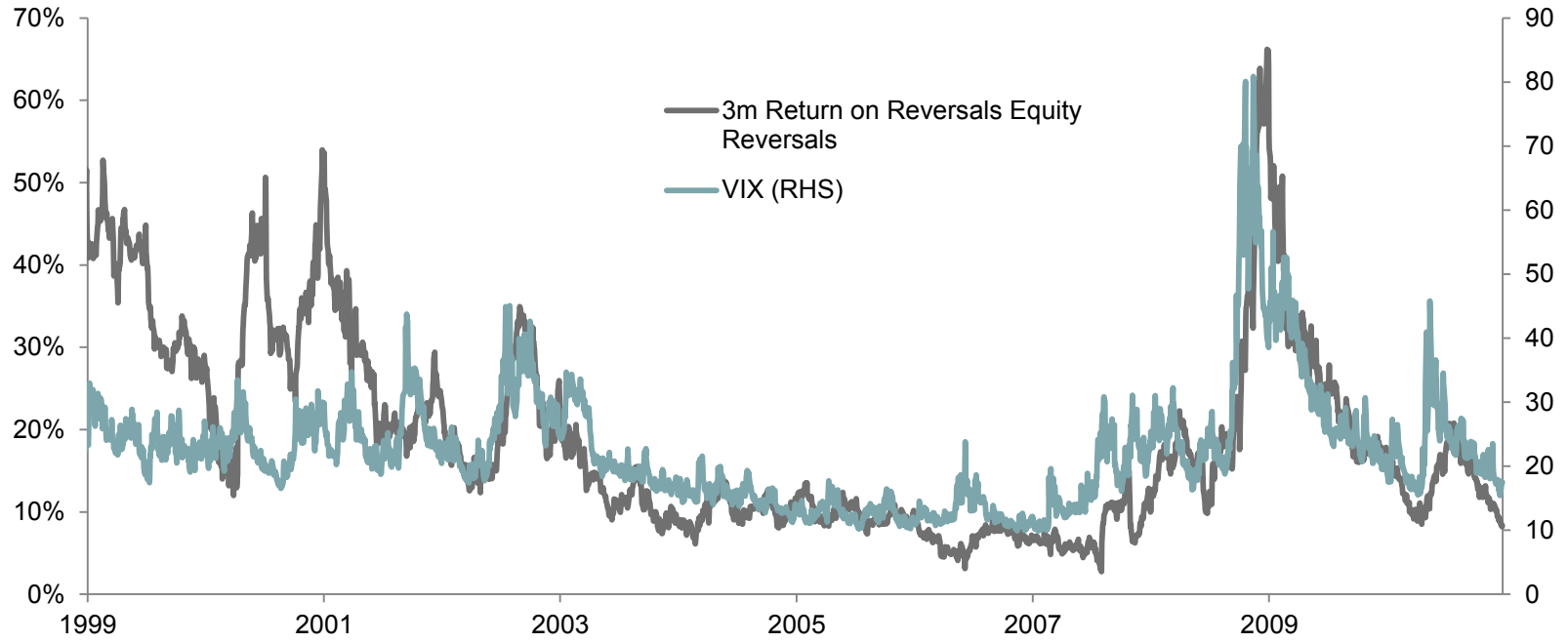
- **Campbell-Grossman-Wang (1993)** Volume is negatively correlated to **mean-reversion (reversals)**. Large volumes are accommodated by risk-averse market-makers. Liquidity premium is compensation paid to market makers for taking this risk.

- **Pástor-Stambaugh (2003)** have defined market liquidity directly by the **return on reversal strategies**, relating this return to volatility, depth of the order book and impact of market-orders. **Returns on reversal strategies** are the best proxy for market-makers' compensation.

- **Nagel (2009)** studied the **returns from mean-reversion trades**, and linked this liquidity measure to implied volatility, a measure of illiquidity.

Reversal strategies do well in volatile and illiquid markets

Time-series of daily reversal strategies in equities (3m MA) and VIX (Nagel 2009)



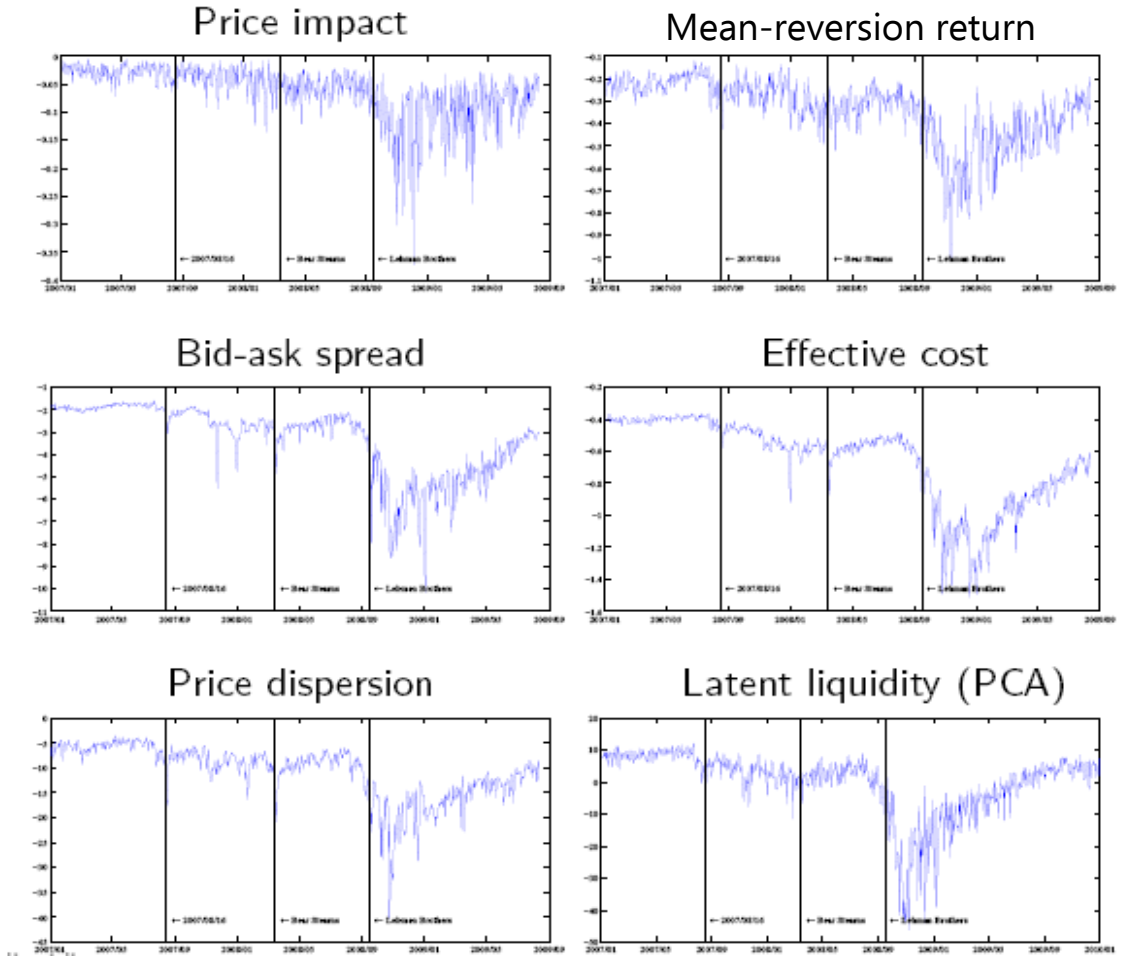
- **Higher volatility** is usually associated with periods of **illiquidity**
- Stocks more under/over-valued to their 5 day moving average (i.e., less liquid stocks) tend to generate higher reversal returns

Source: Stefan Nagel, Evaporating Liquidity (2009) and Bloomberg

Mean reversion is the liquidity premium

All the liquidity definitions are all basically the same. Mean-reversion return is the easiest to monetize.

- **Mancini-Ranaldo-Wrampelmeyer (2011)** have shown that **eight** different FX liquidity measures, including price impact, bid-ask spreads, effective costs, price dispersions *all* show significant commonality (higher than 85% correlation) with **mean-reversion return**.
- **Mean reversion return is** the return for providing liquidity to an otherwise illiquid market.

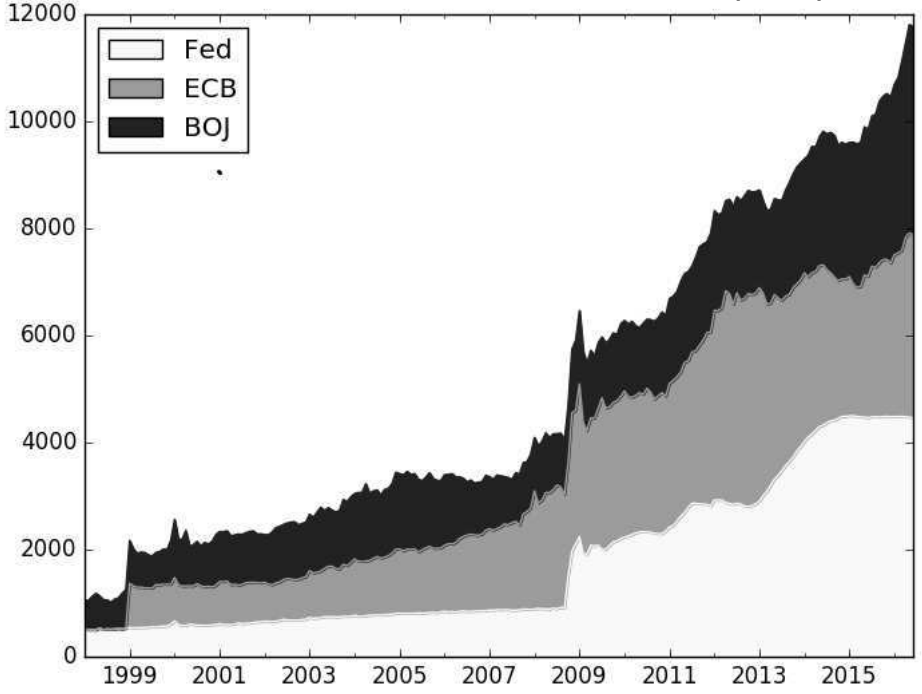


Source: Mancini-Ranaldo-Wrampelmeyer, Liquidity in the Foreign Exchange Market: Measurement, Commonality, and risk premiums, AFA JOF 2013 and Lecture Notes, Wrampelmeyer

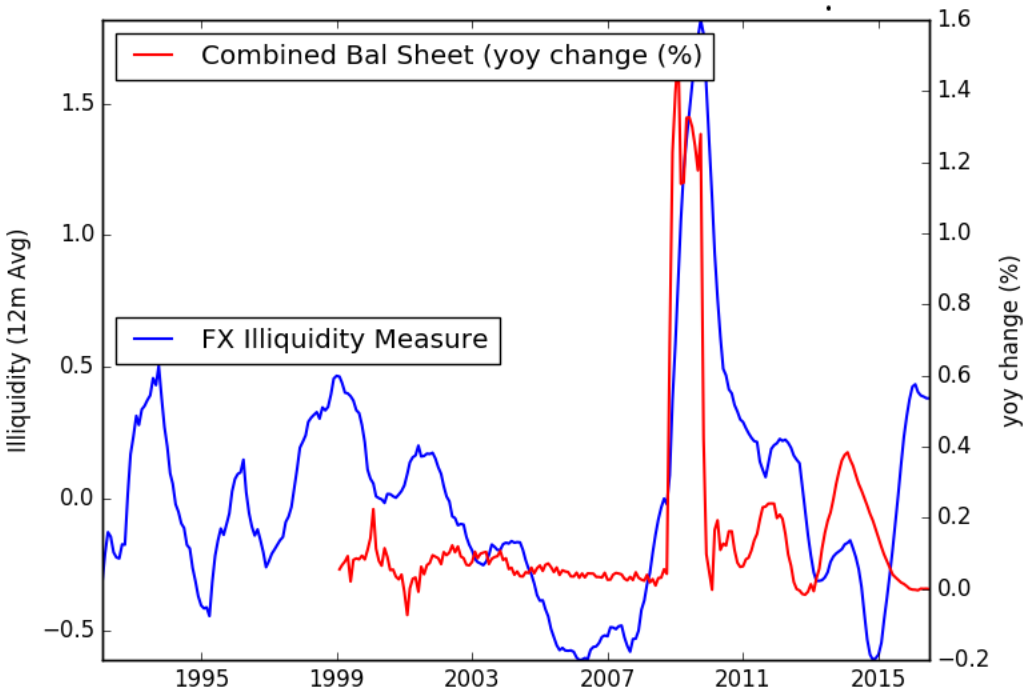
Liquidity – What it is not

Monetary liquidity* is unrelated to *market liquidity

G3 Central bank Combined Balance Sheets ($bns)



G3 Combined Balance Sheet (YOY growth) vs Illiquidity



- Monetary liquidity may *decrease* liquidity in some markets, e.g., US Treasury Bonds, EUR Sovereign Bonds, Gilts, USD MBS, EUR SSAs.
- Monetary liquidity has *little to no impact* on liquidity in other markets such as FX.
- Regulation and risk appetite are far more prominent influences on liquidity than central bank actions

Source: Bloomberg, , Kaurnakh, N, Ranaldo, A and Soderlind, P, Understanding FX Liquidity, 3rd ECB FX Workshop, Sep 2013

Liquidity – What's happened to it?

Why is the liquidity decreasing?

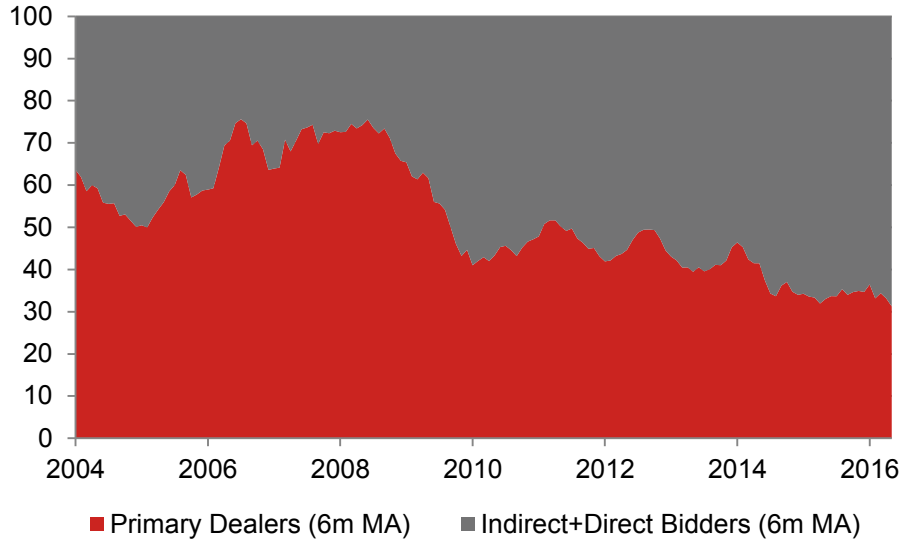
Regulation and risk-aversion have limited market-making activities

…Management is breathing down my neck to cut risk, and I can't make markets like I used to.

-Anonymous Sovereign Bond Trader

Primary Dealer Corporate Bond Holdings

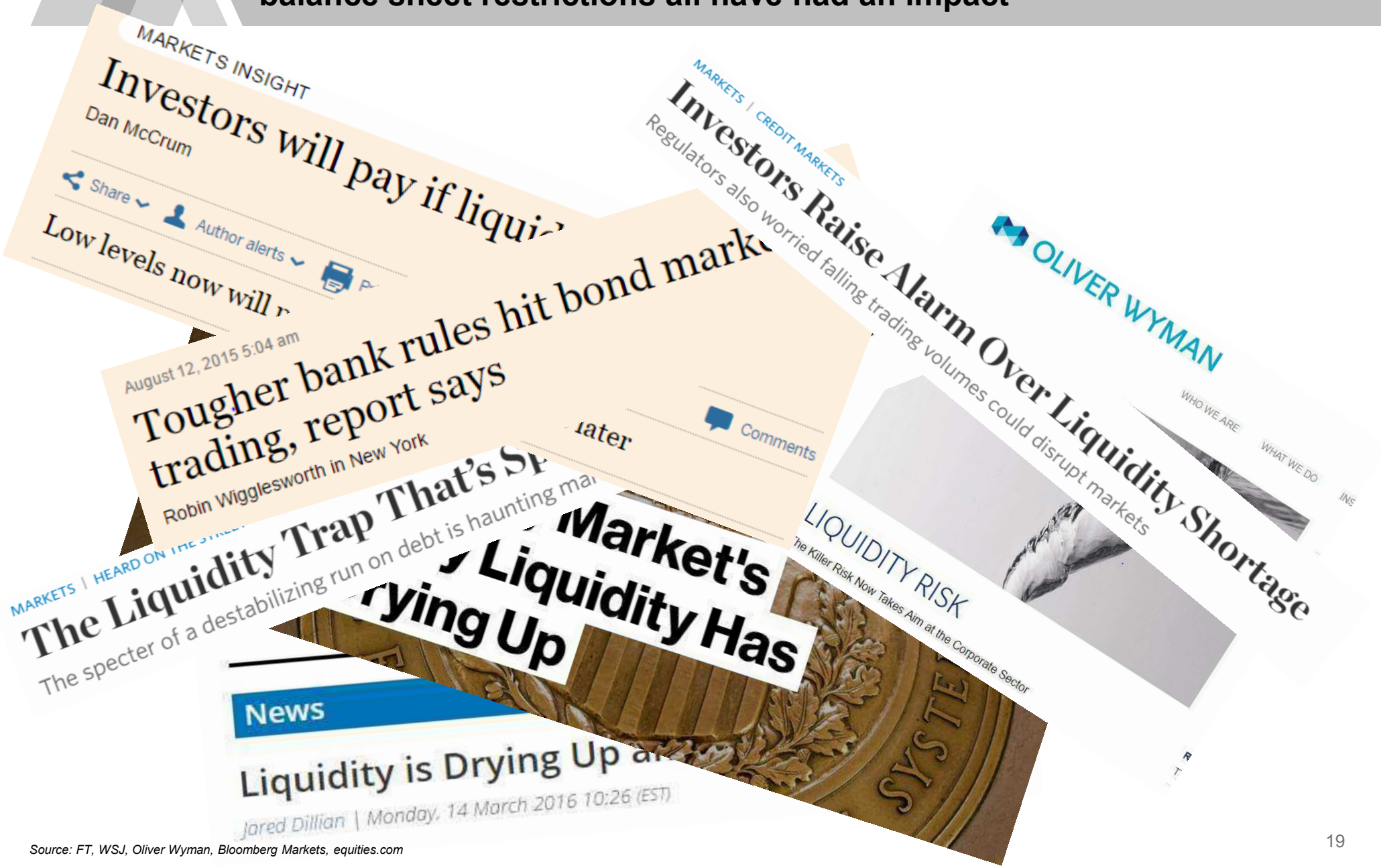
US 5yr Treasury auction dealer vs non-dealer participation



- Market-maker **inventory and risk limits have decreased significantly** as regulatory and internal risk limits have taken hold.
- Due partly to increased regulation, **most measures show liquidity decline in spread markets**, while some also show **decline in core markets**

Source: Liberty Street Economics, Federal Reserve and Bloomberg

Dropping liquidity- regulation, increasing aversion, balance sheet restrictions all have had an impact



Source: FT, WSJ, Oliver Wyman, Bloomberg Markets, equities.com

Studies show illiquidity is problematic

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Illiquidity is on the rise

Regulatory Overshoot and Global Uncertainty help to deplete it.

*There is **clear evidence of a reduction in financial markets liquidity**….**[E]ven relatively more liquid markets are experiencing declining depth**.*

--**Global financial markets liquidity study**, **PWC, August 2015**

*The **impact of regulation is clearer**… restrictions on derivatives trading … have weakened the liquidity of the underlying assets. …. **increased the fragility** of liquidity.*

-- Market Liquidity, Resilient or Fleeting: Global Financial Stability Report, Oct 2015, IMF

*It is clear that the cumulative effects of a series of **regulations** have made it **more difficult and expensive for banks and large securities dealers to act as market makers**…. ….In sum, there are good reasons to worry about market liquidity and to believe that **policymakers may have unintentionally overshot**.*

--Market Liquidity: A Primer, Economic Studies, Brookings Institution, June 2015

Source: PWC, IMF and Brookings Institute

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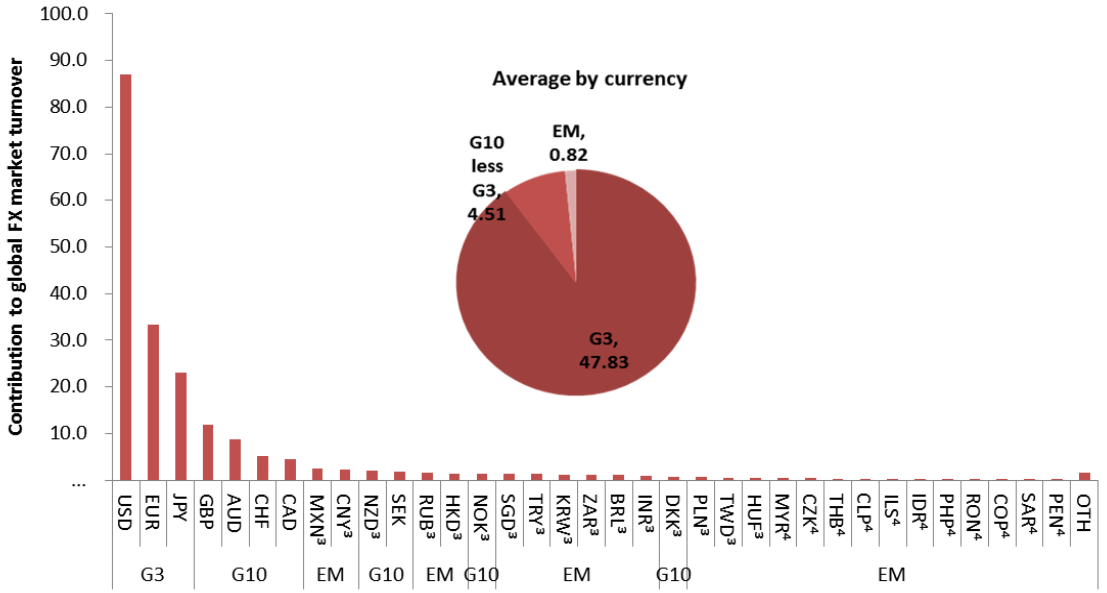
Making markets in FX & Spreads

Measuring illiquidity in order to profit

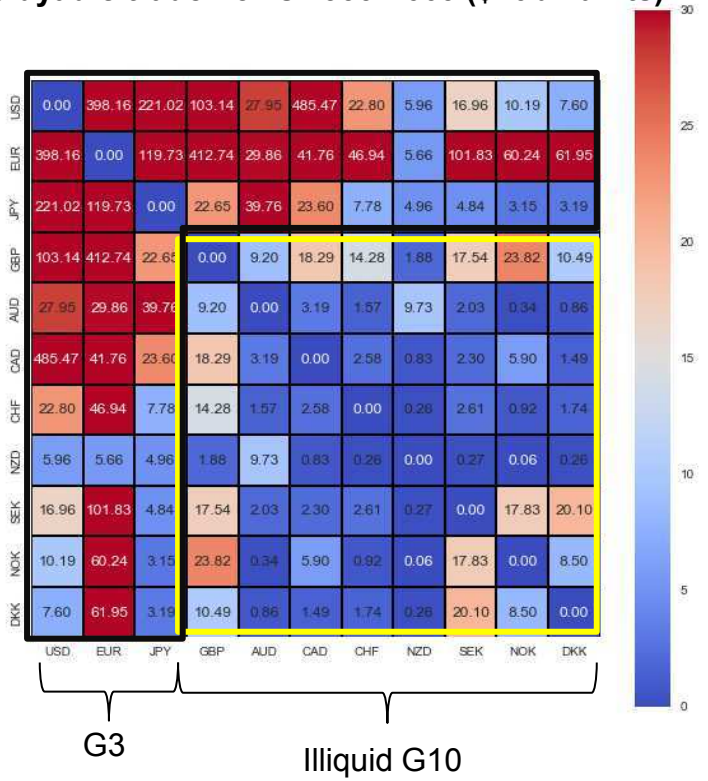
G10 *Liquid* vs *Illiquid* Currencies

G3 FX (USD, EUR, JPY) dominates turnover. Less liquid crosses generally correlate with less bilateral trade flow

Market Turnover Contribution by Currency (sums to 200%)



G10 dyadic trade flows 1999-2009 ($10bn units)

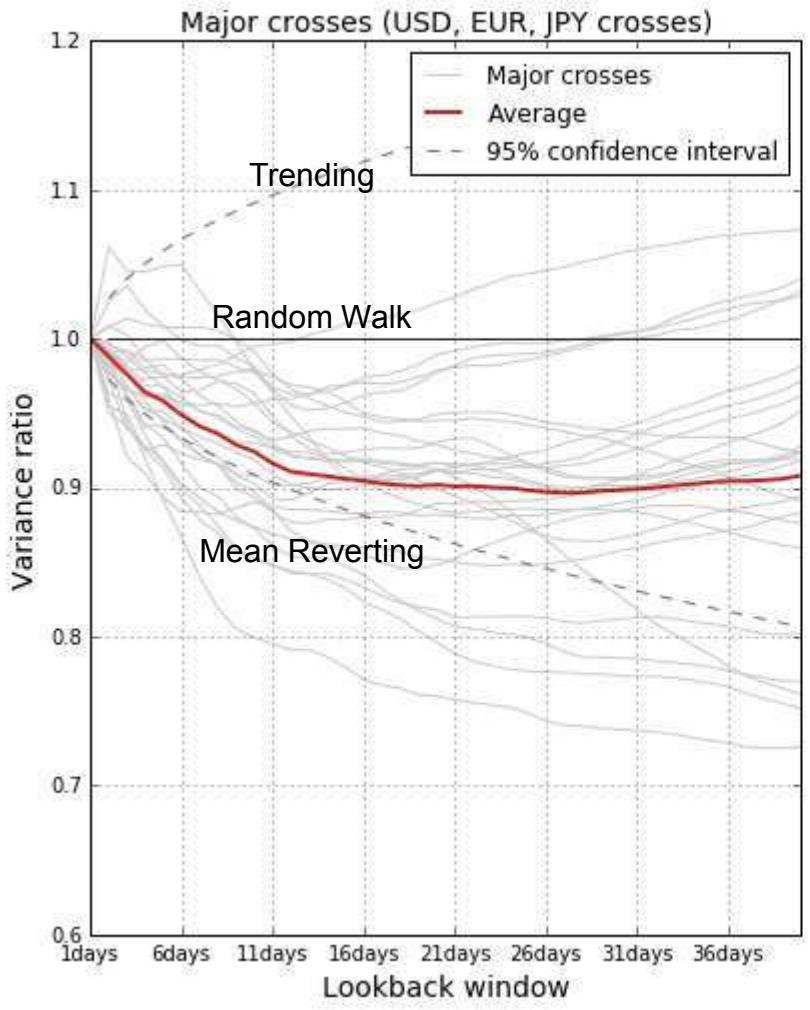


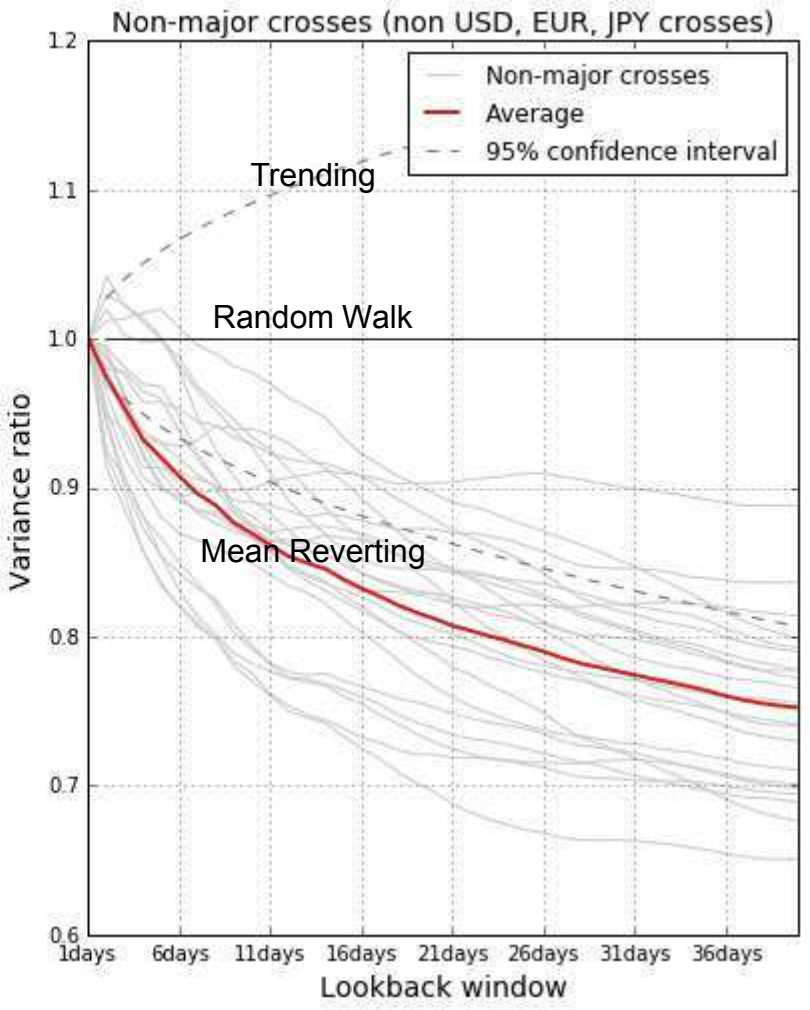
- G3 FX take up 47.3% of total turnover (out of 200%) and illiquid G10 takes up 4.8% on average.
- Larger bilateral trade flow generally corresponds to more liquid crosses.

Source: BIS Triennial CB Survey: FX Turnover in April 2013, (Sep 2013, Table 2). University of Michigan, Correlates of War Project

Illiquid crosses mean-revert more than do liquid ones

Variance Ratio statistics & Classical Confidence Intervals

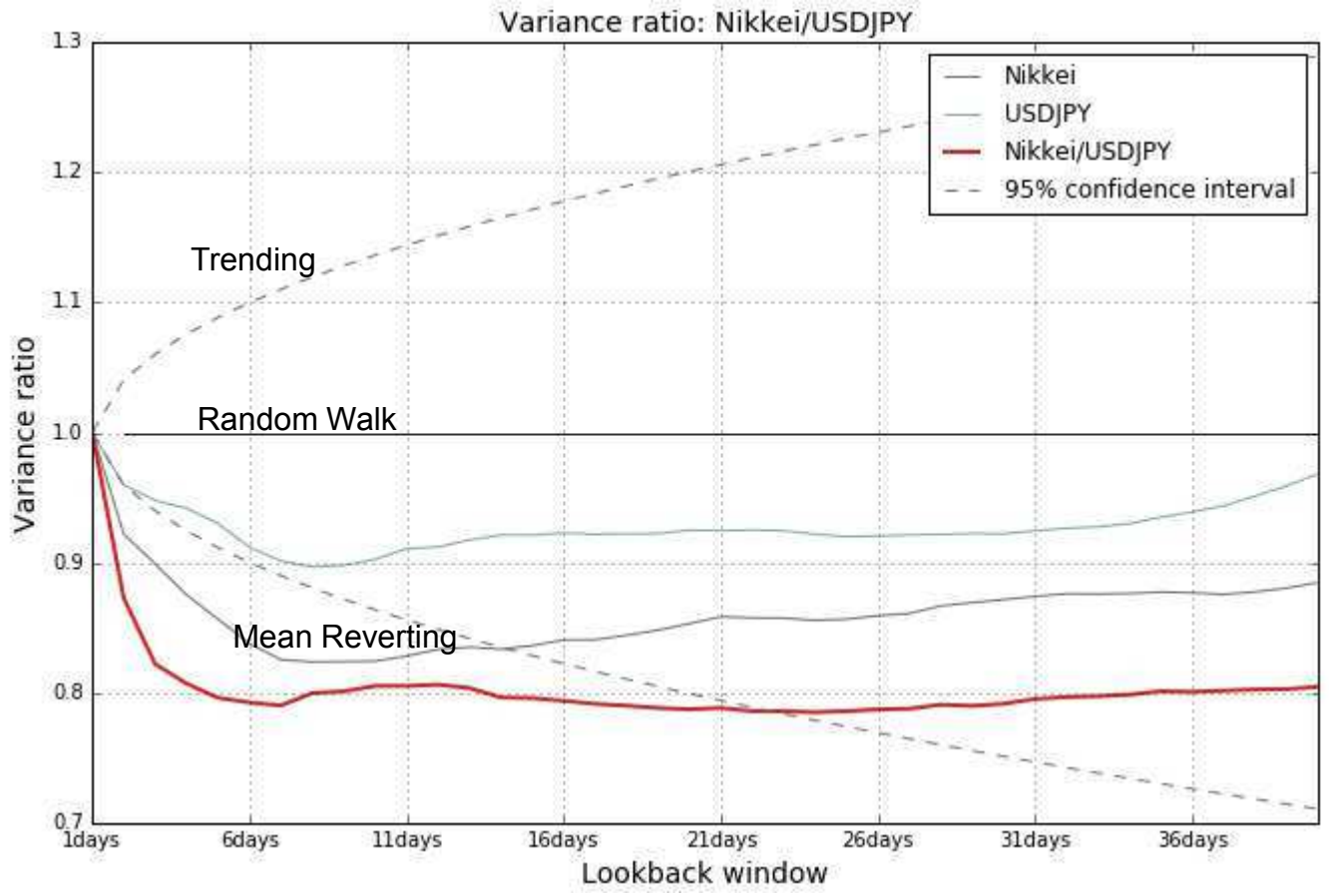




Note: Sample Period: Jan 1995 – Jun 2016. Past performance provides no guarantee of future results.
Source: Nomura

Spread trades mean-revert more than underlyings

Variance ratios & Classical confidence intervals for NKY-USDJPY

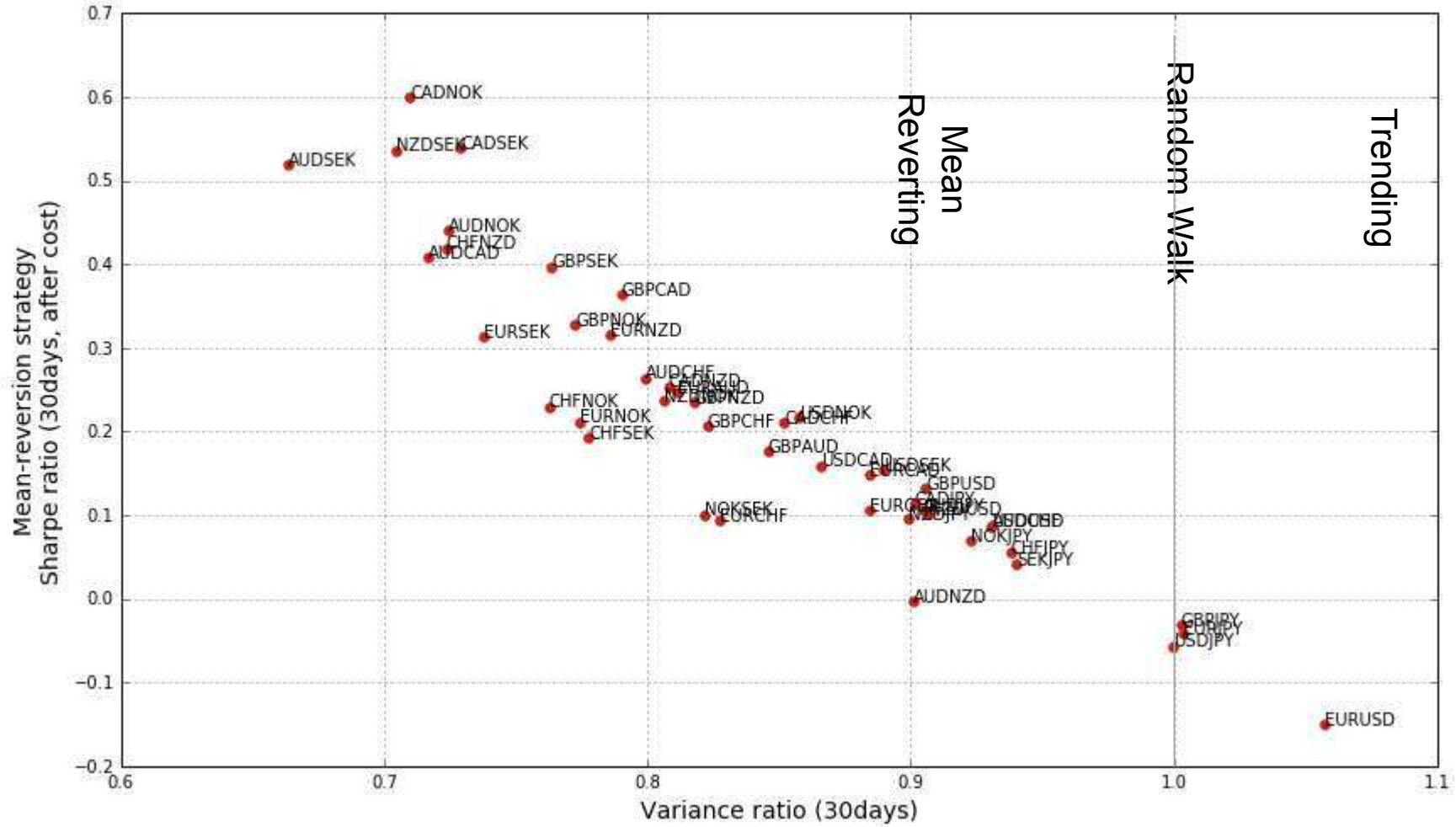


Note: Sample Period: Feb 2007 – Oct 2016. Past performance provides no guarantee of future results.
Source: Nomura

More mean-reversion means *better* trade performance

Smaller variance ratios mean higher mean reversion and better trade performance.

Sharpe (30 day MR strategies) vs 30 day VR



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Source: Nomura

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Constructing a Liquidity Provision Strategy in FX

Nomura G10 FX Mean Reversion Index

Trading Illiquid FX Crosses

The strategy replicates the performance of a mean-reversion trading strategy across the universe of less liquid G10 cross FX pairs

- **The construction is based on less-liquid G10 pairs**
  - 21 currency pairs (we exclude all USD, EUR and JPY crosses and DKK, leaving (7x6)/2 crosses)
  - The index tracks the performance of applying the signals to Nomura's FX Return indices*

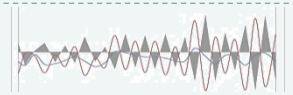
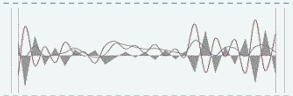
- **A mean reversion signal is computed for each currency pair by comparing volatility of daily returns and volatility of 30-business day return**. These volatilities are computed over a 30-business day period**
  - The resulting signals reflect the strength of deviation from the mean level
  - The overall signal is aggregated per currency (i.e. six pairs for each currency)
  - The individual currency delta is capped at 6% (before leverage); the global delta is capped at 10%
  - Leverage of 50 is applied to the capped signals

- **The following transaction costs applied in the index:**
  - Transaction costs of: 0.01% / 0.10% p.a. for roll cost for GBP, AUD, CHF & CAD;
  - Transaction costs of: 0.02% / 0.20% p.a. for NZD, SEK & NOK.

**Nomura's FX Return Indices are excess return indices incorporating TN (tomorrow-next) daily carry. See appendix for more details*
***The signals are equivalent to the theoretical delta of equal notional amounts of VarSwap positions in each pair whereby we are long daily / short 30-business day varswaps*

Aggregating the signal to reduce transaction costs

The signal across all currency pairs is aggregated (via the "triangle arbitrage") to come up with a single signal in each underlying liquid FX.

CCY Pair (21 pairs)	Mean Reversion Signal Analysis	Signal Aggregation
GBPCHF		0.9%
GBPCAD		(1.2%)
GBPAUD		2.6%
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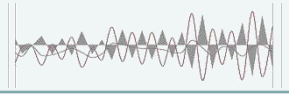
NOKSEK		(1.0%)

Currency (vs USD)	Raw Aggregate Position	Position after Local Cap	Position after Global Cap	Position after Leverage
GBP	4.2%	4.2%	2.9%	146%
CHF	(6.3%)	(6.0%)	(4.2%)	(208%)
CAD	3.2%	3.2%	2.2%	111%
AUD	2.5%	2.5%	1.7%	87%
NZD	4.5%	4.5%	3.1%	156%
SEK	(6.0%)	(6.0%)	(4.2%)	(208%)
NOK	(2.1%)	(2.1%)	(1.5%)	(73%)

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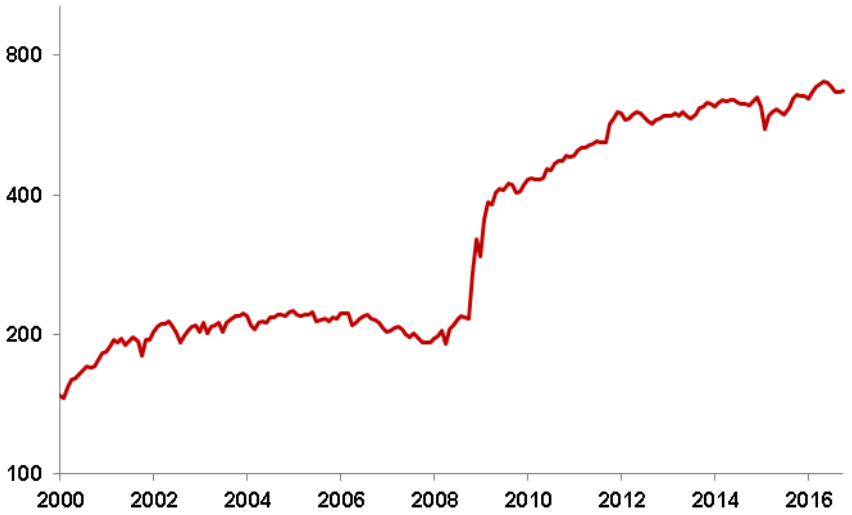
Returns and Risk Characteristics (net of all charges)*



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** 0.50% per annum index charge is included in the performance statistics.*

Source: Nomura, Bloomberg, October 2016. Past performance is no guarantee of future results. Sharpe ratio = annualised return/standard deviation. Calmar ratio = annualised return/maximum drawdown, maximum drawdown = absolute value of the largest peak-to-valley return of the Index during the observed period. Skew is calculated based on monthly return of the index. Index returns are reconstructed using both back-tested and historical data

Constructing a Liquidity Provision Strategy in Spreads

Nomura NKYJPY Spread Reversion Index

Rationale for spread reversion

The co-movement of NKY with USDJPY provides ample opportunities for trading mean-reversion

- The NKY dominated by **export-oriented companies**
  - When the **yen strengthens** (USDJPY falls), Japanese exporters see a **reduced demand** for their products from foreign buyers
  - This **reduced demand** leads to **lower expected corporate earnings**
  - Consequently, **Nikkei falls**
  - **The reverse holds true** - when yen weakens, increased demand for products leads to higher corporate earnings
- This is **confirmed statistically** – changes in JPY lead changes in NKY (not the other way around) (see Appendix)

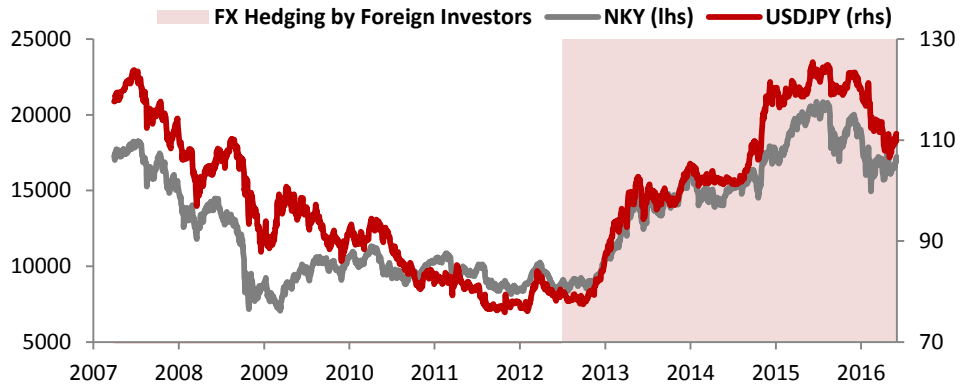
Source: Nomura research, Bloomberg.

Rationale for spread reversion

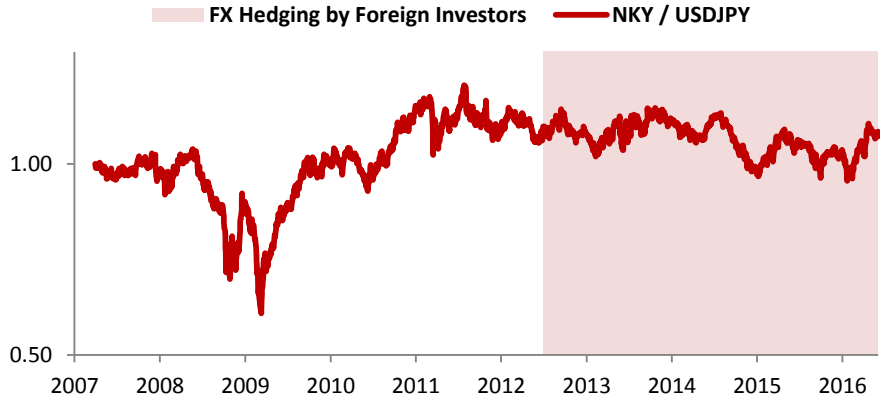
The co-movement of NKY with USDJPY provides ample opportunities for trading mean-reversion

- BoJ's unconventional easing policies have lead to
  - JPY funding of both Japanese equities and dollar-denominated higher-yielding assets
  - Together with FX hedging demand of Japanese equities, this has reinforced the comovement on JPY and NKY
- Recent negative rates, after decades of zero-interest rates, further established yen as the default funding currency for global risk

Co-movement of NKY and USDJPY



Stable mean-reversion spread between NKY and USDJPY



Source: Nomura research, Bloomberg.

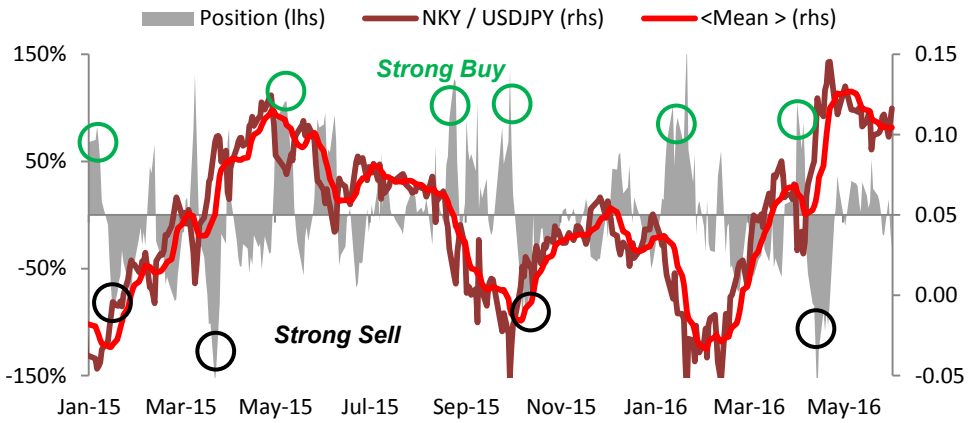
Trading the mean-reversion of NKYJPY spread
– Deciding the direction and position based on signal deviation

Extracting value from mean reversion; Trading signals derived from the deviation of NKY/JPY ratio level from its trailing mean

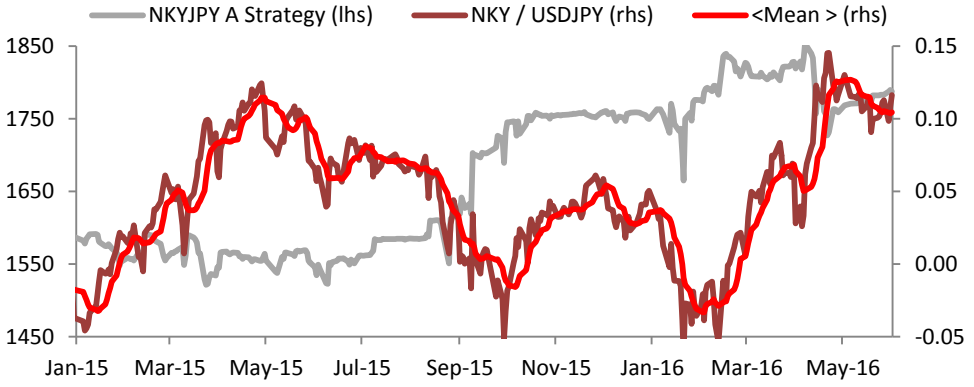
Trading mean-reversion

- Indicator: NKY / USDJPY[1] ratio
- Traded basket: long NKY futures and short USDJPY[1]
- Signals are determined based on the extent to which the ratio deviates from its trailing mean
  - The larger the deviation of the prevailing ratio from its trailing mean[2], the stronger the signal
  - The positions are adjusted daily reflecting the most current signal strengths
- The bottom chart shows the cumulative performance of the mean-reversion trades

Ratio mean-reversion and positioning



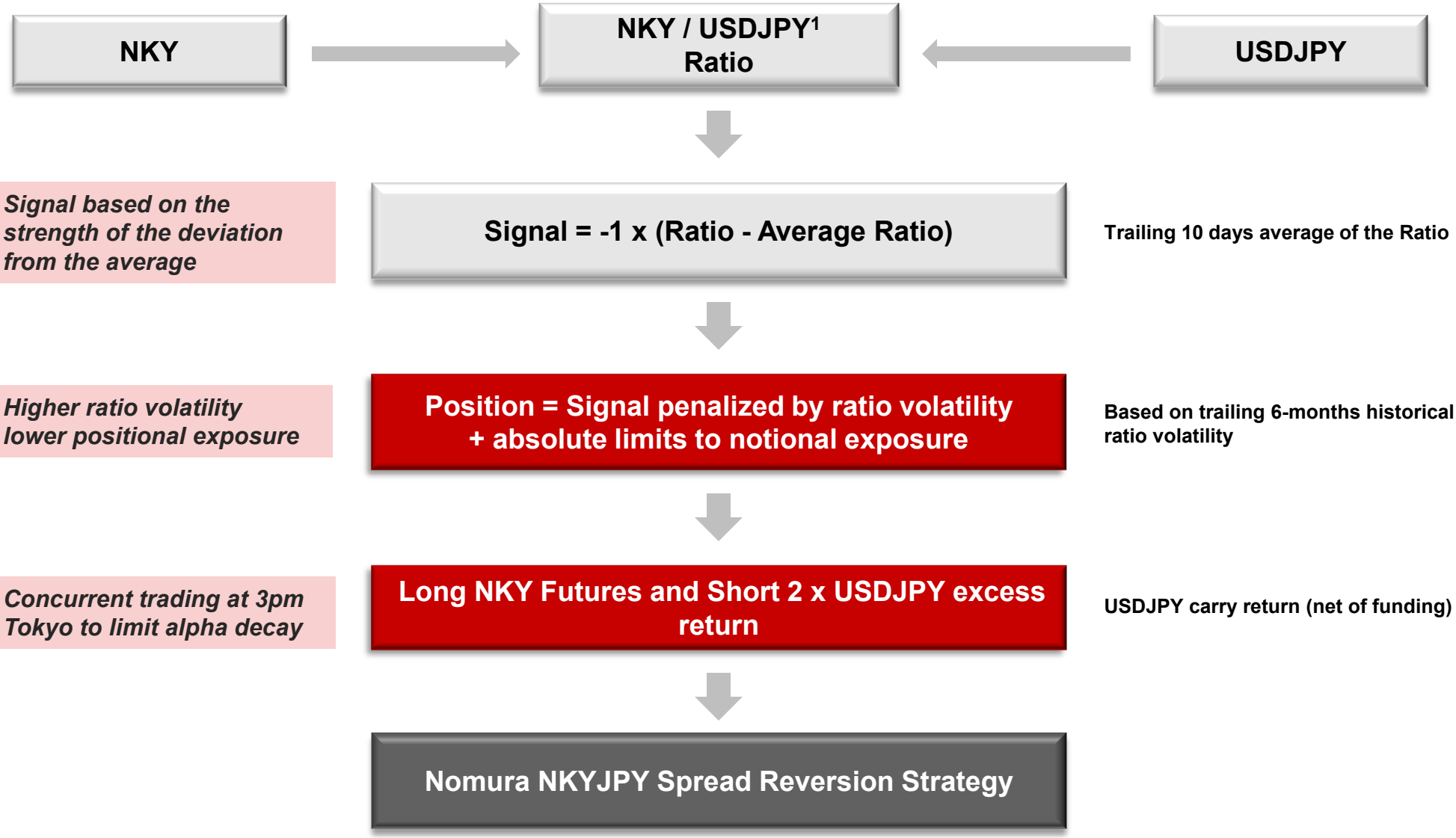
Historical Performance



Source: Nomura Research, Bloomberg

1. *USDJPY derives from 2 x notional exposure of the change in USDJPY levels*
2. *Trailing mean refers to the rolling 10-day average*

Nomura NKYJPY Spread Reversion Strategy mechanism



1. *USDJPY at 2 x exposure*

NKYJPY Spread Reversion A Index

Nomura NKYJPY Spread Reversion A Index (Bloomberg: NMISVNJA Index <GO>)

Style / Risk

Volatility | Momentum | Carry | **Value** | Left Tail | Right Tail

Rationale

- Historically, Nikkei 225 (NKY) and USDJPY exhibit strong co-movements
- NKY has heavy weightings in export-oriented companies
- In recent years, this co-movement between NKY and USDJPY has been further reinforced by Bank of Japan's unconventional easing policies and the FX hedging of Japanese equities positions by foreign investors

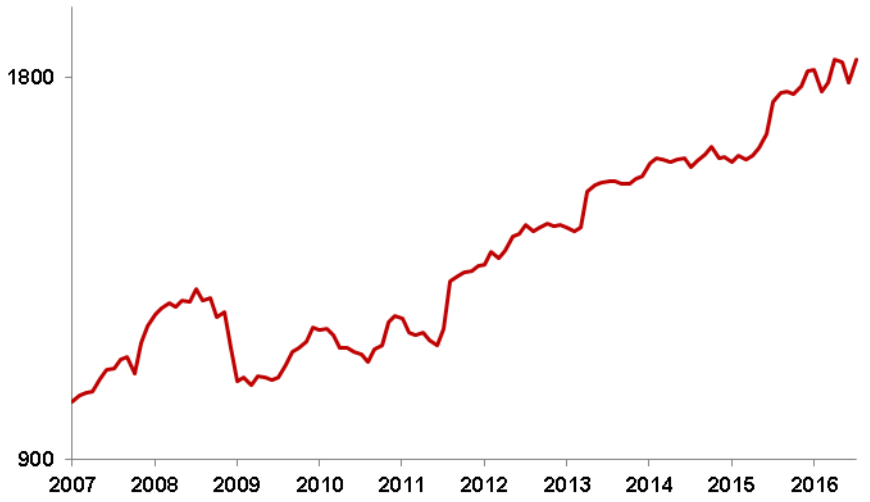
Methodology

- Nomura NKYJPY Spread Reversion Strategy enters concurrent positions in NKY futures contract and USDJPY spot to generate profit from the close relationship between the two instruments
- If NKY / USDJPY level > historical average, short NKY futures and long USD spot against JPY; else long NKY futures and short USD spot against JPY
- The notional exposure on these two instruments is based on two signals:
  - The degree of the deviation from the trailing average of the ratio (NKY/ USDJPY): Larger deviation → Bigger position
  - The historical realized volatility of the ratio: Higher volatility → Smaller position for risk control

Academic / Nomura Research

- Lo and MacKinlay 1988, *Stock Market Prices Do Not Follow Random Walks: Evidence from a Simple Specification Test*
- Goto, Ikeda and Nordvig 2013, *Bullish Equity Flows can be Bearish Yen*
- Goto and Ikeda 2016, *FX hedging flows amid volatile equity movements*

Historical Index Performance



NKYJPY Spread Reversion A	Since Inception	5Y	3Y	1Y
Annualised Return	6.8%	10.1%	7.6%	8.0%
Volatility	7.3%	7.2%	6.7%	9.0%
Sharpe Ratio	**0.92**	**1.39**	**1.13**	**0.89**
Max Drawdown	16.1%	4.0%	4.0%	4.0%
Calmar ratio	**0.42**	**2.50**	**1.89**	**1.98**

Skew since Inception : +0.36

Source: Nomura, Bloomberg; Data as of 30 September 2016 based on monthly returns

Past performance is no guarantee of future results. Sharpe Ratio = Average Return/Volatility. Maximum Drawdown = Absolute value of the largest peak-to-valley return of the Index during the observed period. For further details, please see the full presentations and documentation from Nomura. Always refer to the full documentation before investing in any product

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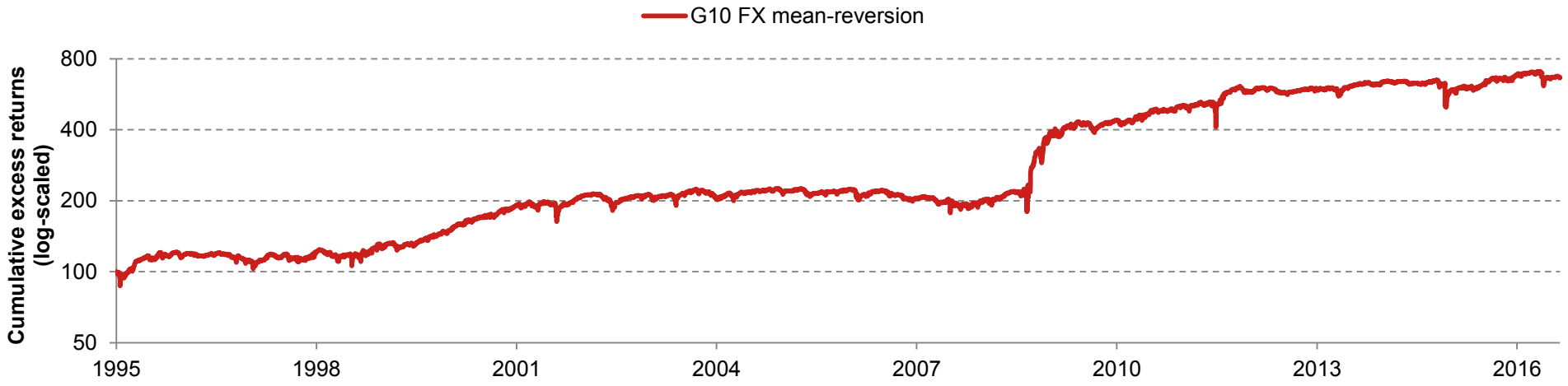
Analysing Returns of Mean-Reversion Strategies

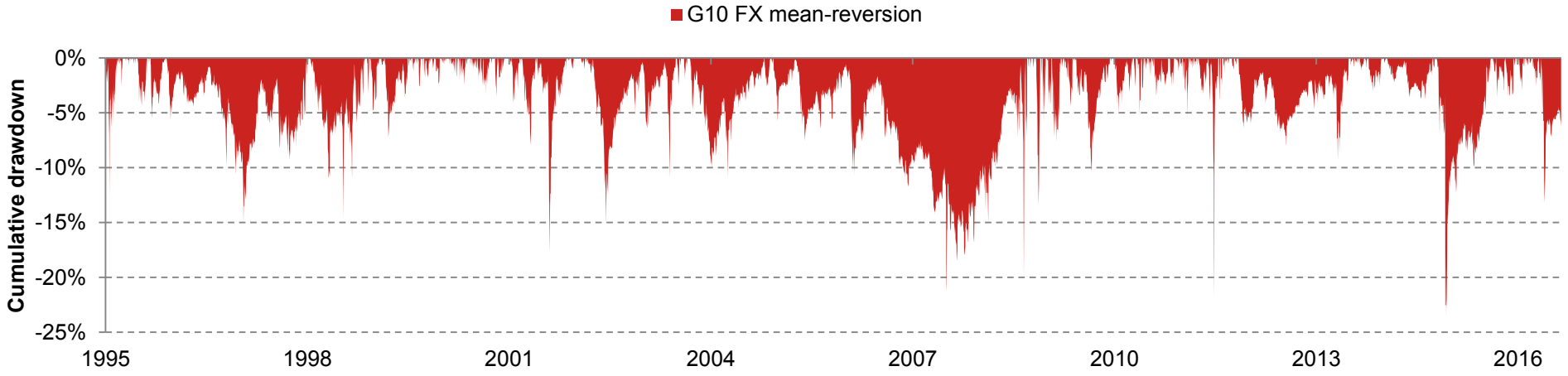
Volatility, Drawdowns and Correlations

G10 FX MR index performs best during crises

Index Level – Nomura G10 FX Mean Reversion Index



Cumulative drawdowns

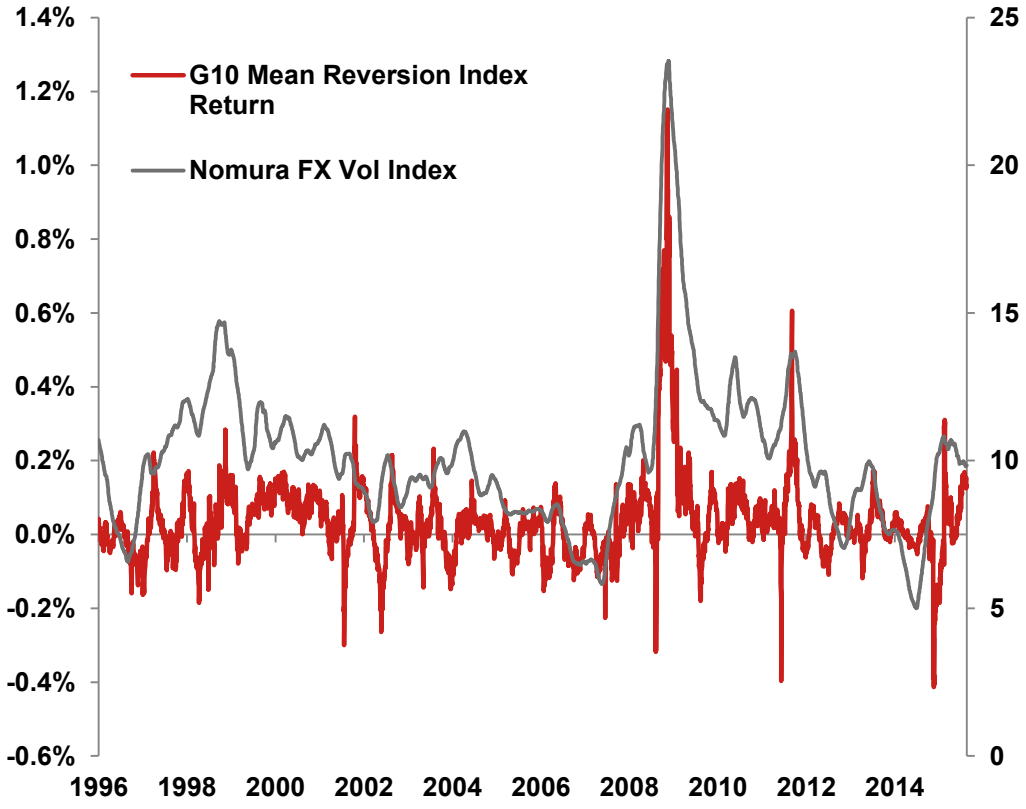


Source: Bloomberg, Nomura. Index performance are reconstructed using both back-tested and historical data. Live performance of the Index from 11-Nov-2015 onwards. Statistics computed over 14-Feb-1995 to 8 Feb-2016. Past performance provides no guarantee of future results.

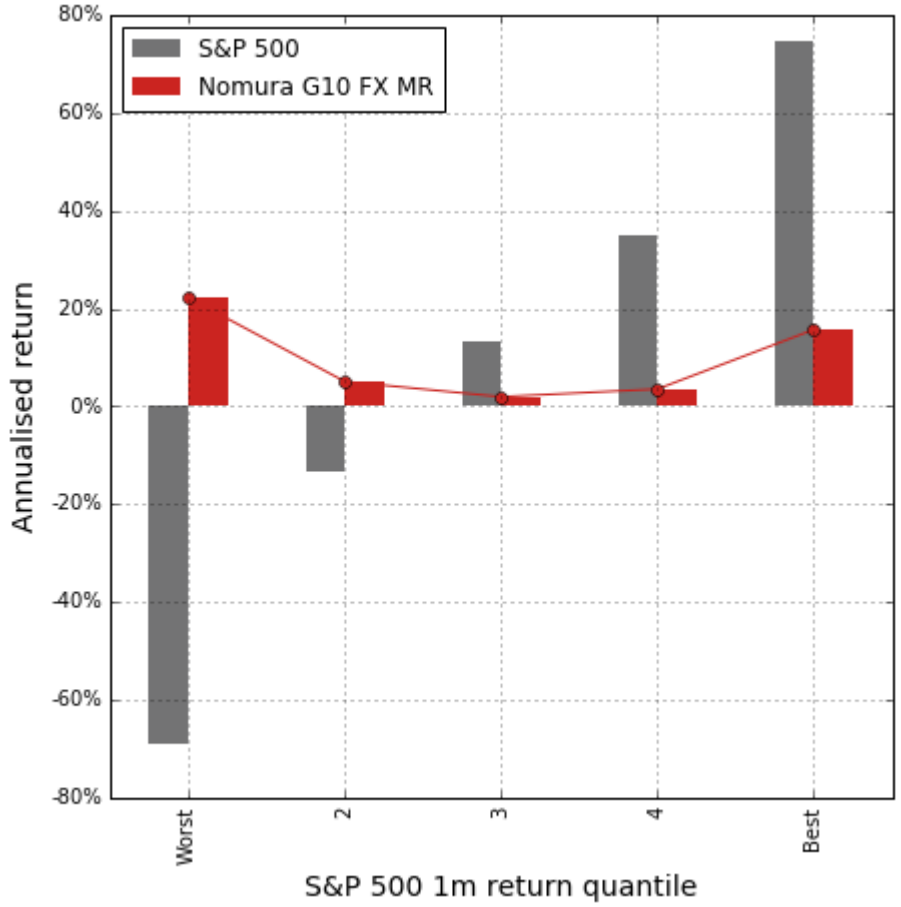
Better returns in volatile markets

As expected, mean reversion returns are higher in volatile markets*

Link between returns and volatility**



Mean reversion performs well in extreme markets***

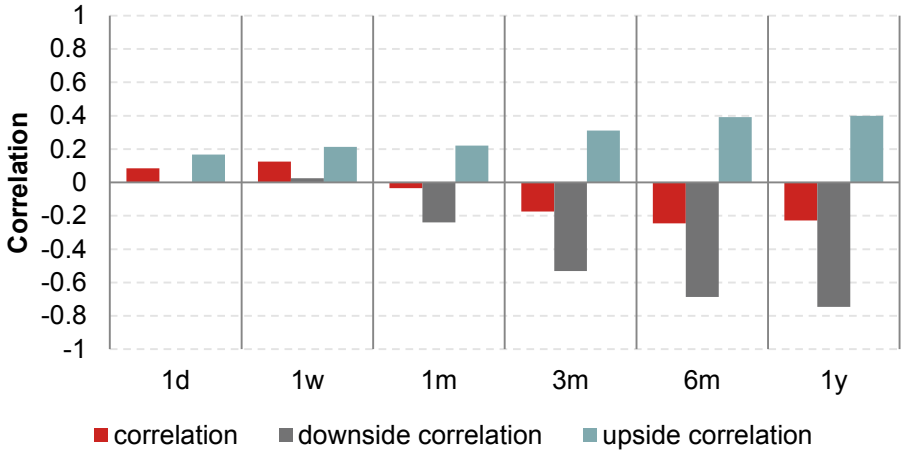


*See Appendix for technical rationale
** The chart depicts the 3 month moving rolling averages of the daily returns of the G10 Mean Reversion Index and the Nomura FX Vol Index
*** Note: Sample Period: Jan 1995 – Jun 2016. Past performance provides no guarantee of future results.
Source: Nomura, Bloomberg

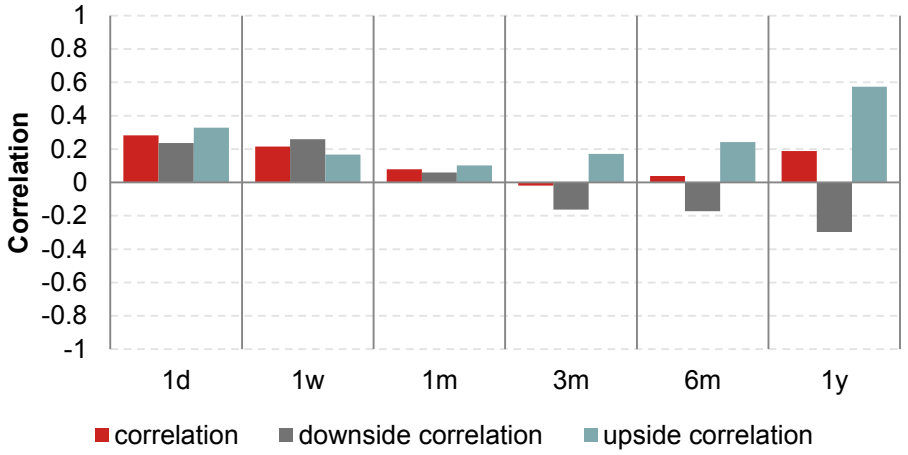
MR has a straddle-like payoff over longer horizons

Drawdowns can be sharp, but Mean Reversion gives downside protection over medium to longer horizons

FX Mean Reversion vs S&P500
Correlation over different return horizons



NKYJPY Spread Reversion vs Nikkei
Correlation over different return horizons

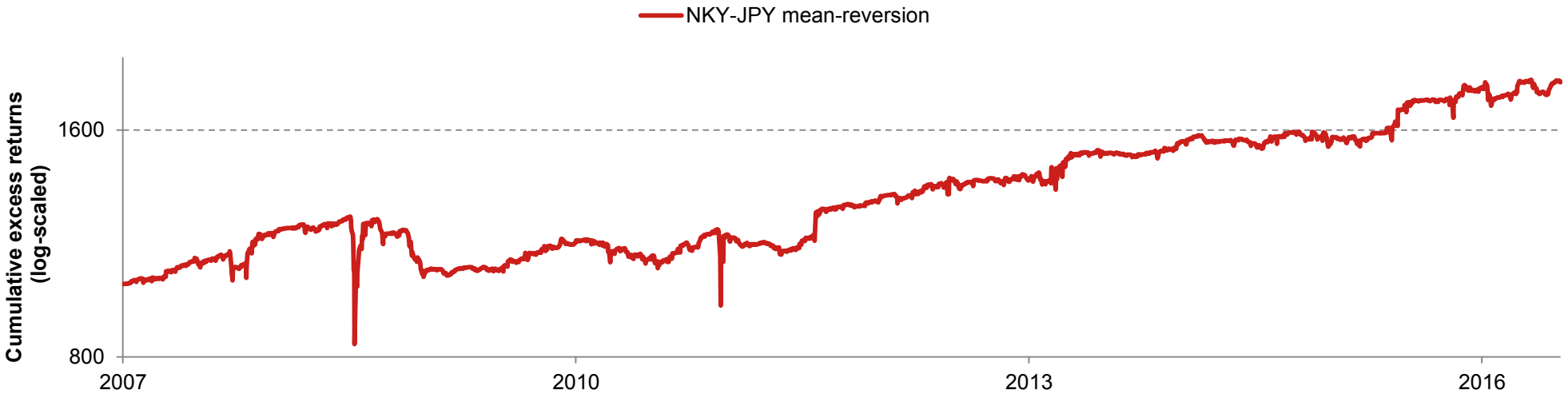


- MR returns typically have a (small) positive correlation at 1day-1week horizon
- The **correlation** to equities becomes very negative **over longer horizons**.
- It has a '**straddle-like**' payoff over longer horizons, with positive upside correlation and negative downside correlations.
- Partial correlations are computed conditioning on equities returns

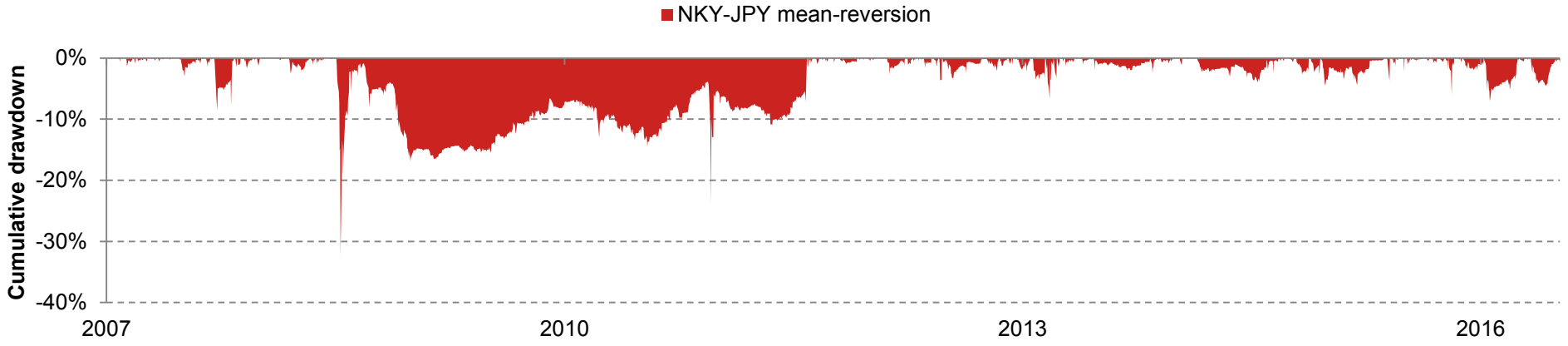
Note: Sample Period: Jan 1995 – Jun 2016. Past performance provides no guarantee of future results.
Source: Nomura, Bloomberg

Nomura NKY-JPY has positive skew and quick recovery

Index Level – Nomura NKY-JPY Mean Reversion Index



Cumulative drawdowns



Source: Nomura.

MR over longer horizons
Higher Sharpe, lower vol, lower kurtosis

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Daily marks are necessary for risk and collateral management, but …

…longer horizons reflect investment decisions

G10 FX Mean Reversion

	1 day	1 week	1 month	3 months
mean	10.59%	10.22%	10.15%	10.30%
variance	3.10%	2.25%	1.83%	2.22%
sharpe	**0.60**	**0.68**	**0.75**	**0.69**
skewness	3.44	2.04	3.42	3.90
kurtosis	163.72	43.85	37.79	29.27

NKYJPY Spread Reversion

	1 day	1 week	1 month	3 months
mean	7.58%	7.08%	6.68%	6.59%
variance	2.96%	1.83%	1.15%	0.82%
sharpe	**0.44**	**0.52**	**0.62**	**0.73**
skewness	4.34	-0.24	1.60	0.25
kurtosis	260.84	102.57	48.96	7.45

Cross Asset Mean Reversion

	1 day	1 week	1 month	3 months
mean	6.64%	6.53%	6.37%	6.34%
variance	1.51%	1.26%	0.89%	0.81%
sharpe	0.54	0.58	0.67	0.70
skewness	0.99	0.10	2.22	2.38
kurtosis	48.63	35.17	26.83	11.94

Generally extending the horizon generally results in

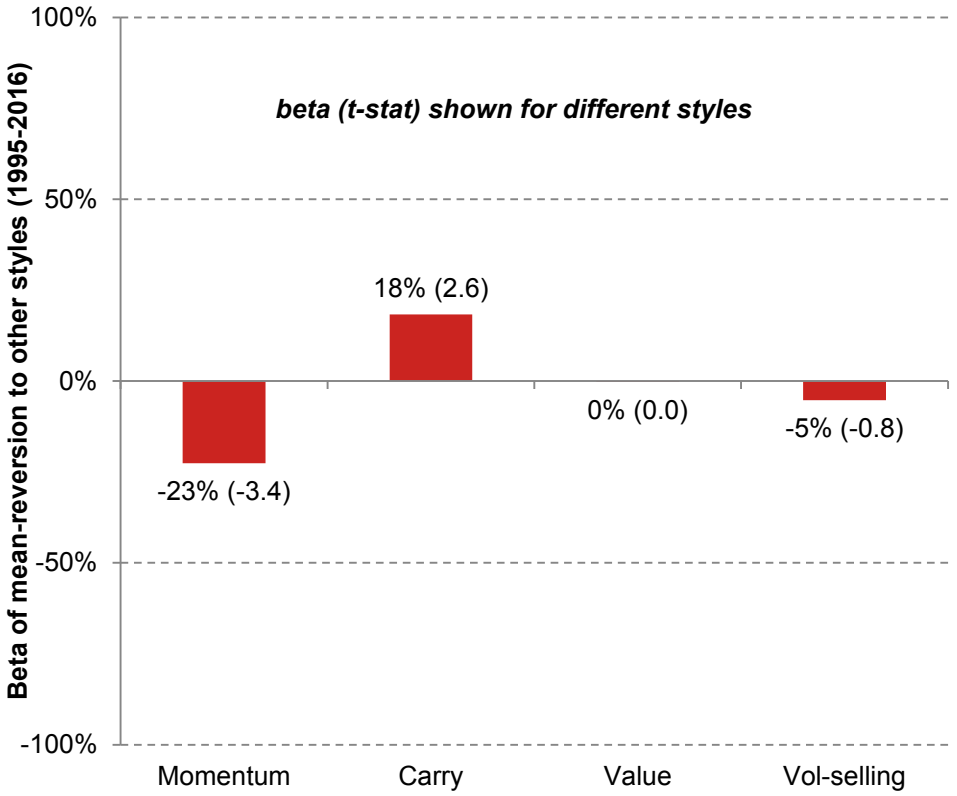
- **Lower Kurtosis**
- **Lower Variance**
- **Higher Sharpe Ratios**

And continuing positive Skewness

Mean-reversion, a differentiating strategy

MR Returns offer genuine diversification from other systematic strategies

MR appears to be different from other investment styles



Cross-correlations among strategies are low

1995-2016	Cross asset mean-rev	Mmtm	Carry	Value	Vol-selling
Cross asset mean-rev	100%	-19%	12%	8%	-2%
Mmtm		100%	22%	-17%	10%
Carry			100%	23%	29%
Value				100%	3%
Vol-selling					100%

Downside correlations to other investment styles are low

1995 - 2016	Mmtm	Carry	Value	Vol-selling
Cross asset mean-rev	7%	22%	12%	-16%

Correlation of mean-rev to vol-selling <u>given</u> vol-selling has negative returns

Source: Nomura. Analysis using monthly returns from 1995 – 2016. Momentum, carry and value are generic cross-asset implementations intended to capture behaviour of a particular investment style.

Conclusions

Genuine liquidity premium as a diversified source of returns

Conclusion

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Market-making via mean-reversion trading

- Most products that supposedly pay “liquidity premia” are usually **high beta** with **no significant premium**
- Market makers make money by providing liquidity to the market.
- Illiquid markets mean-revert and **mean-reversion is a definition of liquidity premium**.
- **Regulatory overshoot** has seriously damaged liquidity.
- Works better for **spread trades** – G10 FX Illiquid crosses, NKY-USDJPY and cross asset have all been identified as robust strategies. Spread trades are less liquid than their underlyings.
- **Mean-reversion strategies outperform** when:
  - **Markets are volatile**
  - **Equities sell off**
  - Over longer horizons, **during both sell-offs and rallies**, with a **straddle-**like payoff
- Mean reversion is one of the only **tradable liquidity-premia strategies**.
- Mean-reversion strategies are a **unique source of returns**, offering **genuine diversification**.

Appendices: Variance Ratio Tests, Theoretical aspects of MR, Traditional Liquidity Strategies, and Spread Trade Causality

Variance Ratio Tests for establishing mean-reversion

Variance ratio tests are the most reliable test for mean-reversion

Lo-MacKinlay (1988) – the variance of random walk should grow linearly in the horizon-

k-day variance ≈ k×1-day variance.

The variance ratio (of k-day returns vs 1-day returns, scaled) scaled, will be centred at 1.

$$Variance\ Ratio(k) = VR(k) = \frac{Var(\mathrm{k})}{Var(1)} = \frac{\frac{1}{m(T,k)}\sum_1^T[\log(S_t/S_{t-k}) - \hat{\mu}k]^2}{\frac{1}{T-1}\cdot\sum_1^T[\log(S_t/S_{t-1}) - \hat{\mu}]^2}$$

$$\text{where } m(T,k) = \frac{k(T-k+1)(T-k)}{T}$$

Then

$$\sqrt{T}\cdot(VR(k,T)-1) \overset{T\to\infty}{\Longrightarrow} \mathcal{N}(0, \frac{2(2k-1)(k-1)}{3k})$$

We use the resulting confidence intervals to establish mean-reversion.

They are only a guide— the confidence intervals over-reject mean-reversion*, especially in small samples (Cechetti-Lam 1994).

Source: Andrew W. Lo and A. Craig MacKinlay, "Stock Market Prices Do Not Follow Random Walks: Evidence from a Simple Specification Test", Rev. Financ. Stud. (1988)
* i.e., the test has Low Power

Mean-reversion returns – links to volatility

Simple models show mean-reversion returns can increase with volatility

Ornstein-Uhlenbeck for underlying, optimal mean-reverting weight for strategy

The underlying price process is assumed to be OU: (e.g., $S_t = \log(P_t)$)

$$dS_t = \alpha(\mu - S_t)dt + \sigma dW_t$$

and we will assume $\mu = 0$ and we want to find the distribution of the PnL for the strategy given by $PnL(T) = \int_0^T \theta_t dS_t$ with $\theta_t = -S_t$. Noting that OU is easily solved via multiplying constants:

$$S(T) = e^{-\alpha T}S_0 + \int_0^T e^{-\alpha(T-t)}\sigma dW_t$$

and the terminal density is merely a normal random variable with distribution $\mathcal{N}(e^{-\alpha T}S_0, \frac{\sigma^2(1-e^{-2\alpha T})}{2\alpha})$ to find the PNL distribution, we have to integrate by parts, i.e.,$\theta_t dS_t = -S_t dS_t = -\frac{1}{2}d(S_t^2) + \frac{1}{2}dS_t dS_t = -\frac{1}{2}d(S_t^2) + \frac{1}{2}\sigma^2 dt$. . Consequently, we have

$$PnL(T) = -\frac{1}{2}(S_T^2 - S_0^2) + \frac{\sigma^2 T}{2}$$

Using the distribution of S_T we can see that $E[S_T^2] = e^{-2\alpha T}S_0^2 + \frac{\sigma^2}{2\alpha}(1 - e^{-2\alpha T})$

$$E_T[PnL] = \frac{1}{2}(1 - e^{-2\alpha T})S_0^2 - \frac{\sigma^2}{4\alpha}(1 - e^{-2\alpha T}) + \frac{\sigma^2 T}{2}$$

If α is small (slow mean reversion) and T is small, the PnL may be negative, perhaps giving an explanation for short-term drawdowns. We note that the Expected PNL is always positive for large enough horizon T compared to the mean-reversion speed. (T> $(1 - e^{-2\alpha T})/2\alpha$).

Unscaled returns are positively related to variance/volatility, especially at longer timescales.

Mean reversion and variance reversion

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Why is mean-reversion returns related to variance ratios? Variance-reversion returns are an explanation.

Replicating the spread between a 1-day Var swap and a k-day Var Swap

Variance swaps pay the realized log variance (less a strike), i.e.,

$$Var_T^{LN} = \frac{1}{T}\sum_1^T \left\{ \left[\ln\left(\frac{S_t}{S_{t-1}}\right)\right]^2 - Strike^2 \right\}$$

If we take the spread between a 1-day return variance swap and an (overlapping) k-day return variance swap. The daily MTM of the Variance swap is given by* $Var_{t,T}^{LN} = Df_t(t+T)\left[\frac{t}{T}\sum_1^T\left[\ln\left(\frac{S_t}{S_{t-1}}\right)\right]^2 - \frac{T-t}{T}\left(Implied\ Vol(t,T)\right)^2 - Strike^2\right]$

A spread trade between two variance swaps is essentially a mean-reversion strategy, i.e.,

$$Var_T^{LN}(1) - Var_T^{LN}(n) = \frac{1}{T}\sum_1^T \left\{ \left[\ln\left(\frac{S_{T-i}}{S_{T-i-1}}\right)\right]^2 - \left[\ln\left(\frac{S_{T-i}}{S_{T-i-n}}\right)\right]^2 \right\}$$

If we attempt to replicate this strategy by delta hedging the daily MtM, (ignoring vega and theta terms) we get

$$\Delta_t \propto \frac{1}{S_t}\left(\ln(S_t) - \ln\left(\frac{S_t}{S_{t-n}}\right)\right) = \frac{1}{S_t}\left(\ln(S_t) - \frac{1}{n}\sum_0^{n-1}\ln\left(\frac{S_{t-i}}{S_{t-i-1}}\right)\right)$$

Which we can see, subject to scaling , is just **a mean-reversion strategy in log returns**.

Variance Reversion is just a scaling of mean reversion.

* See Everything you always wanted to know about variance swaps http://sbossu.com/docs/VarSwaps.pdf

Why don't traditional liquidity strategies pay for liquidity?

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There is no way to get exposure to illiquidity alone!

This aggregate index-level analysis concurs with most academic studies, which show

- **No evidence of a premium** in
  - LBOs (Phalippou, 2013),
  - Infrastructure(Bianchi et al, 2014),
  - EUR REITs (Moss-Lux, 2014),
- **Clear** evidence in startups, but **no evidence** in VC Funds (Korteweg-Nagel 2013)
- **Mixed evidence of risk premium with problems of significant collinearity (with credit)**
  - Small caps (Ben-Rephael et al, 2015),
  - Corporates (Chen et al 2006),
  - CDS (Gehde-Trapp, et al 2015)

Irrespective, there is **no means of extracting any premium except dynamic factor hedging**.

JPY *causes* NKY but NKY *does not cause* JPY

Granger causality suggests USDJPY leads, and NKY follows, not vice versa

Liquidity shocks in JPY get transmitted immediately or with delay to NKY

- Granger Causality tests confirm that **JPY *causes* NKY** but **NKY does *not cause* JPY**, as JPYUSD is one of the most liquid assets traded, while NKY is far less so
- Returns to **pairs trading** are known to have **exposure to economy-wide liquidity shocks** with periods of lower liquidity corresponding with higher returns (Englelberg-Gao-Jagannathan, 2009)

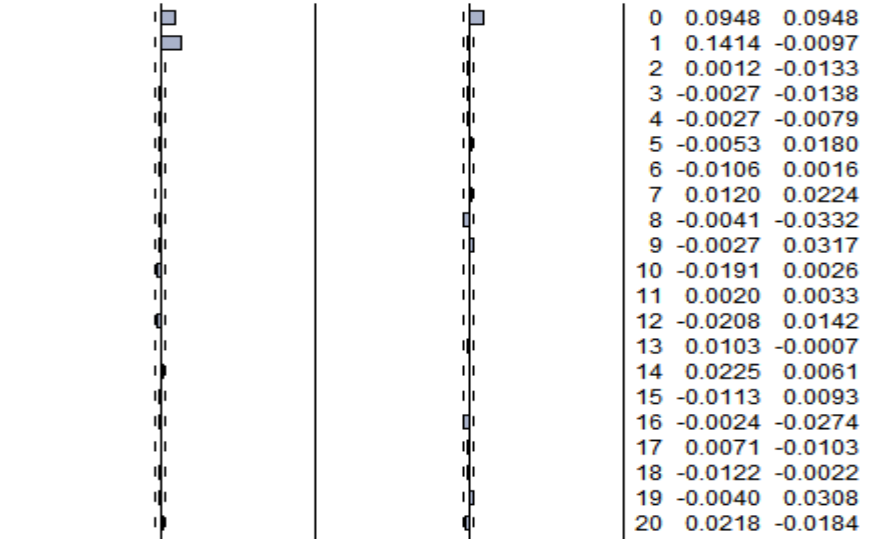
Pairwise Granger Causality Tests
Date: 09/20/16 Time: 15:07
Sample: 1 10000
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
JPY_RET does not Granger Cause NKY_RET	5509	59.7704	2.E-26
NKY_RET does not Granger Cause JPY_RET		0.56225	0.5700

Pairwise Granger Causality Tests
Date: 09/20/16 Time: 15:06
Sample: 1 10000
Lags: 4

Null Hypothesis:	Obs	F-Statistic	Prob.
JPY_RET does not Granger Cause NKY_RET	4979	26.7064	6.E-22
NKY_RET does not Granger Cause JPY_RET		0.43331	0.7847

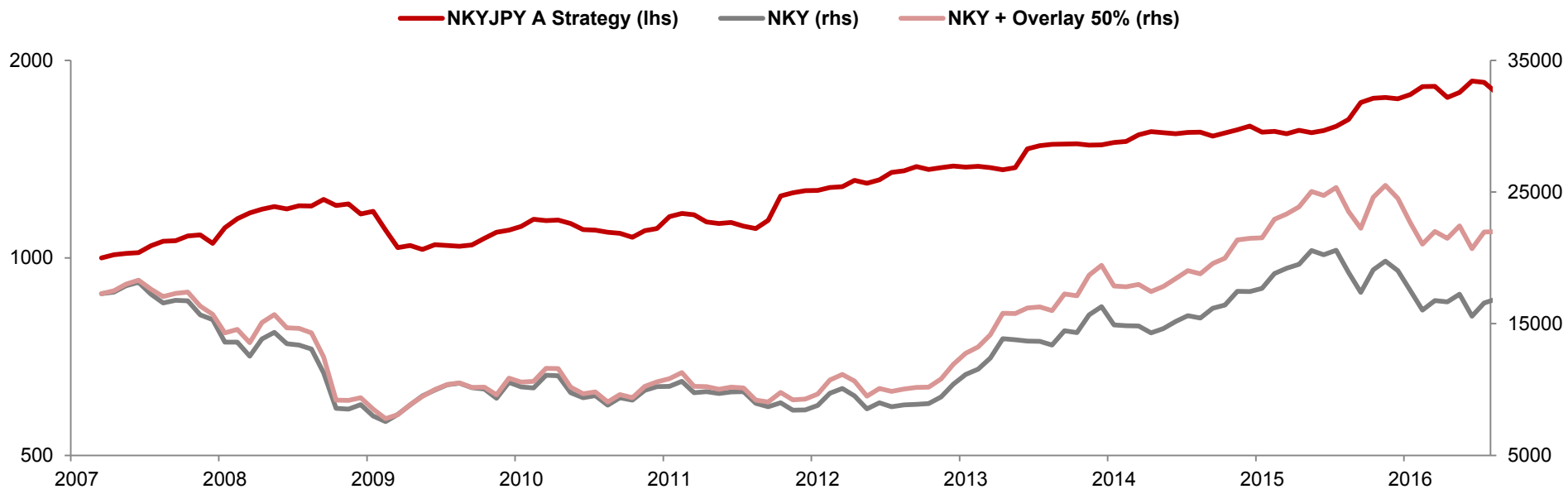
Date: 09/20/16 Time: 14:56
Sample: 1 10000
Included observations: 6086
Correlations are asymptotically consistent approximations



NKY_RET,JPY_RET(-i)	NKY_RET,JPY_RET(+i)	i	lag	lead
		0	0.0948	0.0948
		1	0.1414	-0.0097
		2	0.0012	-0.0133
		3	-0.0027	-0.0138
		4	-0.0027	-0.0079
		5	-0.0053	0.0180
		6	-0.0106	0.0016
		7	0.0120	0.0224
		8	-0.0041	-0.0332
		9	-0.0027	0.0317
		10	-0.0191	0.0026
		11	0.0020	0.0033
		12	-0.0208	0.0142
		13	0.0103	-0.0007
		14	0.0225	0.0061
		15	-0.0113	0.0093
		16	-0.0024	-0.0274
		17	0.0071	-0.0103
		18	-0.0122	-0.0022
		19	-0.0040	0.0308
		20	0.0218	-0.0184

Nomura NKYJPY Spread Reversion A Strategy

NKYJPY Spread Reversion Strategy exhibits stable risk-adjusted return with low equity beta

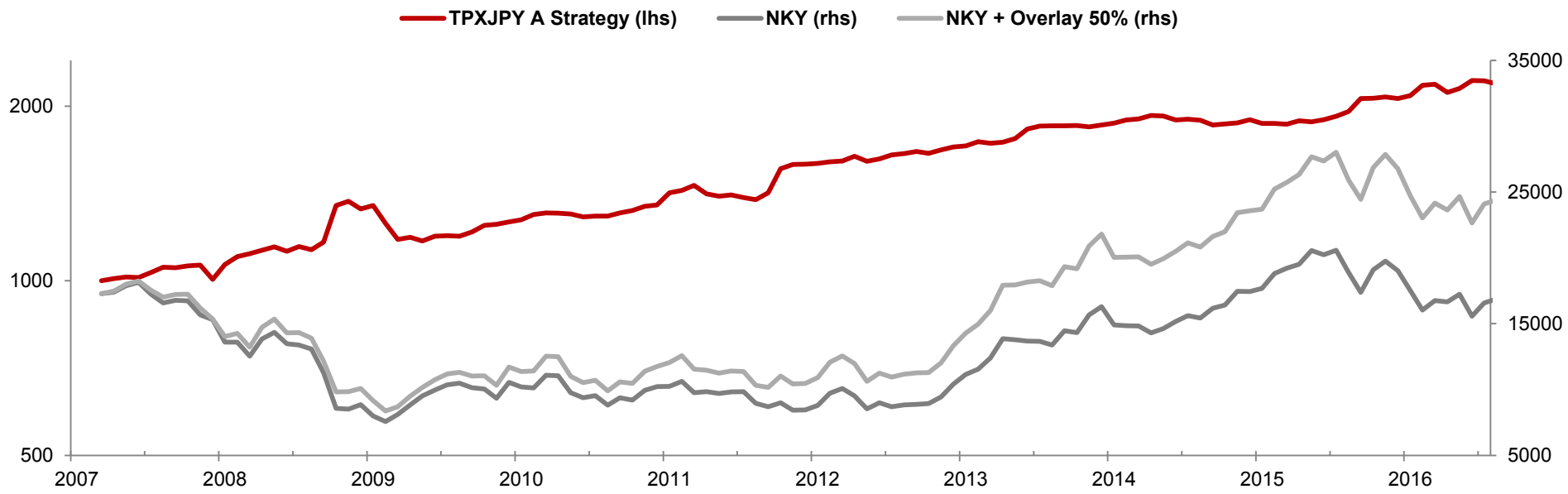


Pro Forma	NKYJPY A Strategy			NKY Index			NKY with 50% NKYJPY Overlay*			Outperformance		
	Since 04/2007	3 YR	1 YR	Since 04/2007	3 YR	1 YR	Since 04/2007	3 YR	1 YR	Since 04/2007	3 YR	1 YR
Ann. Return	6.4%	6.2%	9.8%	2.0%	9.4%	-8.7%	4.9%	12.1%	-4.7%	2.9%	2.7%	4.1%
Ann. Volatility	7.3%	6.4%	9.9%	21.1%	18.2%	23.0%	21.3%	17.1%	21.4%	3.7%	3.0%	4.5%
Information Ratio	0.88	0.98	0.99	0.10	0.52	-0.38	0.23	0.71	-0.22	0.77	0.91	0.89
Max. Drawdown (mDD)	16%	4%	4%	58%	24%	21%	57%	19%	19%			
mDD/Volatility	2.2	0.6	0.4	2.76	1.34	0.92	2.70	1.10	0.88			
Corr. with NKY	-13%	-47%	-48%									

Source: Bloomberg, Nomura; data as of 31 August 2016 based on monthly returns; strategy performances are net of all cost and charges
**Overlay 50% is an unfunded 50% matching notional of Nomura NKYJPY Spread Reversion A Strategy with NKY Index*

Nomura TPXJPY Spread Reversion A Strategy

TPXJPY Spread Reversion Strategy exhibits stable risk-adjusted return with low equity beta



Pro Forma	TPXJPY A Strategy			NKY Index			NKY with 50% TPXJPY Overlay*			Outperformance		
	Since 04/2007	3 YR	1 YR	Since 04/2007	3 YR	1 YR	Since 04/2007	3 YR	1 YR	Since 04/2007	3 YR	1 YR
Ann. Return	8.7%	5.7%	11.3%	2.0%	9.4%	-8.7%	5.8%	11.8%	-4.0%	3.8%	2.4%	4.8%
Ann. Volatility	8.8%	5.6%	8.3%	21.1%	18.2%	23.0%	20.6%	17.0%	21.3%	3.8%	2.5%	3.7%
Information Ratio	0.99	1.03	1.36	0.10	0.52	-0.38	0.28	0.69	-0.19	0.98	0.95	1.28
Max. Drawdown (mDD)	15%	4%	3%	58%	24%	21%	54%	19%	19%			
mDD/Volatility	1.7	0.7	0.4	2.76	1.34	0.92	2.63	1.12	0.88			
Corr. with NKY	-33%	-55%	-57%									

Source: Bloomberg, Nomura; data as of 31 August 2016 based on monthly returns; strategy performances are net of all cost and charges
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Trading the mean-reversion of NKYJPY spread – Adjusting position based on signal volatility to mitigate risks

NOMURA

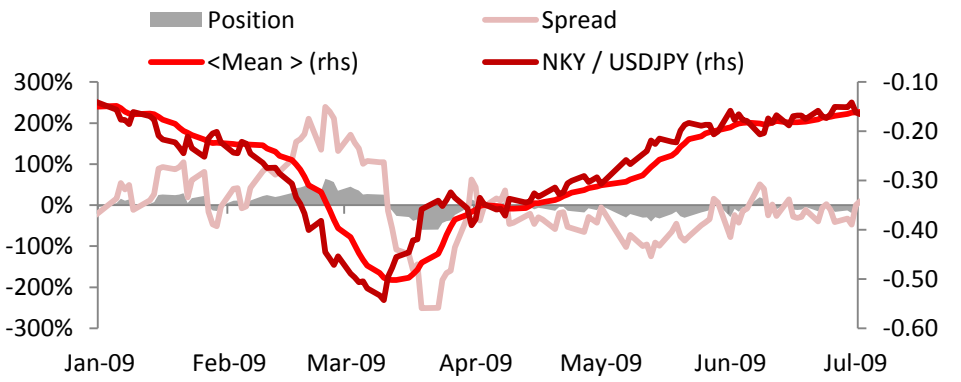
- **Vol Scaling to reduce impact of drawdowns**

Exposure adjustment and risk mitigation

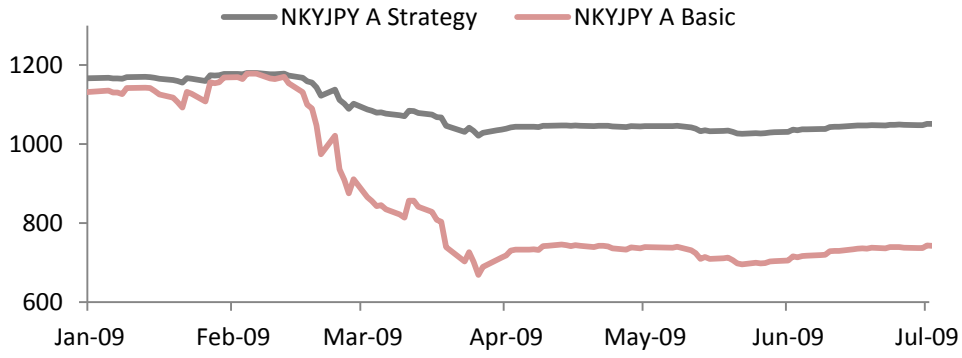
Taking episode of Q1 2009 equity as the case study

- In February 2009, while the NKY continued to decline with the rest of global risky assets, Yen appreciation was halted temporarily by concerns about Japan's trade deficit
- This divergence in the NKY/USDJPY ratio from its trailing mean suggested a strong "buy" based on the raw deviation (observed ratio deviation from its mean (Spread). For the next few weeks, the spread continues to diverge resulting in a substantial drawdown in the naive implementation (as shown in "NKYJPY A Basic" in right hand side bottom chart)
- Nomura NKYJPY Spread Reversion Strategy penalizes signals based on the prevailing NKY/USDJPY ratio volatility, reducing the market exposure of the strategy when the ratio volatility is high.
- Such an implementation means that Nomura's NKYJPY Strategy holds a reduced exposure of the long/short spread (Position) at times when the NKY/USDJPY ratio shows high realized volatility. Such reduction in signal helps to reduce the drawdown during times of high ratio volatility.
  - For example in 2009, NKYJPY A Strategy showed a significantly smaller drawdown as compared with the NKYJPY A "Basic" strategy (~18% lesser loss)

NKYJPY ratio during 1st half of 2009



Strategy performance during 1st half of 2009



Source: Bloomberg, Nomura Research. <Mean> in the chart refers to the rolling 10-day average

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