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**
***n* months predict *n* months**	NA	**"Autocorrelation"** Fama and French (1988) Lo and MacKinlay (1988)
***m* months predict *n* months**	**"Standard momentum"** Jegadeesh and Titman (1993) Asness (1994) Asness-Moskowitz-Pedersen	**Moskowitz-Ooi-Pedersen**

- 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

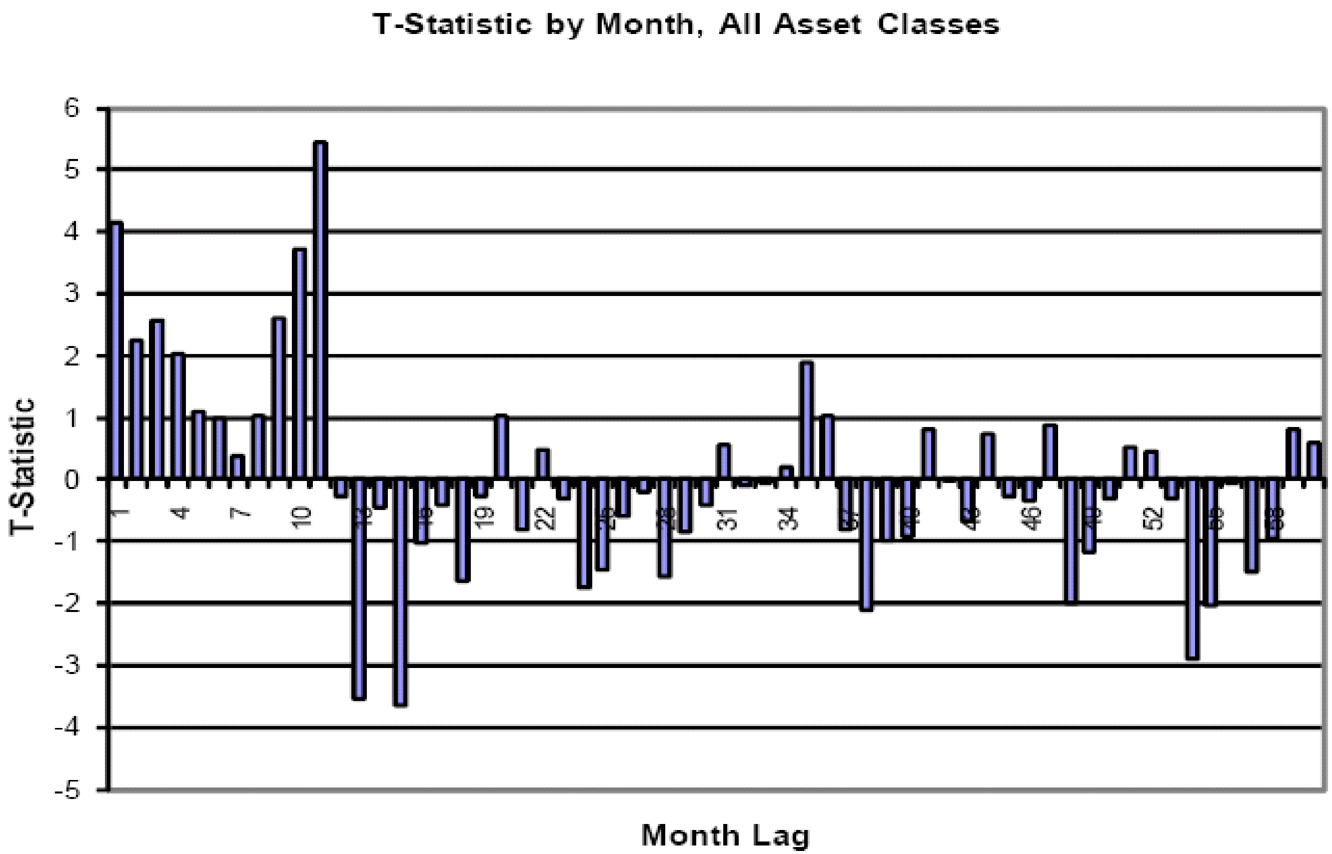
- Conclusion

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 predictability – regression evidence:

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

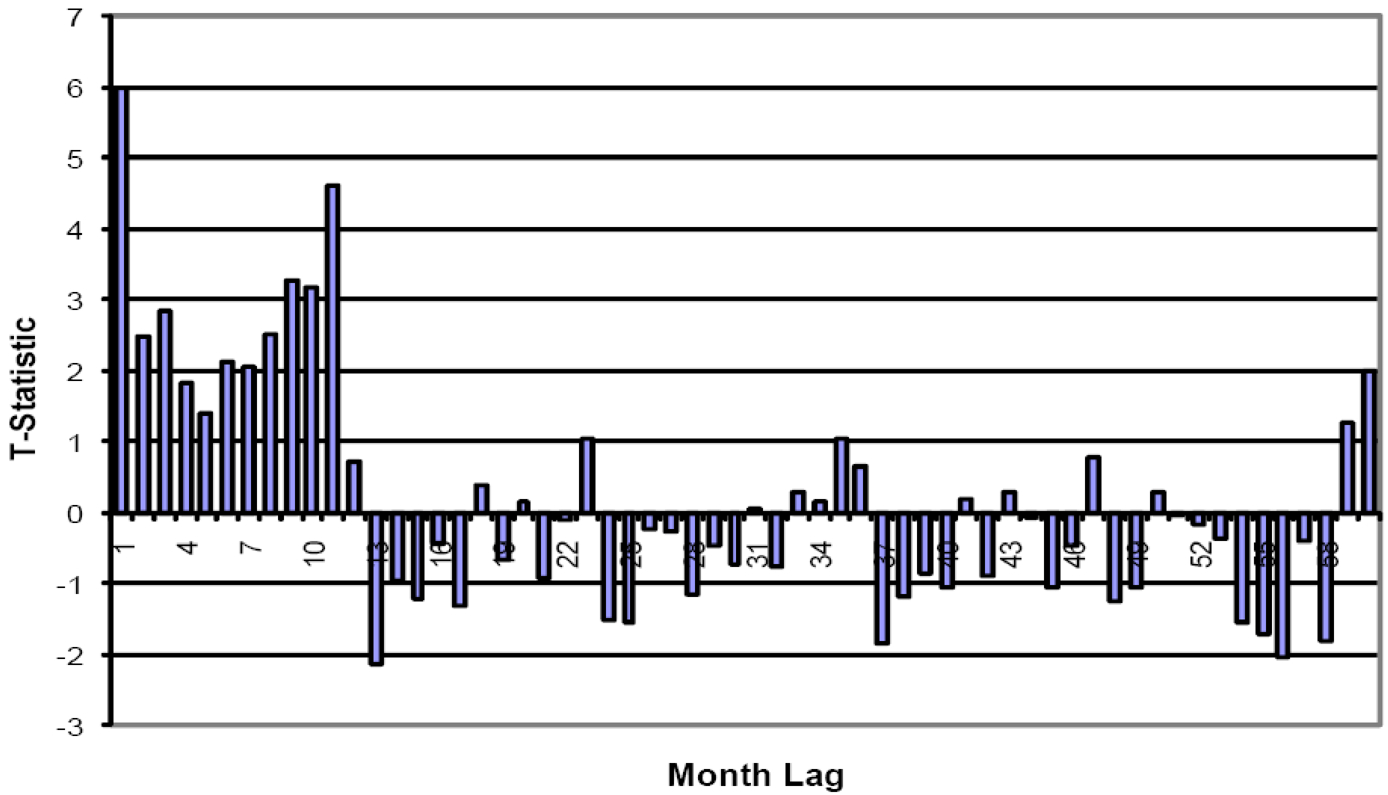


Time Series Momentum - Moskowitz, Ooi, and Pedersen (2010)

Time series predictability – regression evidence:

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

T-Statistic by Month, All Asset Classes



Trading on TS Momentum

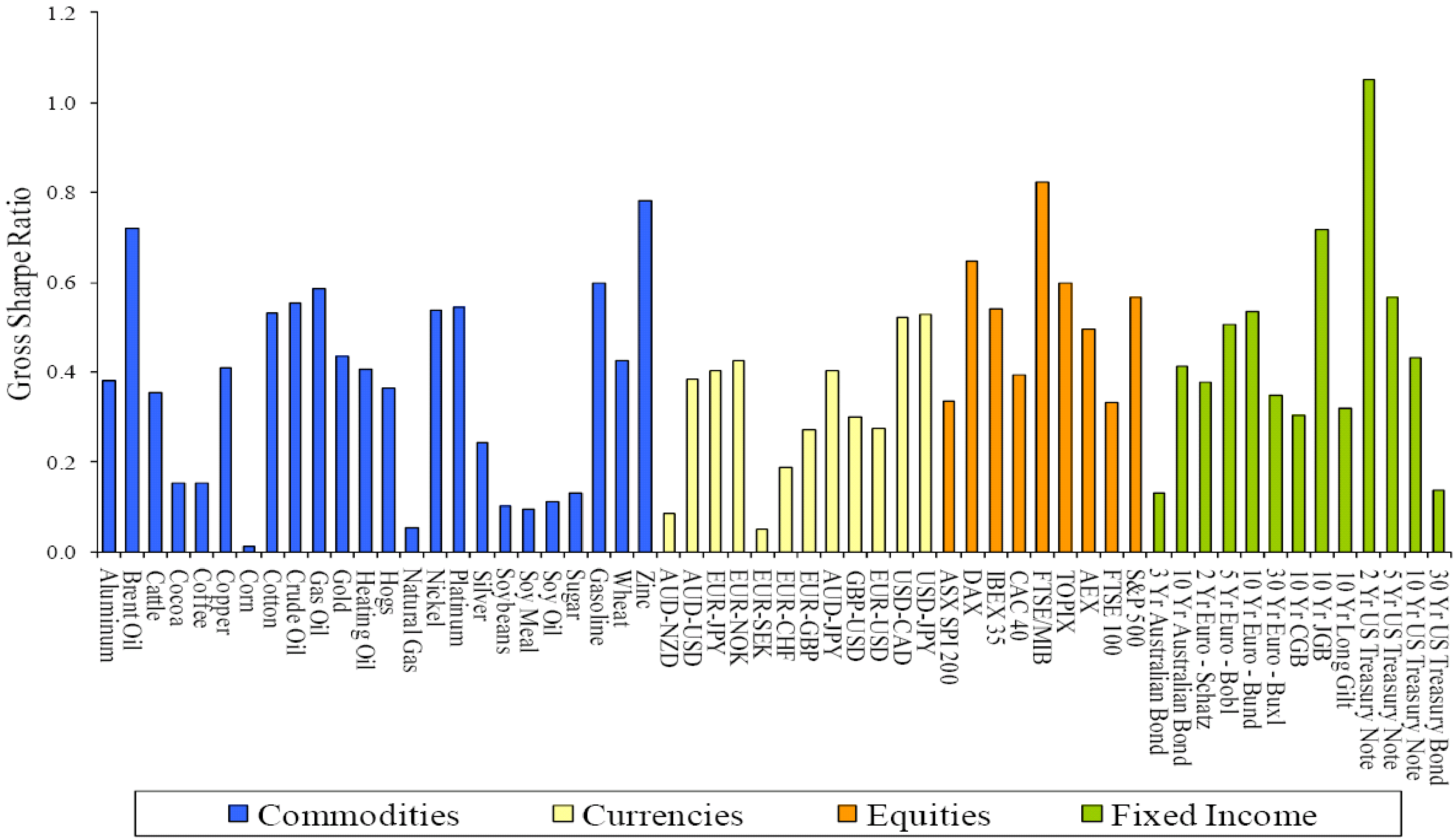
- Simple 12M TS Momentum strategy
  - Buy if the excess return over the past 12 months was positive
  - Take a short position if the return was negative
  - Scale the position such that the ex ante annualized volatility is 0.60%

- Return of 12M TS Momentum strategy for security *s:*

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

Sharpe Ratio of TS Momentum by Instrument

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



Time Series Momentum - Moskowitz, Ooi, and Pedersen (2010)

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:

Panel A: Fama and French Factors

		MSCI World	SMB	HML	UMD	Intercept	R^2
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)	

Panel B: Asness, Moskowitz, and Pedersen (2010) Factors

		MSCI World		VAL Everywhere	MOM Everywhere	Intercept	R^2
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)	

- 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

Lookback Period (Months)	Holding Period (Months): 1	3	6	9	12	24	36	48
	Panel A: All Assets							
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)

Panel A: Regression of TS-MOM on XS-MOM

Dependent Variable	Independent Variables: XS-MOM ALL	XS-MOM COM	XS-MOM EQ	XS-MOM FI	XS-MOM FX	XS-MOM US Stocks	Intercept	R^2
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

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

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

$$E[r_{t,t+1}^{XS}] = \frac{tr(\Omega)}{N} - \frac{1'\Omega 1}{N^2} + 12\sigma_\mu^2$$

$$= \underbrace{\frac{N-1}{N^2} tr(\Omega)}_{\text{auto-covariance}} - \underbrace{\frac{1}{N^2}[1'\Omega 1 - tr(\Omega)]}_{\text{cross-covariance}} + \underbrace{12\ \sigma_\mu^2}_{\text{mean effect}}$$

components:

- where

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

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

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

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:

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

components: auto-covariance mean-squared effect

Decomposing Time Series Momentum vs. Cross-Sectional Momentum

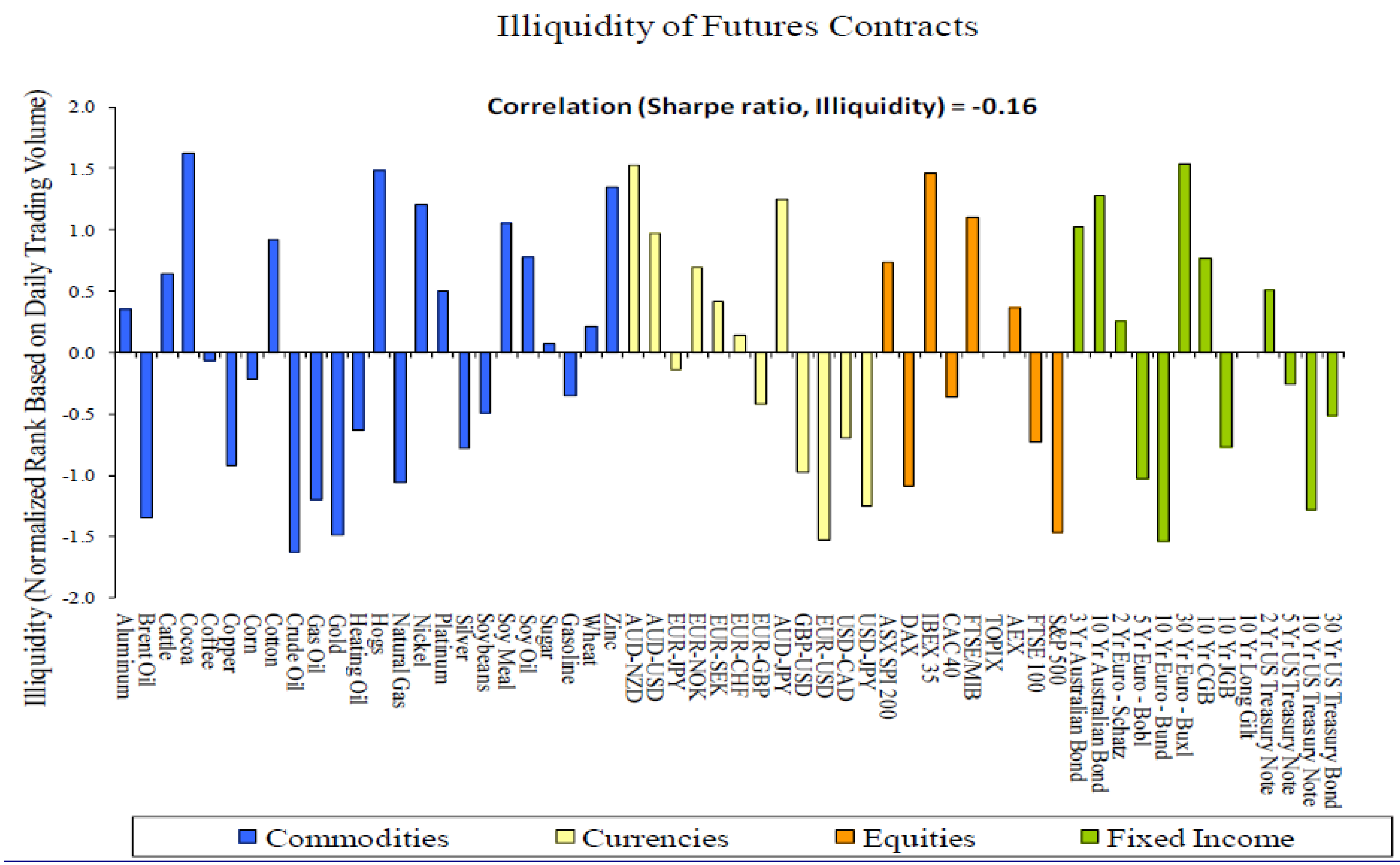
- The auto-covariance (own past 12-months return co-varies with next month return) explains most of the returns

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%

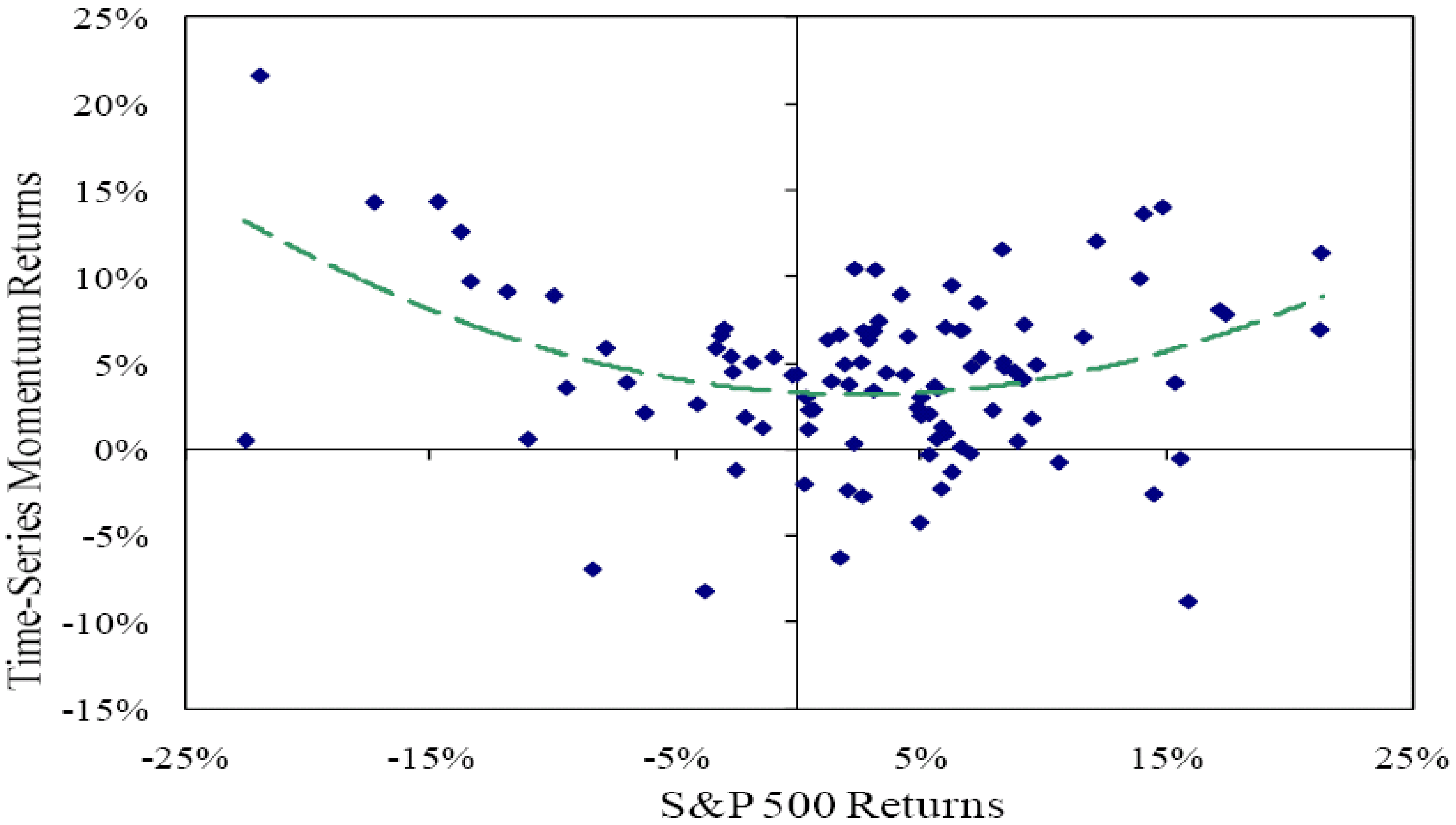
Potential Explanations: Transaction Costs

- 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



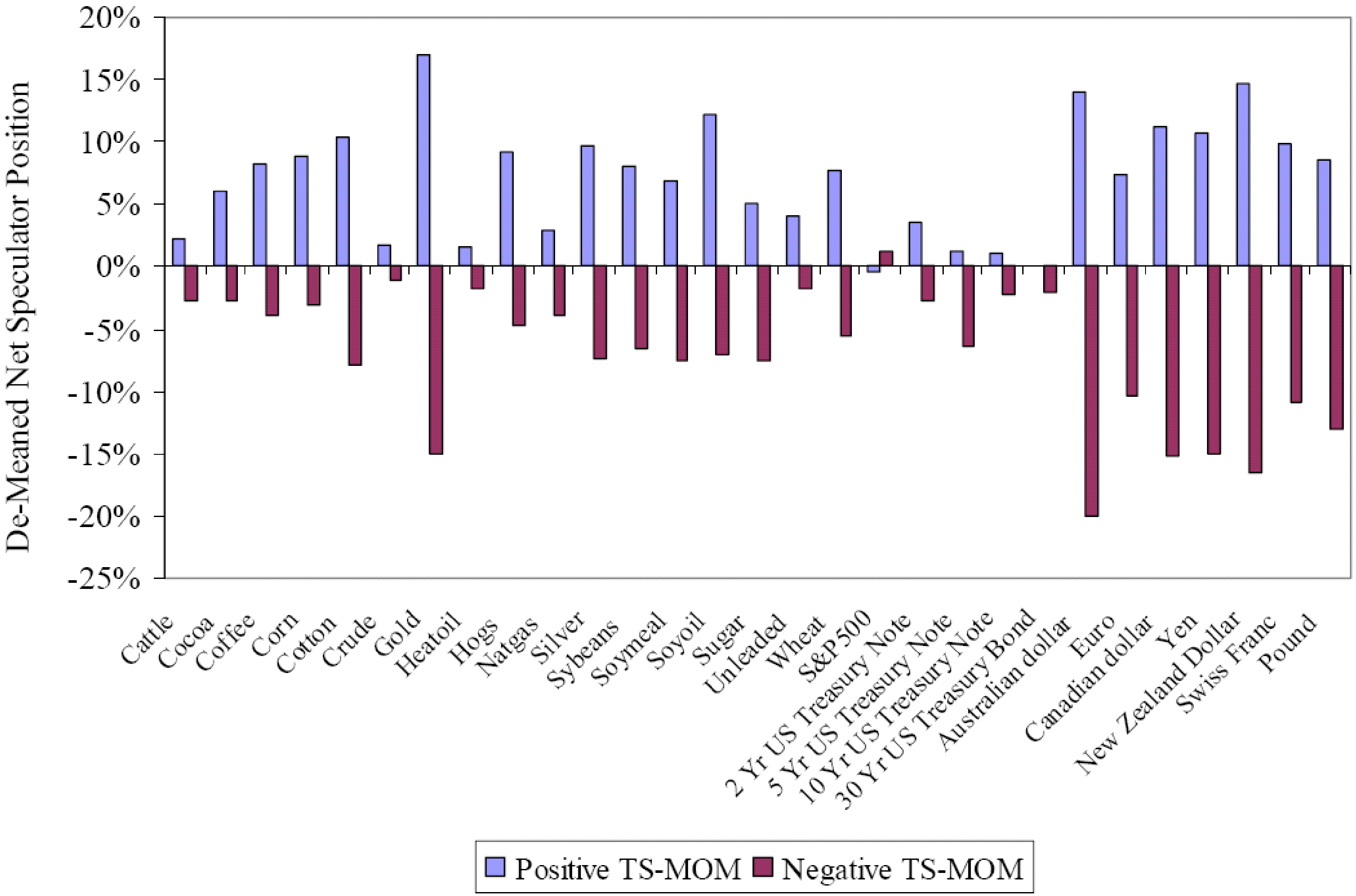
Other Potential Explanations

- 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

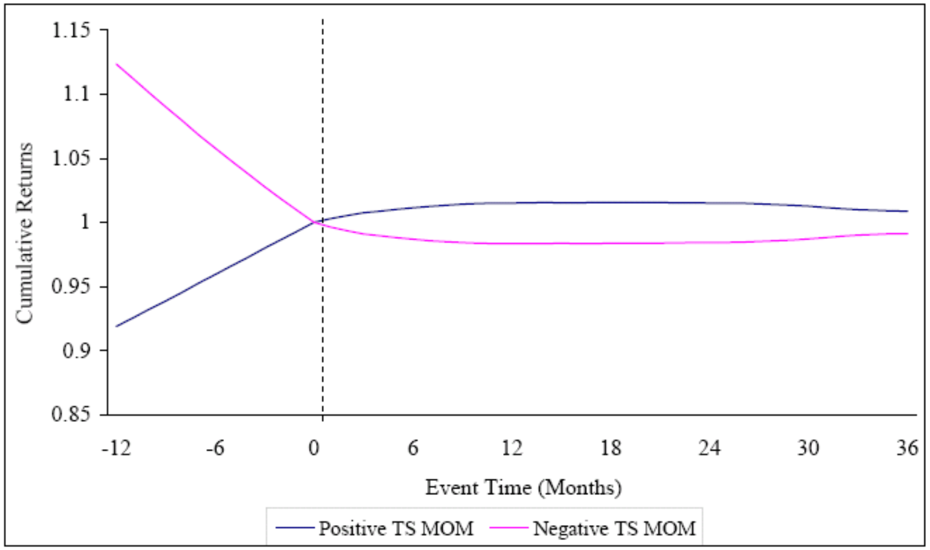
Who Trades on Time Series Momentum

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

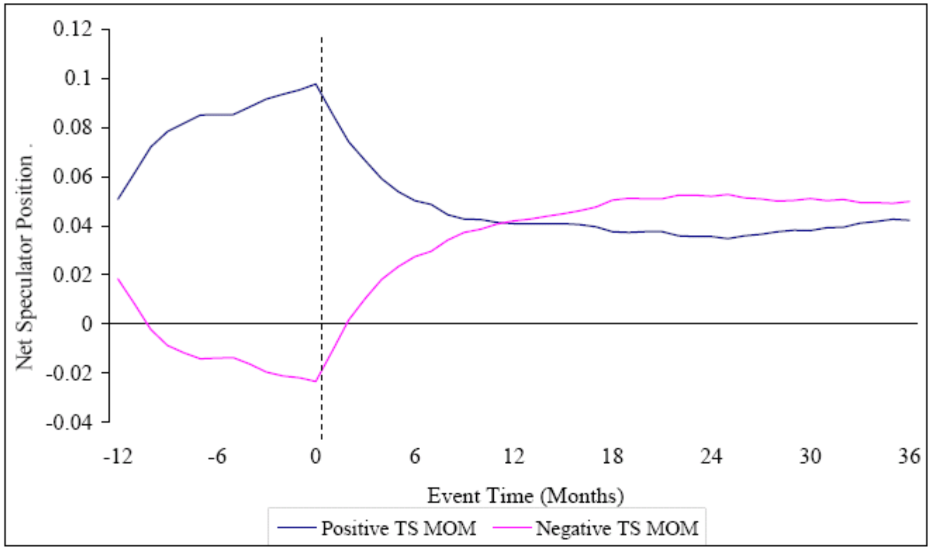


Event Study of Time Series Momentum

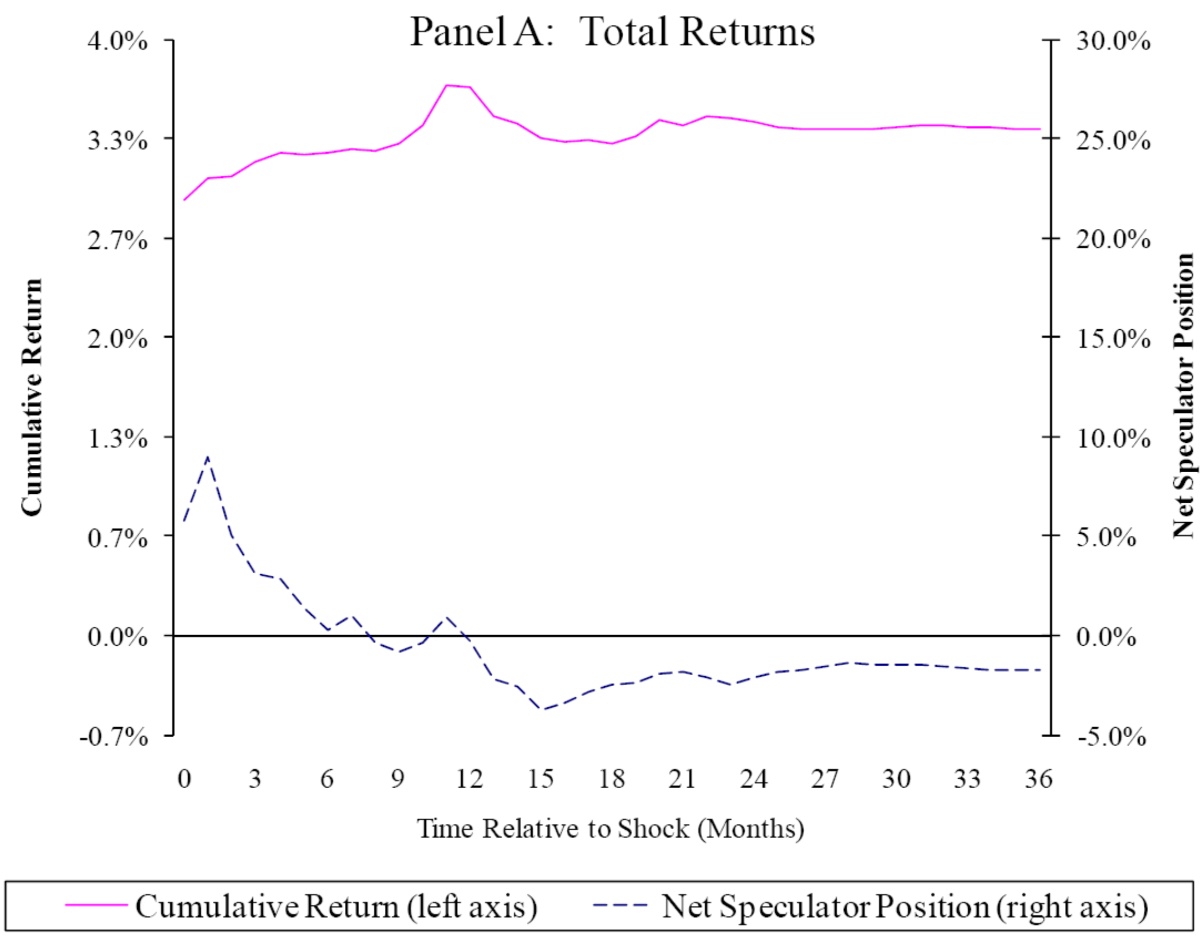
Panel A: Cumulative Returns in Event Time



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

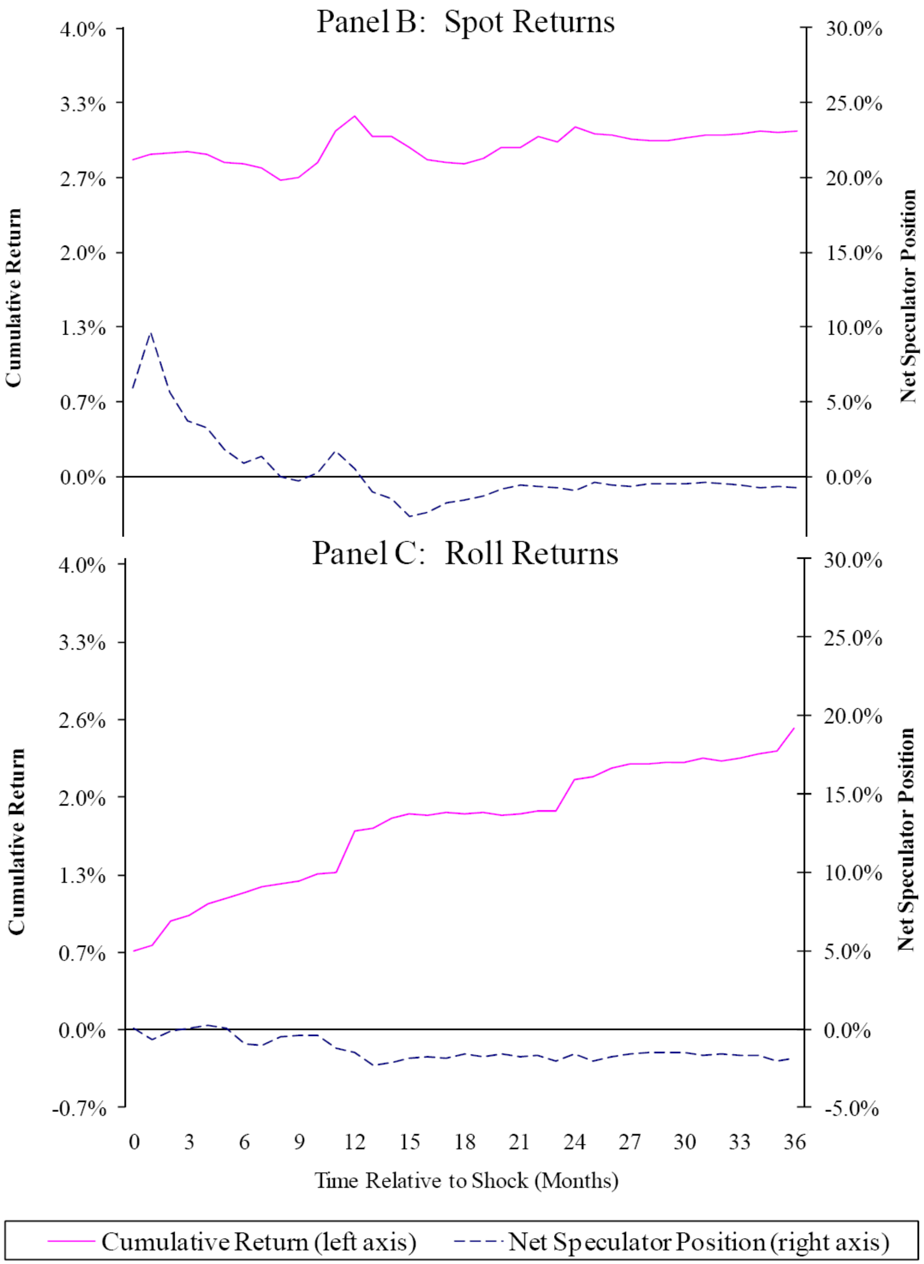
$$\text{price change}_{t-12,t} = \frac{\text{price}_t - \text{price}_{t-12}}{\text{price}_{t-12}} - r^f_{t-12,t}$$

  - Seems mostly due to over-reaction:

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

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

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



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)

	Full TS Mom	Spot Price Mom	Roll Mom	Chg Net Speculator Position	Intercept	R2
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