

# *Time Series Momentum*

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## *Time Series Momentum: Definition*

- Time series momentum
  - **A security's *own* past return predicts its future return**

Cf. the standard momentum considered in the literature:

- Cross-sectional momentum
  - **A security's *outperformance relative to peers* predicts future *relative outperformance***

## *Time Series Momentum: Motivation*

- Time series momentum most direct test of **random walk hypothesis**
- Time series momentum most direct test of **continuation and delayed reversal theories**:
  - Both behavioral and rational theories are about absolute returns (not relative returns)
- Time series momentum can be analyzed **globally for all asset classes**
  - stocks, bonds, currencies, commodities
  - general patterns challenge theories that only apply to stocks

## *Time Series Momentum: Main Results*

- Time series momentum
  - Strong predictor of returns for equity, bond, currency, and commodity futures
- What is *not* explaining time series momentum:
  - TS momentum different from standard cross-sectional momentum
  - Not captured by standard risk factors: large abnormal returns
  - Not crash risk: performs well in extreme markets
  - Not related to transaction costs
- Evidence points towards:
  - Initial under-reaction and delayed over-reaction
  - Hedging pressure

## Related Literature

Related behavioral theories:

- Barberis-Shleifer-Vishny (1998), Daniel-Hirshleifer-Subrahmanyam (1998), Hong-Stein (1999), ...

What's new:

- Looking at time series momentum:

	Cross-sectional	Time series
<b><i>n</i> months predict <i>n</i> months</b>	NA	<b>“Autocorrelation”</b> Fama and French (1988) Lo and MacKinlay (1988)
<b><i>m</i> months predict <i>n</i> months</b>	<b>“Standard momentum”</b> Jegadeesh and Titman (1993) Asness (1994) Asness-Moskowitz-Pedersen	<b>Moskowitz-Ooi-Pedersen</b>

- Look at broad asset classes (Equity, FX, bonds, commodities)
- Effect of speculator vs. hedgers
- Price changes vs. roll returns
- Extreme markets

# Outline of Talk

- Data
  
- Time series momentum
  - Regression evidence
  - TS-momentum strategies
  
- Time series momentum vs. cross-sectional momentum
  
- Possible explanations
  - Transactions costs and liquidity
  - Crash risk
  - Under-reaction and slow information diffusion
  - Delayed over-reaction and sentiment
  - Hedging
  
- Who trades on trends:
  - Speculators or hedgers?
  - The evolution of a trend
  
- Conclusion

# Data

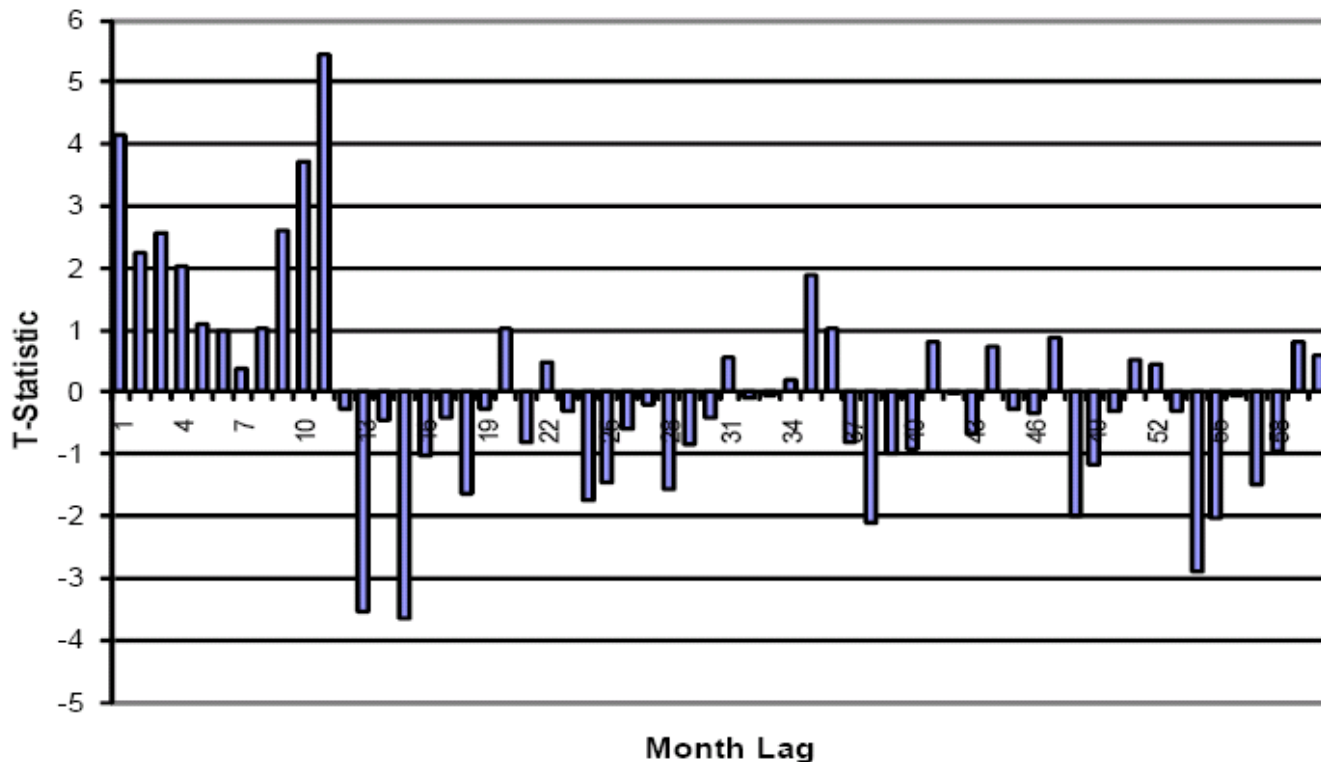
- Equity indices:
  - Global equity index futures from Datastream
  - Prior to the availability of futures data, we use MSCI country index returns
- Bond indices:
  - Bond futures from Datastream, and prior to that, JP Morgan country level bond indices
  - Scale to constant duration
- Currencies:
  - Forward rates from 1989 from Citigroup, and prior to that use
  - Spot exchange rates: Datastream and IBOR short rates: Bloomberg
- Commodity futures
  - Aluminum, Copper, Nickel, Zinc, Lead, Tin: London Metal Exchange (LME)
  - Brent Crude, Gas Oil: Intercontinental Exchange (ICE)
  - Live Cattle, Lean Hogs: Chicago Mercantile Exchange (CME)
  - Corn, Soybeans, Soy Meal, Soy Oil, Wheat: Chicago Board of Trade (CBOT)
  - WTI Crude, RBOB Gasoline, Heating Oil, Natural Gas: New York Mercantile Exchange (NYMEX)
  - Gold, Silver: New York Commodities Exchange (COMEX)
  - Cotton, Coffee, Cocoa, Sugar: New York Board of Trade (NYBOT, ICE)
  - Platinum: Tokyo Commodity Exchange (TOCOM)

## Time Series Momentum: Regression Evidence

Time series predictability – regression evidence:

$$r_t^s / \sigma_{t-1}^s = \alpha + \beta_h r_{t-h}^s / \sigma_{t-h-1}^s + \varepsilon_t^s$$

T-Statistic by Month, All Asset Classes

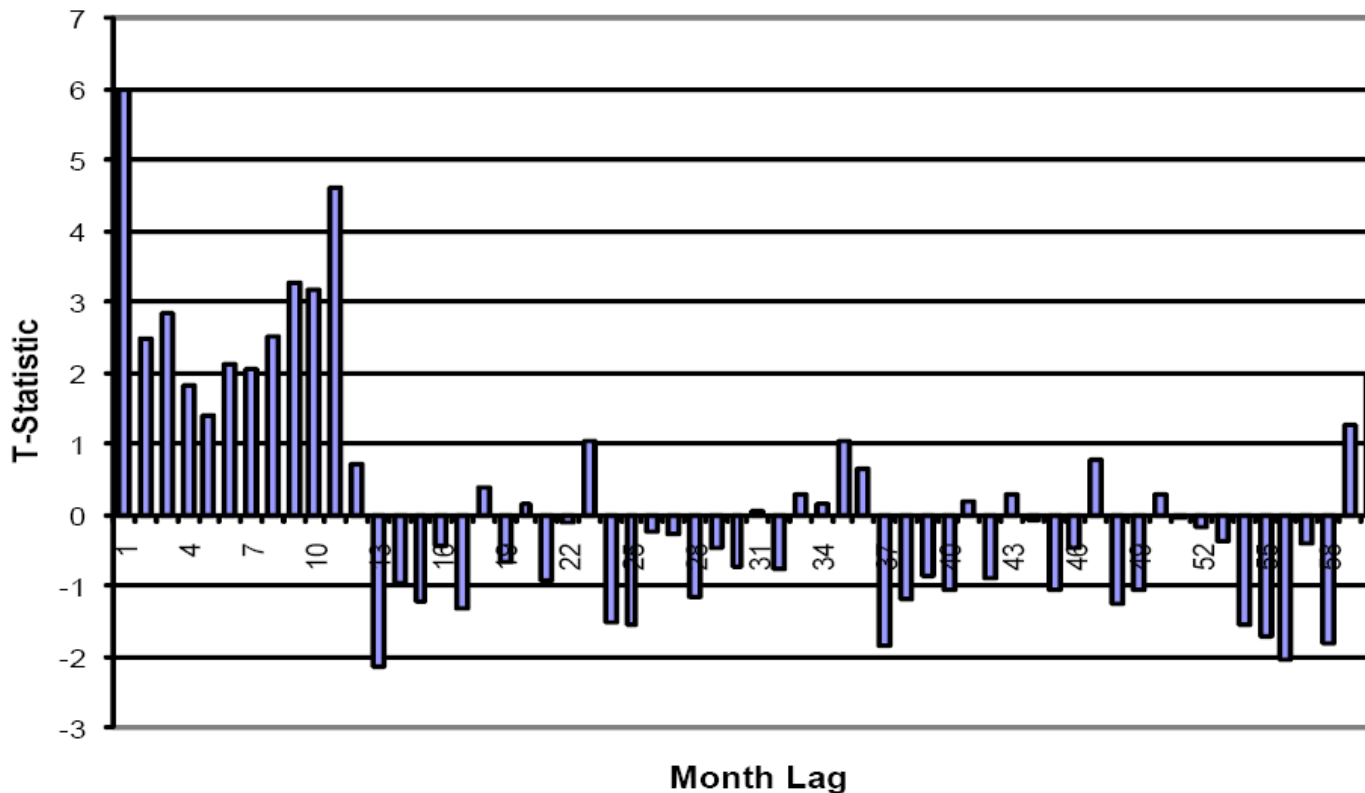


# Time Series Momentum: Regression Evidence Using Only Signs

Time series predictability – regression evidence:

$$r_t^s / \sigma_{t-1}^s = \alpha + \beta_h \text{sign}(r_{t-h}^s) + \varepsilon_t^s$$

T-Statistic by Month, All Asset Classes



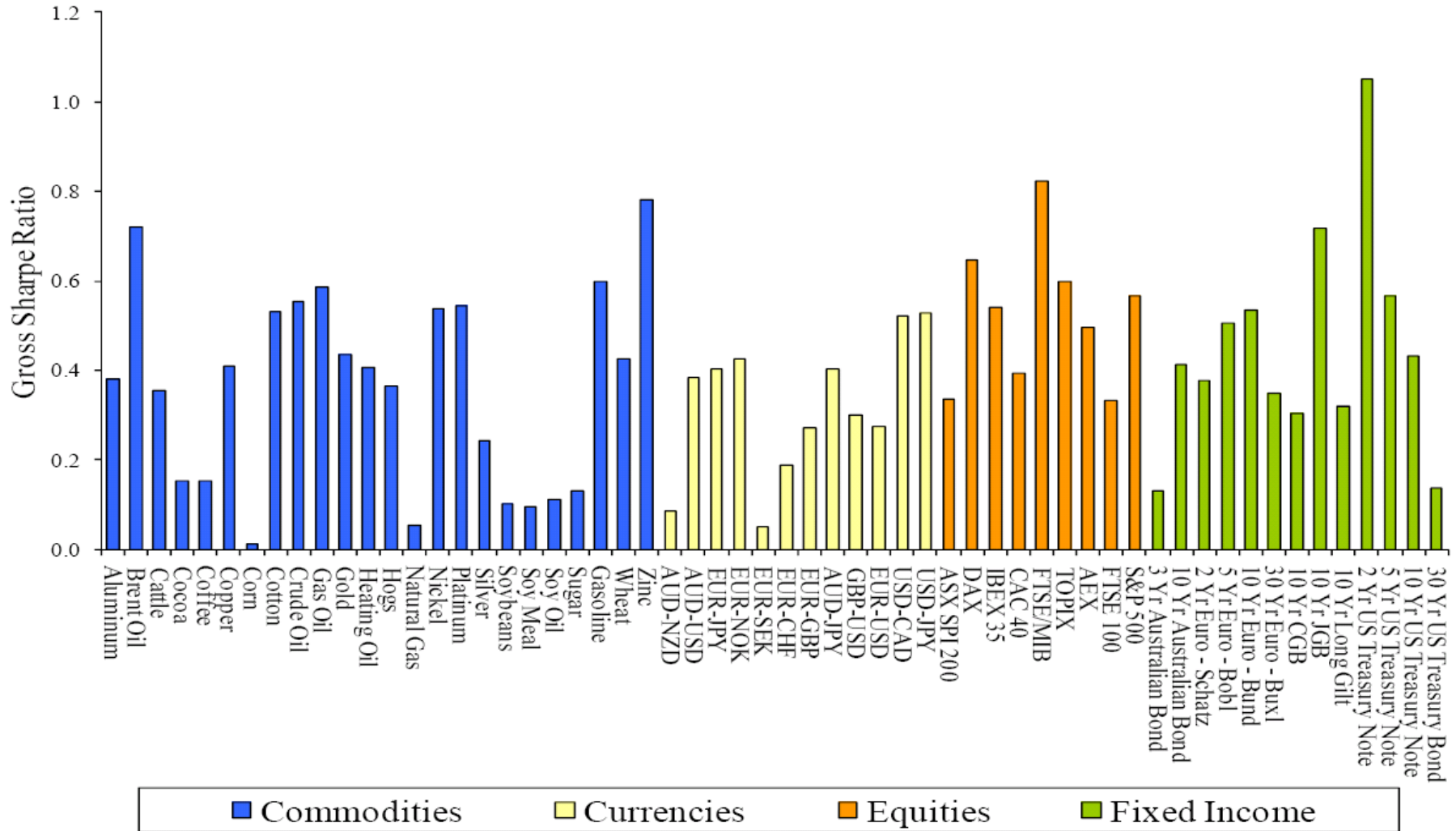
## Trading on TS Momentum

- Simple 12M TS Momentum strategy
  - Buy if the excess return over the past 12 months was positive
  - Take a short position if the return was negative
  - Scale the position such that the ex ante annualized volatility is 0.60%
- Return of 12M TS Momentum strategy for security  $s$ :

$$r_{t,t+1}^{TS-MOM,s} = \text{sign}(r_{t-12,t}^s) \frac{0.60\%}{\sigma_t^s} r_{t,t+1}^s$$

# Sharpe Ratio of TS Momentum by Instrument

**Simple 12M TS Momentum strategy:** 
$$r_{t,t+1}^{TS-MOM,s} = \text{sign}(r_{t-12,t}^s) \frac{0.60\%}{\sigma_t^s} r_{t,t+1}^s$$



## *Diversified TS Momentum Strategy*

### Diversified TS Momentum Strategy

- Trade the 12M TS mom strategy across all 58 liquid instruments
- This strategy has an annualized volatility of 9-10%
- Realistic and implementable use of margin capital (5-20%)

## *Diversified Time Series Momentum Strategy*

Performance of diversified TS momentum strategy and loadings on standard factors:

<b>Panel A: Fama and French Factors</b>							
		MSCI World	SMB	HML	UMD	Intercept	R <sup>2</sup>
Monthly	Coefficient	0.03	-0.04	-0.01	0.22	1.26%	16%
	(t-stat)	(1.00)	(-0.92)	(-0.23)	(7.15)	(8.55)	
Quarterly	Coefficient	0.02	-0.14	-0.01	0.25	3.80%	25%
	(t-stat)	(0.29)	(-1.48)	(-0.07)	(4.49)	(8.15)	
<b>Panel B: Asness, Moskowitz, and Pedersen (2010) Factors</b>							
		MSCI World	VAL Everywhere	MOM Everywhere	Intercept	R <sup>2</sup>	
Monthly	Coefficient	0.05	0.06	0.48	0.94%	30%	
	(t-stat)	(1.53)	(1.22)	(9.41)	(6.28)		
Quarterly	Coefficient	0.05	0.12	0.50	2.65%	33%	
	(t-stat)	(0.94)	(1.53)	(6.13)	(5.00)		

## Other TS Momentum Strategies

- Vary the look-back period and holding period
- Consider abnormal return

$$r_t^{TS-MOM(k,h)} = \alpha + \beta_1 MKT_t + \beta_2 BOND_t + \beta_3 GSCI_t + sSMB_t + hHML_t + mUMD_t + \varepsilon_t$$

- T-stat of alpha of TS Momentum strategies with different look-back and holding periods

		Holding Period (Months)							
		1	3	6	9	12	24	36	48
<b>Panel A: All Assets</b>									
Lookback Period (Months)	1	4.34	4.68	3.83	4.29	5.12	3.02	2.74	1.90
	3	5.35	4.42	3.54	4.73	4.50	2.60	1.97	1.52
	6	5.03	4.54	4.93	5.32	4.43	2.79	1.89	1.42
	9	6.06	6.13	5.78	5.07	4.10	2.57	1.45	1.19
	12	6.61	5.60	4.44	3.69	2.85	1.68	0.66	0.46
	24	3.95	3.19	2.44	1.95	1.50	0.20	-0.09	-0.33
	36	2.70	2.20	1.44	0.96	0.62	0.28	0.07	0.20
	48	1.84	1.55	1.16	1.00	0.86	0.38	0.46	0.74

- Significant performance in *each* asset class with a large variety of look-back and holding periods

## *Time Series Momentum vs. Cross-Sectional Momentum*

- Large intercepts to cross-sectional momentum strategies in the same asset classes, using factors from Asness, Moskowitz, and Pedersen (2010)

<b>Panel A: Regression of TS-MOM on XS-MOM</b>								
	Independent Variables						Intercept	$R^2$
	XS-MOM ALL	XS-MOM COM	XS-MOM EQ	XS-MOM FI	XS-MOM FX	XS-MOM US Stocks		
TS-MOM ALL	0.57 (15.52)						0.66% (5.64)	45%
TS-MOM ALL		0.62 (7.00)	0.43 (4.67)	0.34 (3.74)	0.71 (8.23)	0.34 (3.26)	0.64% (5.50)	48%
TS-MOM COM		0.61 (14.29)					0.23% (3.99)	41%
TS-MOM COM		0.58 (13.48)	0.05 (1.07)	0.02 (0.53)	0.13 (3.16)	0.08 (1.52)	0.20% (3.50)	44%
TS-MOM EQ			0.32 (7.33)				0.18% (2.95)	15%
TS-MOM EQ		0.06 (1.29)	0.23 (5.09)	0.03 (0.64)	0.05 (1.11)	0.22 (4.28)	0.16% (2.74)	22%
TS-MOM FI				0.32 (6.48)			0.20% (3.24)	12%
TS-MOM FI		-0.05 (-0.96)	0.13 (2.54)	0.29 (5.83)	0.02 (0.53)	0.05 (0.89)	0.17% (2.72)	15%
TS-MOM FX					0.51 (21.18)		0.13% (3.98)	60%
TS-MOM FX		0.03 (0.99)	0.01 (0.51)	0.00 (-0.15)	0.51 (20.41)	-0.01 (-0.35)	0.13% (3.64)	60%

## Decomposing Time Series Momentum vs. Cross-Sectional Momentum

- Writing cross-sectional momentum returns as

$$r_{t,t+1}^{XS} = \sum_{i=1}^N w_t^{XS,i} r_{t,t+1}^i \quad \text{with portfolio weights} \quad w_t^{XS,i} = \frac{1}{N} (r_{t-12,t}^i - r_{t-12,t}^{EW})$$

- We can decompose expected returns, following Lo-MacKinlay (1990) and Lewellen (2002):

$$\begin{aligned} E[r_{t,t+1}^{XS}] &= \frac{tr(\Omega)}{N} - \frac{1' \Omega 1}{N^2} + 12 \sigma_{\mu}^2 \\ &= \underbrace{\frac{N-1}{N^2} tr(\Omega)}_{\text{auto-covariance}} - \underbrace{\frac{1}{N^2} [1' \Omega 1 - tr(\Omega)]}_{\text{cross-covariance}} + \underbrace{12 \sigma_{\mu}^2}_{\text{mean effect}} \end{aligned}$$

components:                      auto-covariance                      cross-covariance                      mean effect

- where

$$\mu^i = E(r_{t,t+1}^i) = E(r_{t-12,t}^i) / 12$$

$$\Omega = E[(R_{t-12,t} - 12\mu)(R_{t,t+1} - \mu)']$$

$$R_{t,s} = [r_{t,s}^1, \dots, r_{t,s}^N]'$$

## Decomposing Time Series Momentum vs. Cross-Sectional Momentum

➤ We can make a similar decomposition of time series momentum

➤ Portfolio weights:

$$w_t^{TS,i} = \frac{1}{N} r_{t-12,t}^i$$

➤ Decomposition:

$$\begin{aligned} E\left(r_{t,t+1}^{TS}\right) &= E\left(w_t^{TS,i} r_{t,t+1}^i\right) \\ &= \underbrace{\frac{\text{tr}(\Omega)}{N}}_{\text{auto-covariance}} + 12 \underbrace{\frac{\mu' \mu}{N}}_{\text{mean-squared effect}} \end{aligned}$$

components:

auto-covariance

mean-squared effect

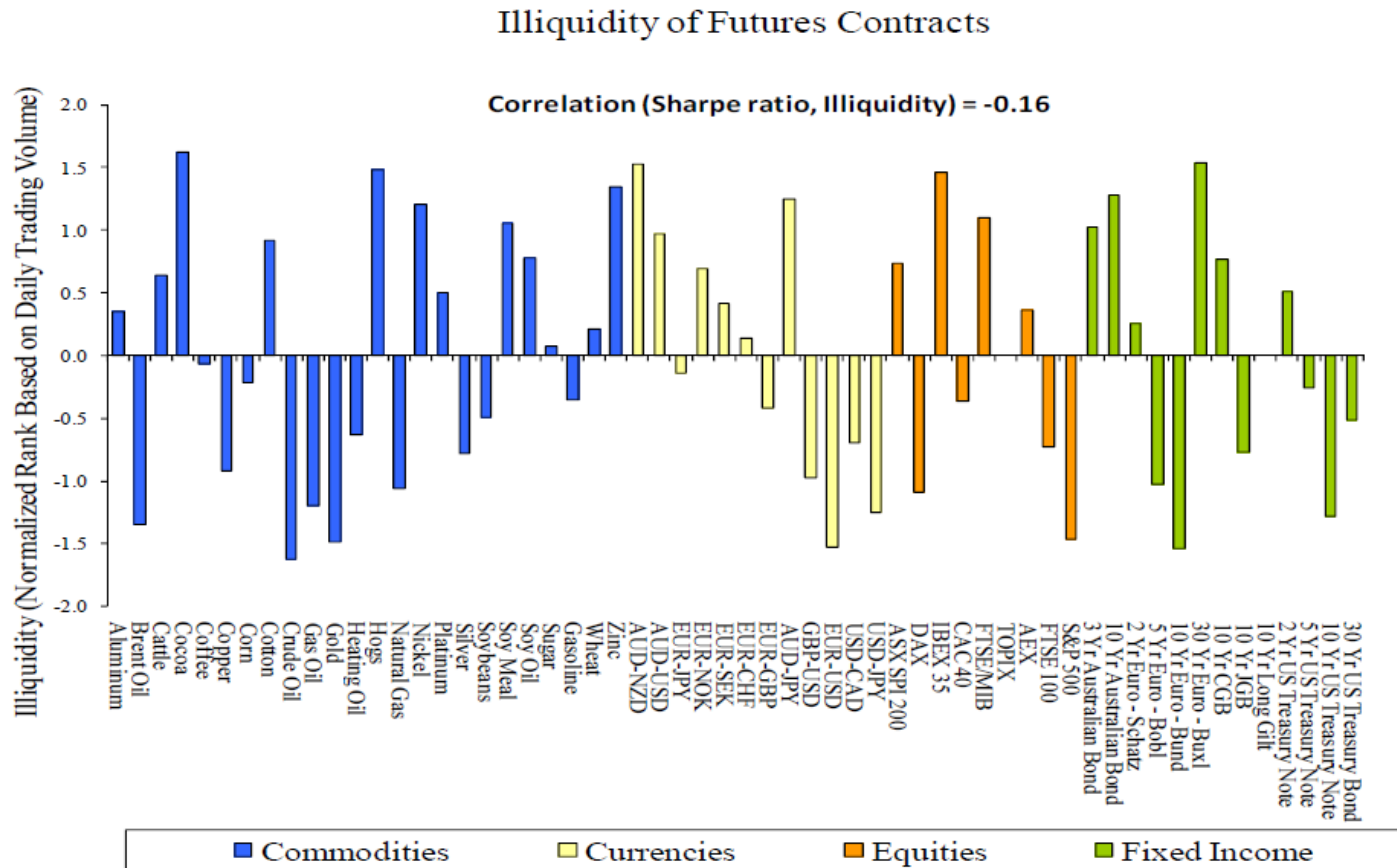
## Decomposing Time Series Momentum vs. Cross-Sectional Momentum

- The auto-covariance (own past 12-months return co-varies with next month return) explains most of the returns

Panel B: Decomposition of TS-MOM and XS-MOM							
	XS-MOM Decomposition				TS-MOM Decomposition		
	Auto	Cross	Mean	Total	Auto	Mean Squared	Total
ALL	0.53%	-0.03%	0.12%	0.61%	0.54%	0.29%	0.83%
COM	0.41%	-0.13%	0.11%	0.39%	0.43%	0.17%	0.59%
EQ	0.74%	-0.62%	0.02%	0.14%	0.83%	0.17%	1.00%
FI	0.32%	-0.10%	0.05%	0.27%	0.35%	0.70%	1.05%
FX	0.71%	-0.55%	0.02%	0.18%	0.80%	0.17%	0.96%

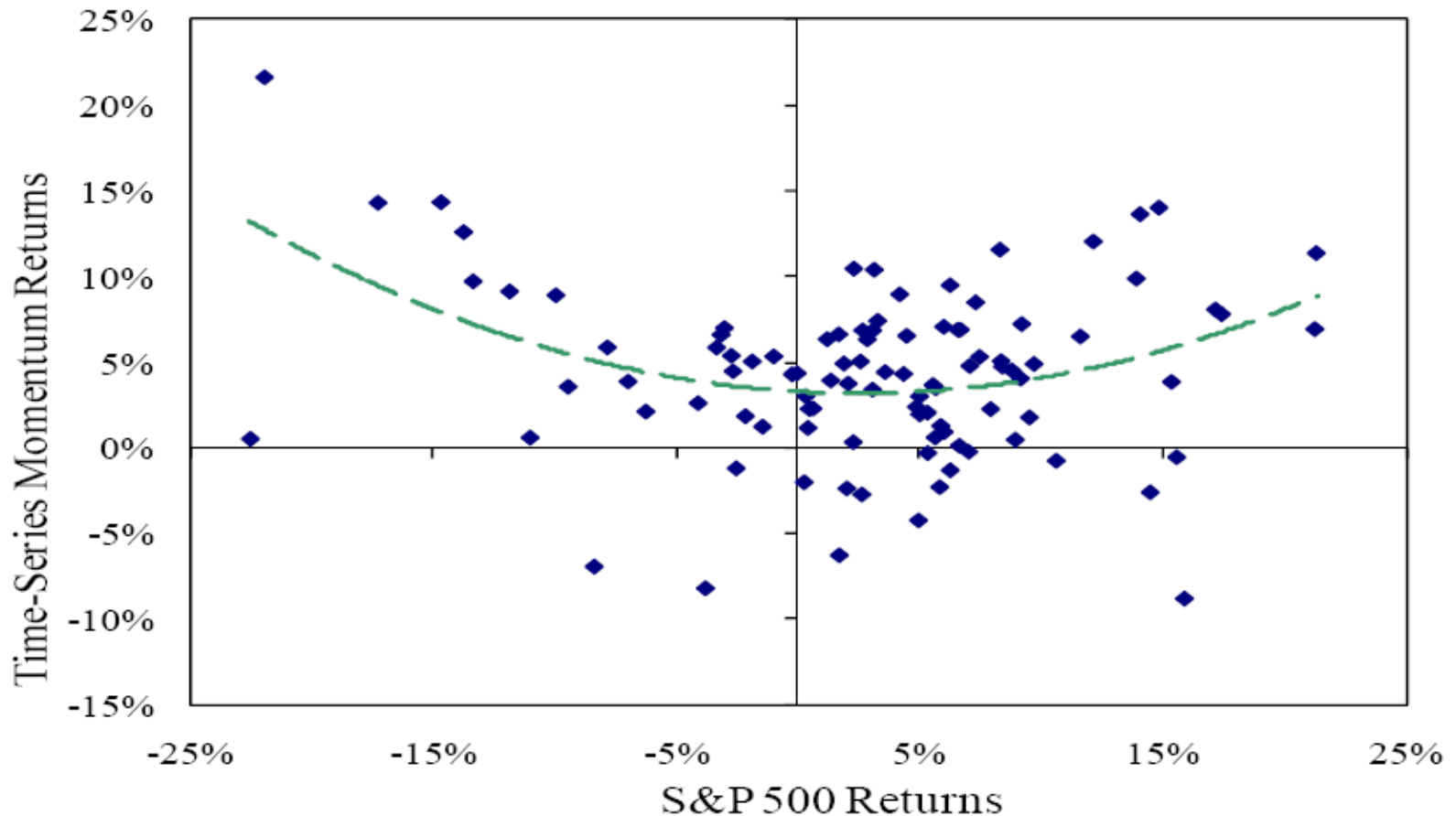
## Potential Explanations: Transaction Costs

- In the time series, overall performance has low correlation to aggregate liquidity
- In the cross section, the performance by instrument is not related to their relative liquidity:



## Potential Explanations: Crash Risk

- TS momentum and large market moves: non-overlapping quarterly returns
  - has in fact done *well* during large down markets

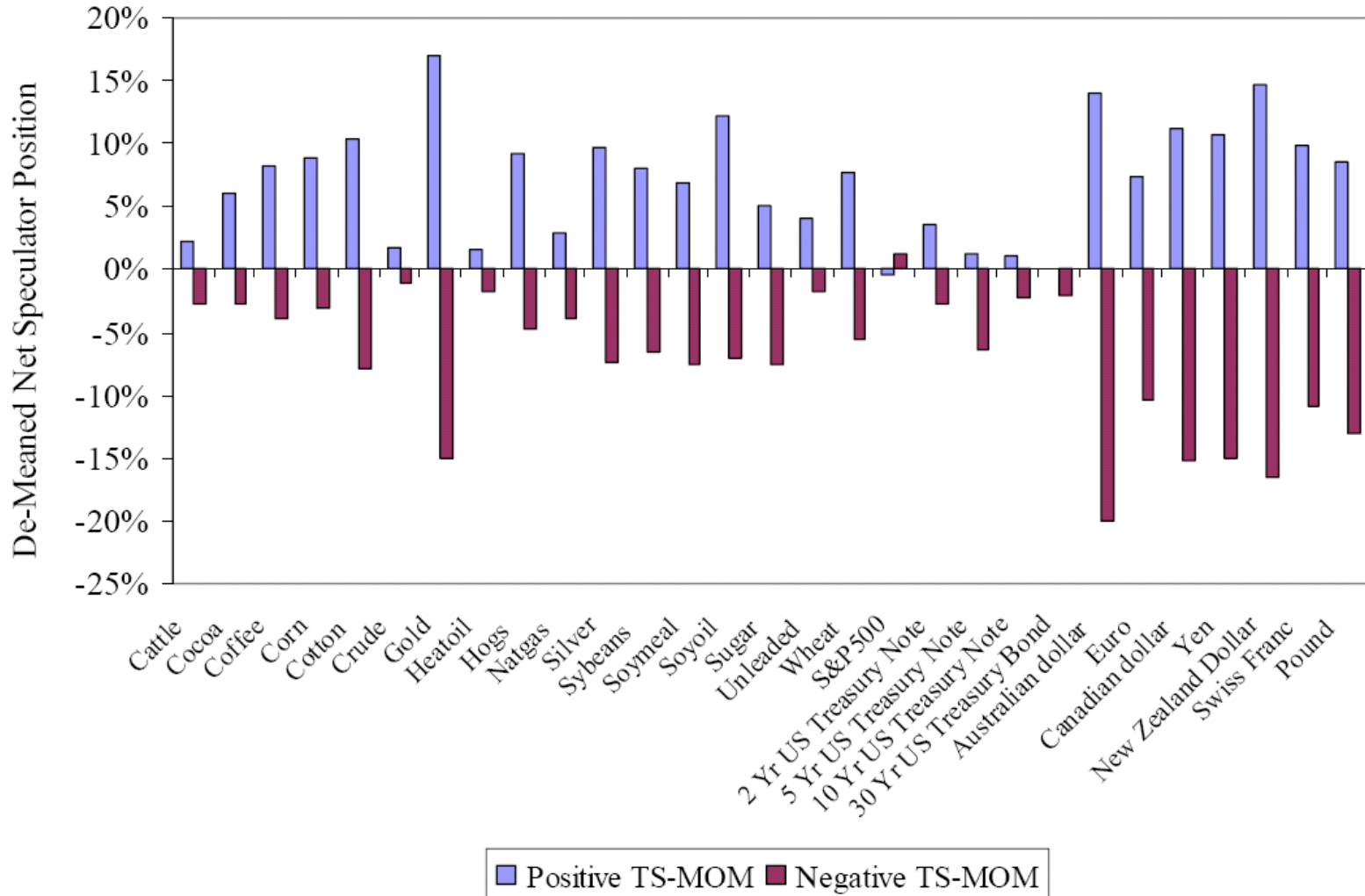


## *Other Potential Explanations*

- Other potential explanations:
  - Under-reaction and slow information diffusion
  - Delayed over-reaction
  - Hedging
  
- To analyze these, we need to
  - Consider the evolution of a trend
  - Look at who trades on trends

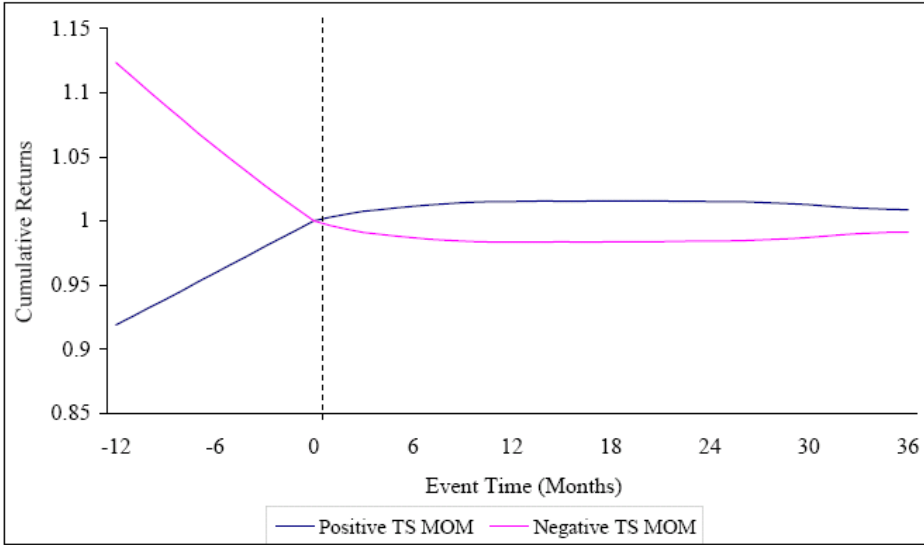
## Who Trades on Time Series Momentum

$$\text{Net Speculator Position} = \frac{\text{Speculator Long Positions} - \text{Speculator Short Positions}}{\text{Open Interest}}$$

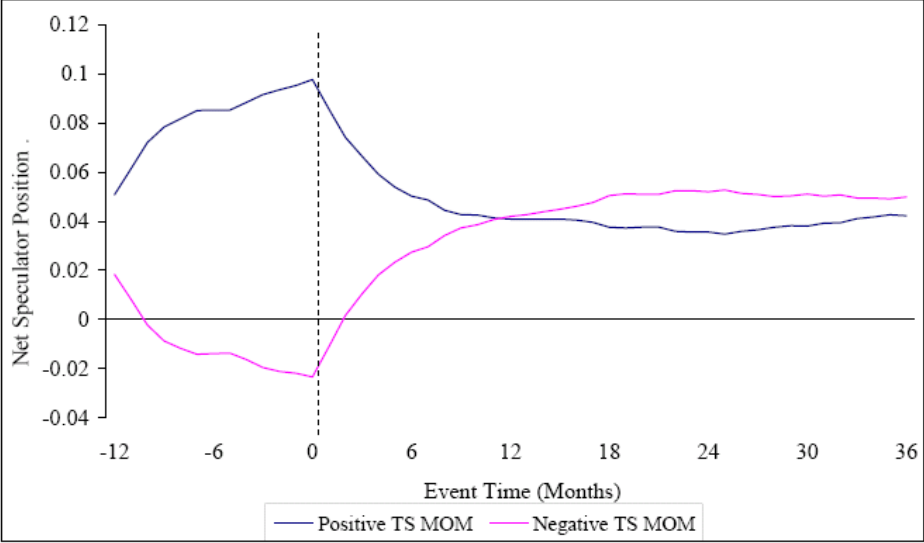


# Event Study of Time Series Momentum

Panel A: Cumulative Returns in Event Time

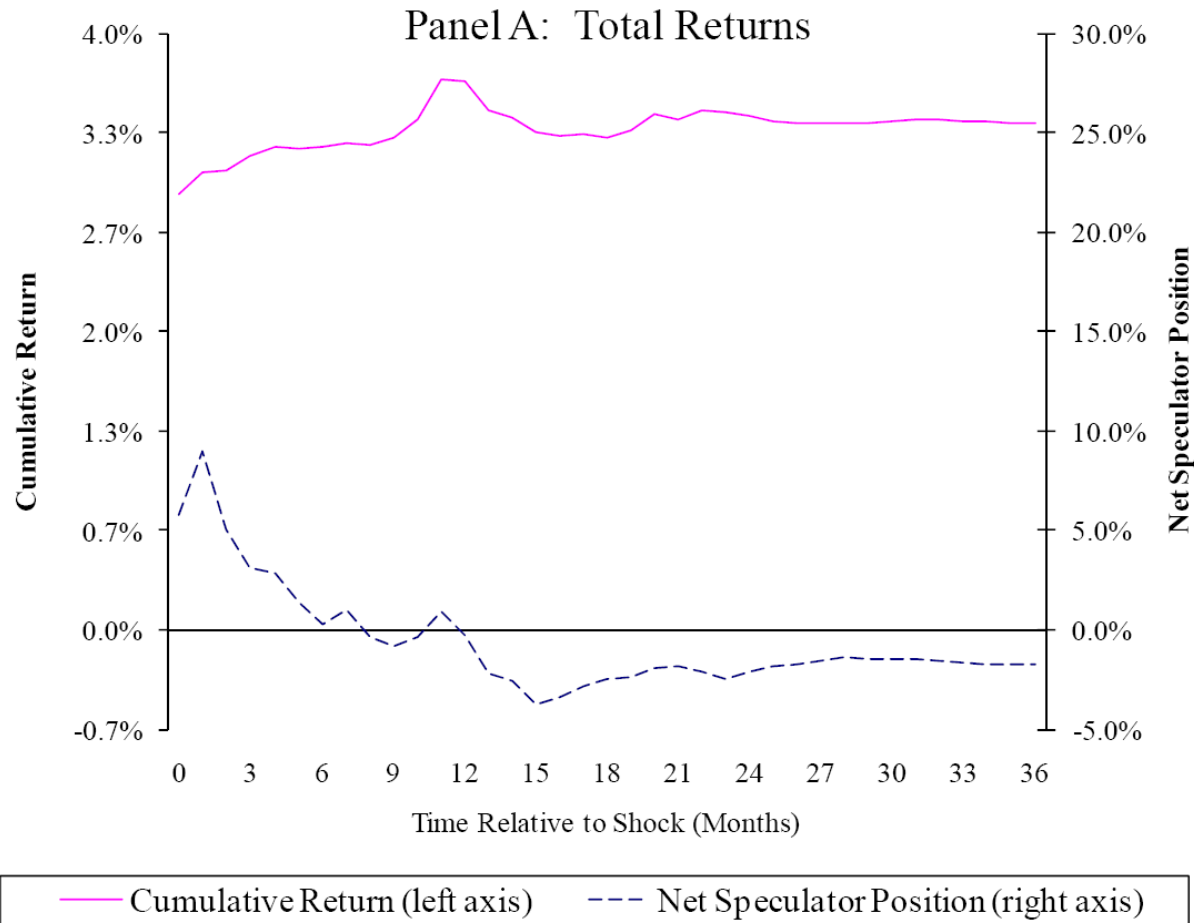


Panel B: Net Speculator Positions in Event Time



# Impulse Response from Shock to Returns

## I: Total Returns



- Evidence is consistent with elements of both
  - Initial under-reaction
  - Delayed over-reaction

# Impulse Response from Shock to Returns

## II: Splitting Total Returns into Spot Price Changes and Roll Returns

- Over- and under-reaction (slow information diffusion)
  - Should show up in price changes

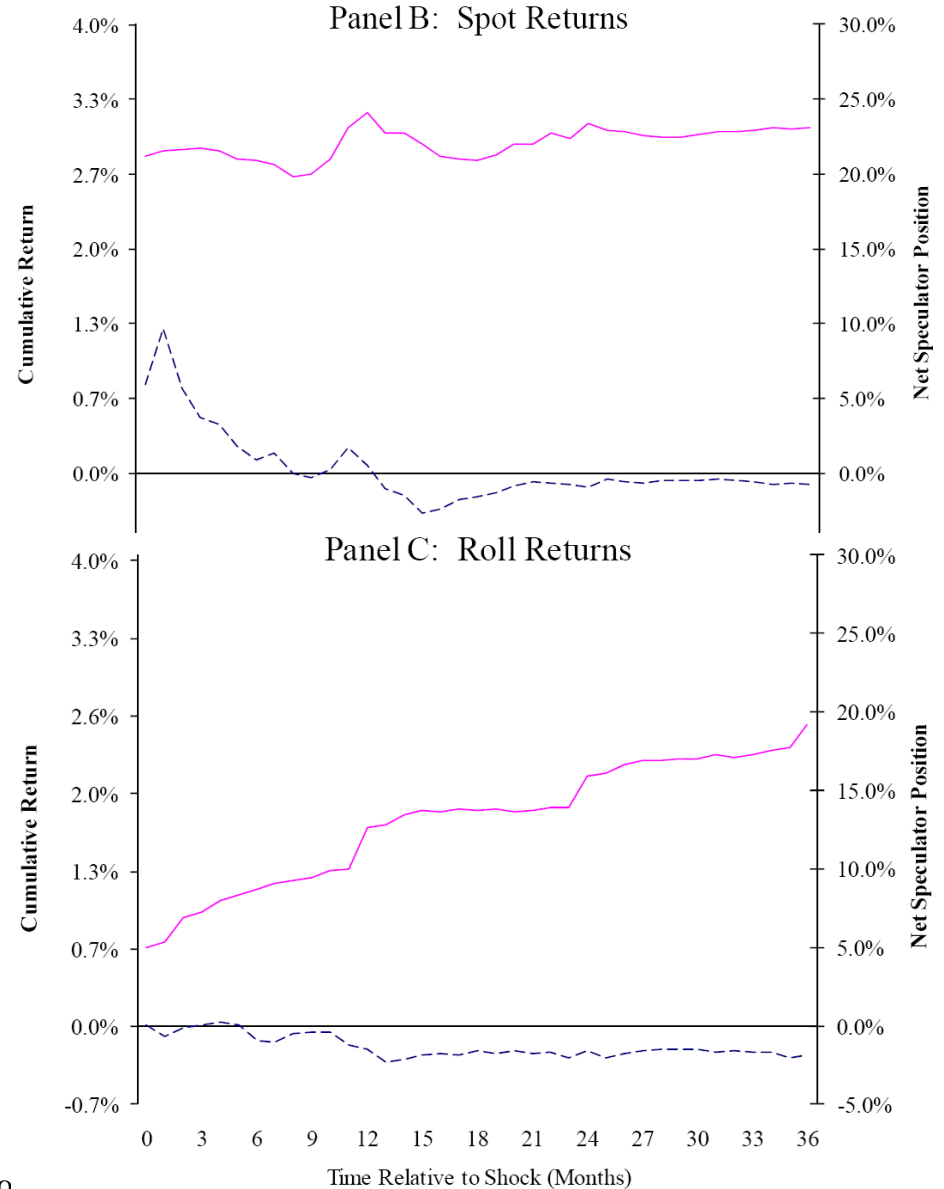
$$\text{price change}_{t-12,t} = \frac{\text{price}_t - \text{price}_{t-12}}{\text{price}_{t-12}} - r_{t-12,t}^f$$

- Seems mostly due to over-reaction:

- Hedging pressure
  - Should affect the futures curve shape, leading to roll returns defined as:

$$\text{futures return}_{t-12,t} = \text{price change}_{t-12,t} + \text{roll return}_{t-12,t}$$

- Deviation from cost-of-carry relation
- Hedging effects persistent:



Time Series Momentum - Mo

— Cumulative Return (left axis)    - - - Net Speculator Position (right axis)

## *Spot Prices, Roll Returns, and Positions*

What predicts returns:

- spot price changes (slow information diffusion)
- roll returns (hedging pressure measured by the shape of the futures curve)
- speculator positions (hedging pressure measured using noisy CFTC position data)

	<b>Full TS Mom</b>	<b>Spot Price Mom</b>	<b>Roll Mom</b>	<b>Chg Net Speculator Position</b>	<b>Intercept</b>	<b>R2</b>
Coefficient	0.019				0.09%	0.6%
T-stat	(3.54)				(1.31)	
Coefficient		0.014			0.12%	0.3%
T-stat		(2.27)			(1.72)	
Coefficient			0.024		0.08%	0.3%
T-stat			(3.22)		(1.09)	
Coefficient				0.007	0.12%	0.2%
T-stat				(2.66)	(1.64)	
Coefficient	0.017			0.004	0.10%	0.7%
T-stat	(3.10)			(1.65)	(1.34)	
Coefficient		0.017	0.030		0.08%	0.6%
T-stat		(2.72)	(3.90)		(1.03)	
Coefficient		0.014	0.030	0.005	0.07%	0.8%
T-stat		(2.10)	(3.93)	(1.89)	(0.99)	

## *Conclusion: A Trending Walk Down Wall Street*

- Time series momentum
  - Strong predictor of returns in each asset class
  - Different from standard cross-sectional momentum
  
- Not captured by
  - Standard risk factors
  - Crash risk
  - Transaction costs
  
- Evidence points towards
  - Initial under-reaction
  - Delayed over-reaction
    - TS momentum returns partly reverse
  - Hedging pressure
    - Hedgers short TS momentum, speculators are long
    - Hedger positions, and especially the resulting roll yields, predict TS momentum returns