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:

What’s new:
- Looking at time series momentum:

<table>
<thead>
<tr>
<th>Time series</th>
<th>Cross-sectional</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n$ months predict $n$ months</td>
<td>NA</td>
</tr>
</tbody>
</table>
| $m$ months predict $n$ months | “Standard momentum”
  - Jegadeesh and Titman (1993)
  - Asness (1994)
  - Asness-Moskowitz-Pedersen |
|                          | “Autocorrelation”
  - Fama and French (1988)
  - Lo and MacKinlay (1988) |
|                          | 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:

\[ \frac{r^s_t}{\sigma^s_{t-1}} = \alpha + \beta \frac{r^s_{t-h}}{\sigma^s_{t-h-1}} + \epsilon^s_t \]
Time series predictability – regression evidence:

\[ \frac{r_t^s}{\sigma_{t-1}^s} = \alpha + \beta \cdot \text{sign}(r_{t-h}^s) + \varepsilon_t^s \]

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 $s$:

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

$$r^s_{t,t+1} = \text{sign}(r^s_{t-12,t}) \frac{0.60\%}{\sigma_t^s} r^s_{t,t+1}$$
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**

<table>
<thead>
<tr>
<th></th>
<th>MSCI World</th>
<th>SMB</th>
<th>HML</th>
<th>UMD</th>
<th>Intercept</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient (t-stat)</td>
<td>0.03 (1.00)</td>
<td>-0.04 (-0.92)</td>
<td>-0.01 (-0.23)</td>
<td>0.22 (7.15)</td>
<td>1.26% (8.55)</td>
<td>16%</td>
</tr>
<tr>
<td>Quarterly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient (t-stat)</td>
<td>0.02 (0.29)</td>
<td>-0.14 (-1.48)</td>
<td>-0.01 (-0.07)</td>
<td>0.25 (4.49)</td>
<td>3.80% (8.15)</td>
<td>25%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>MSCI World</th>
<th>VAL Everywhere</th>
<th>MOM Everywhere</th>
<th>Intercept</th>
<th>$R^2$</th>
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<tbody>
<tr>
<td>Monthly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient (t-stat)</td>
<td>0.05 (1.53)</td>
<td>0.06 (1.22)</td>
<td>0.48 (9.41)</td>
<td>0.94% (6.28)</td>
<td>30%</td>
</tr>
<tr>
<td>Quarterly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient (t-stat)</td>
<td>0.05 (0.94)</td>
<td>0.12 (1.53)</td>
<td>0.50 (6.13)</td>
<td>2.65% (5.00)</td>
<td>33%</td>
</tr>
</tbody>
</table>
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

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

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

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>XS-MOM ALL</th>
<th>XS-MOM COM</th>
<th>XS-MOM EQ</th>
<th>XS-MOM FI</th>
<th>XS-MOM FX</th>
<th>XS-MOM US Stocks</th>
<th>Intercept</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS-MOM ALL</td>
<td>0.57</td>
<td>0.62</td>
<td>0.61</td>
<td>0.58</td>
<td>0.08</td>
<td>0.66% (5.64)</td>
<td>45%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(15.52)</td>
<td>(7.00)</td>
<td>(14.29)</td>
<td>(13.48)</td>
<td>(1.52)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TS-MOM COM</td>
<td>0.43</td>
<td>0.34</td>
<td>0.02</td>
<td>0.13</td>
<td>0.08</td>
<td>0.23% (3.99)</td>
<td>41%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(4.67)</td>
<td>(3.74)</td>
<td>(0.53)</td>
<td>(3.16)</td>
<td>(1.52)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TS-MOM EQ</td>
<td>0.71</td>
<td>0.34</td>
<td>0.13</td>
<td>0.02</td>
<td>0.22</td>
<td>0.18% (2.95)</td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(8.23)</td>
<td>(3.26)</td>
<td>(3.16)</td>
<td>(0.53)</td>
<td>(4.28)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TS-MOM FI</td>
<td>0.05</td>
<td>0.03</td>
<td>0.05</td>
<td>0.02</td>
<td>0.17%</td>
<td>0.20% (3.24)</td>
<td>12%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.07)</td>
<td>(0.64)</td>
<td>(1.11)</td>
<td>(0.89)</td>
<td>(2.72)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TS-MOM FX</td>
<td>-0.01</td>
<td>0.51</td>
<td>0.51</td>
<td>-0.01</td>
<td>0.13%</td>
<td>0.13% (3.98)</td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-0.15)</td>
<td>(20.41)</td>
<td>(20.41)</td>
<td>(-0.35)</td>
<td>(3.64)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Decomposing Time Series Momentum vs. Cross-Sectional Momentum

Writing cross-sectional momentum returns as

\[ r_{t,t+1}^{\text{XS}} = \sum_{i=1}^{N} w_t^{\text{XS},i} r_{t,t+1}^i \]

with portfolio weights

\[ w_t^{\text{XS},i} = \frac{1}{N} (r_{t-12,t}^i - r_{t-12,t}^{\text{EW}}) \]

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

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

\[
= \frac{N-1}{N^2} \text{tr}(\Omega) - \frac{1}{N^2} [1'\Omega 1 - \text{tr}(\Omega)] + 12 \sigma_\mu^2
\]

components: auto-covariance cross-covariance mean effect

where

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

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

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

\[
E(r_{t,t+1}^{TS}) = E(w_{t}^{TS,i} r_{t,t+1}^{i}) = \frac{tr(\Omega)}{N} + 12 \frac{\mu'\mu}{N}
\]

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

<table>
<thead>
<tr>
<th>Panel B: Decomposition of TS-MOM and XS-MOM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>XS-MOM Decomposition</strong></td>
</tr>
<tr>
<td>Auto</td>
</tr>
<tr>
<td>ALL</td>
</tr>
<tr>
<td>COM</td>
</tr>
<tr>
<td>EQ</td>
</tr>
<tr>
<td>FI</td>
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<td>FX</td>
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<tr>
<td><strong>TS-MOM Decomposition</strong></td>
</tr>
<tr>
<td>Auto</td>
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<tr>
<td>ALL</td>
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<tr>
<td>COM</td>
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<td>EQ</td>
</tr>
<tr>
<td>FI</td>
</tr>
<tr>
<td>FX</td>
</tr>
</tbody>
</table>
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:

![Graph showing Illiquidity of Futures Contracts with correlation (Sharpe ratio, illiquidity) = -0.16]
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

Net Speculator Position = \frac{Speculator Long Positions - Speculator Short Positions}{Open Interest}
Event Study of Time Series Momentum

Panel A: Cumulative Returns in Event Time

Panel B: Net Speculator Positions in Event Time
Evidence is consistent with elements of both
- Initial under-reaction
- Delayed over-reaction
Over- and under-reaction (slow information diffusion)
- Should show up in price changes
\[
\text{price change}_{t-12,t} = \frac{\text{price}_t - \text{price}_{t-12} - r^f_{t-12,t}}{\text{price}_{t-12}}
\]
- 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:
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)
- speculative positions (hedging pressure measured using noisy CFTC position data)

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