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Asset Management

The Liquidity Crunch in Quant Equities
Analysis and Implications

December 13, 2007

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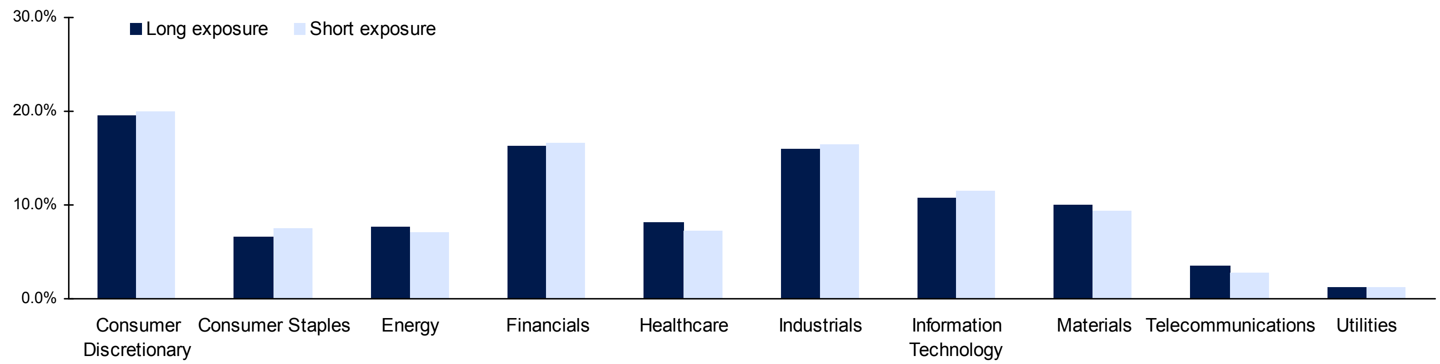
Agenda

What do quants do?

- **Identify fundamental return-driving factors**
- **Create portfolios with optimal exposures to those factors**
- **Identify and hedge exposures to risk factors**
- **Use optimizers to make trade-offs**
  — Seek to maximize expected returns, net of expected trading costs, subject to a risk budget

Global Equity Opportunities, Plc



[1] Standard Deviation
Standard deviation is a statistical measure of the degree to which an individual value in a probability distribution deviates from the mean of the distribution. The above information is as of December 16, 2005. GSAM portfolio holdings are not stagnant and may change over time without prior notice. Source: Goldman Sachs. Please see appendix for other important disclosures.

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Alpha/beta separation

We search for alpha in many places:

- Global stock selection
- Relative value strategies in currencies; fixed income and equity indices
- Timing strategies in stocks, bonds, and other indices
- Strategies in commodities, volatilities, credit, correlations, yield curves, emerging markets, and insurance
- Over 2 dozen strategies in total

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Fundamentals drive alpha

Valuation
How is the company priced relative to fundamental accounting measures?
Sample Metric:
Book-to-price ratio

Profitability
What are the company's profit margins? How efficient are its operations?
Sample Metric:
Earnings-to-sales ratio

Analyst Sentiment
Are analysts upgrading or downgrading their view of this company?
Sample Metric:
Earnings forecast revisions

XYZ Co. Alpha

Earnings Quality
Were earnings derived from sustainable sources?
Sample Metric:
Accruals-to-total-assets

Momentum
How has the market responded to the company's changing fortunes?
Sample Metric:
Price momentum

Management Impact
How is the company's management employing its capital?
Sample Metric:
Change in shares outstanding

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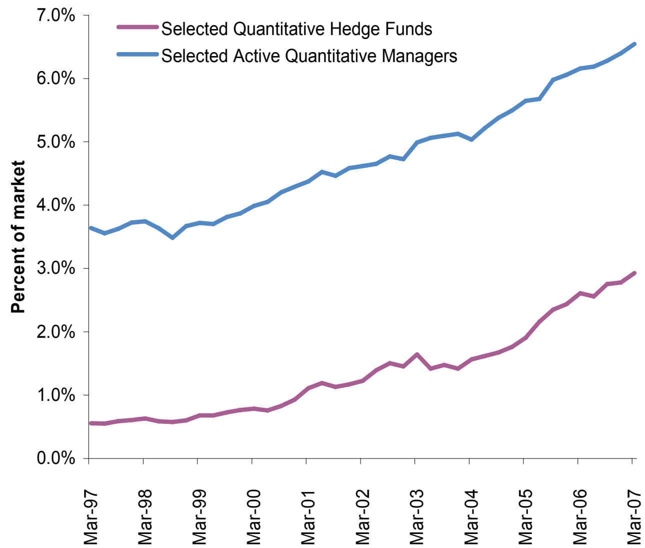
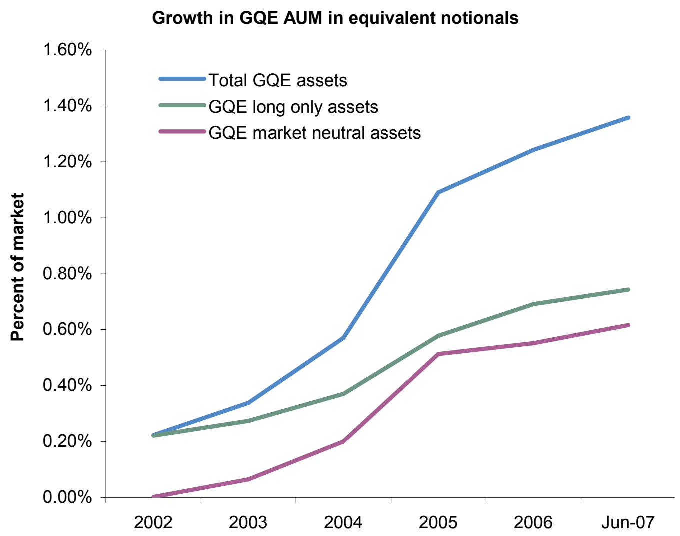
The quant explosion

- **Quants started in low-risk enhanced-index and GTAA strategies (1980s)**
- **Success lead to imitation, extensions and growth (1990s):**
  - — Expanded into high-risk, levered hedge funds
  - — Statistical arbitrage managers added low-frequency fundamental factors
- **Assets in all parts of the space grew rapidly (2000s)**





For illustrative purposes only.
The chart on the left shows selected hedge fund assets and selected active quantitative manager assets as a percentage of the Russell 3000 Index. The universe of managers examined were those institutions filing holdings data with 13Fs which were picked up in the Thomson ownership database. We screened for Quantitative Managers who we consider our main competitors and other factors we deemed relevant. The chart on the right shows the growth in GQE assets. Total GQE assets includes both market neutral assets and long only assets. GQE market neutral assets also includes long/short (Flex) assets. Long only assets and market neutral assets have been scaled based on tracking error.

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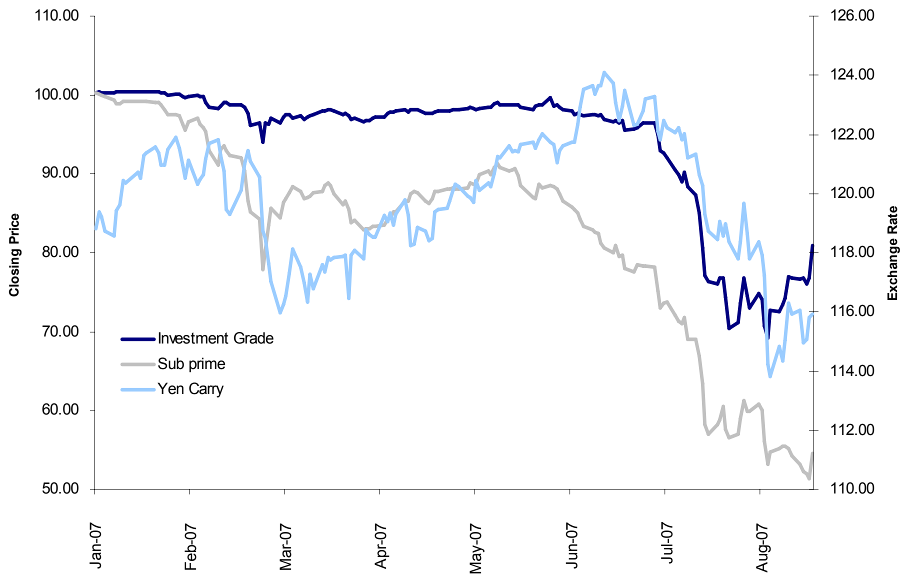
The liquidity crunch of August 2007

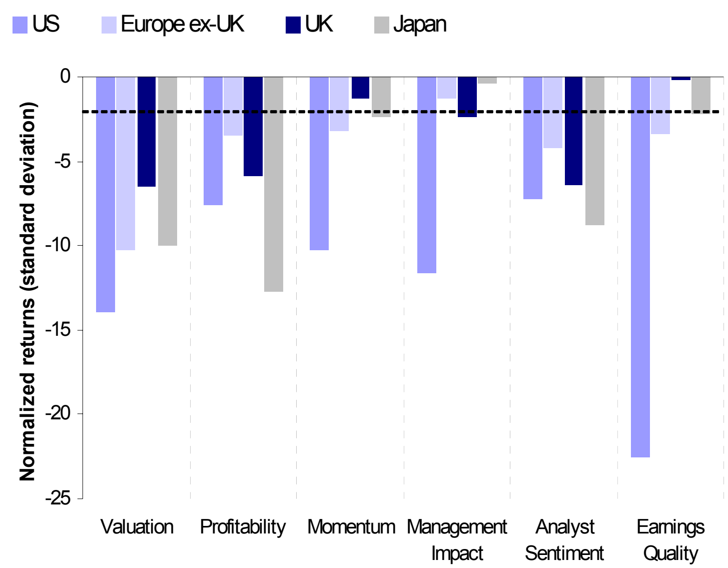
What happened?

- Sub-prime mortgage market disruption
  - Starts January 2007; Substantial acceleration in June 2007
- Spillover to investment-grade credit markets shortly thereafter
- Spillover to yen carry trade
- Spillover to US quant equity strategies, and then international quant strategies in early August

Contagion – YTD 2007



Theme returns by region (August 1 - August 10, 2007)*



For illustrative purposes only.
Contagion graph source: ABX BBB-Tranch closing price, ABX A, USD/Yen exchange rate (PACE). Theme returns source: Goldman Sachs Asset Management (PACE).
*Theme returns are shown as of August 1 – 9 for the US and as of August 1 – 10 for Europe ex-UK, UK and Japan.

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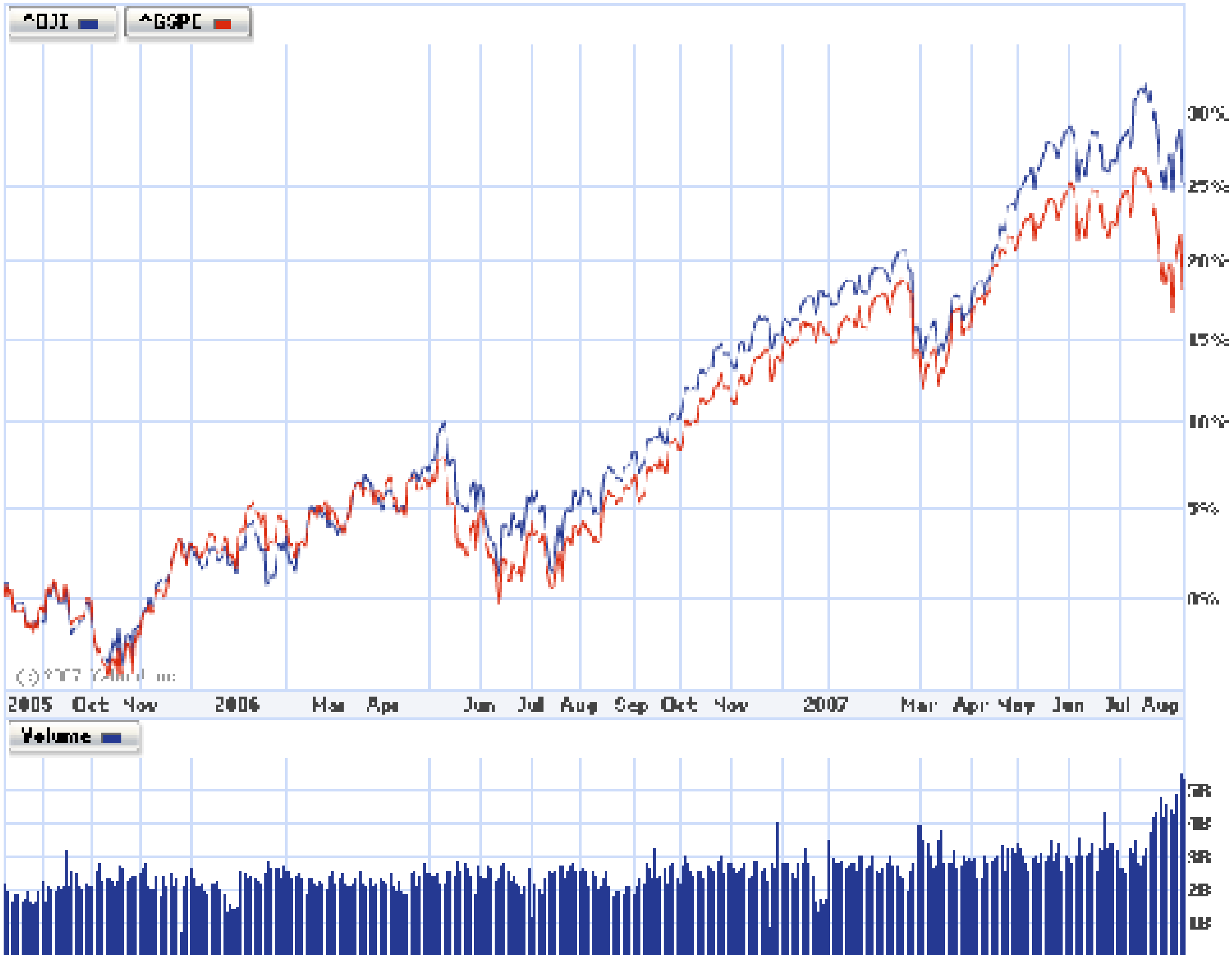
S&P and DJIA Cumulative Returns
August 6 - August 10

S&P and DJIA Cumulative Returns
August ‘05 - August 10, 2007



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VIX
August 6 - August 10

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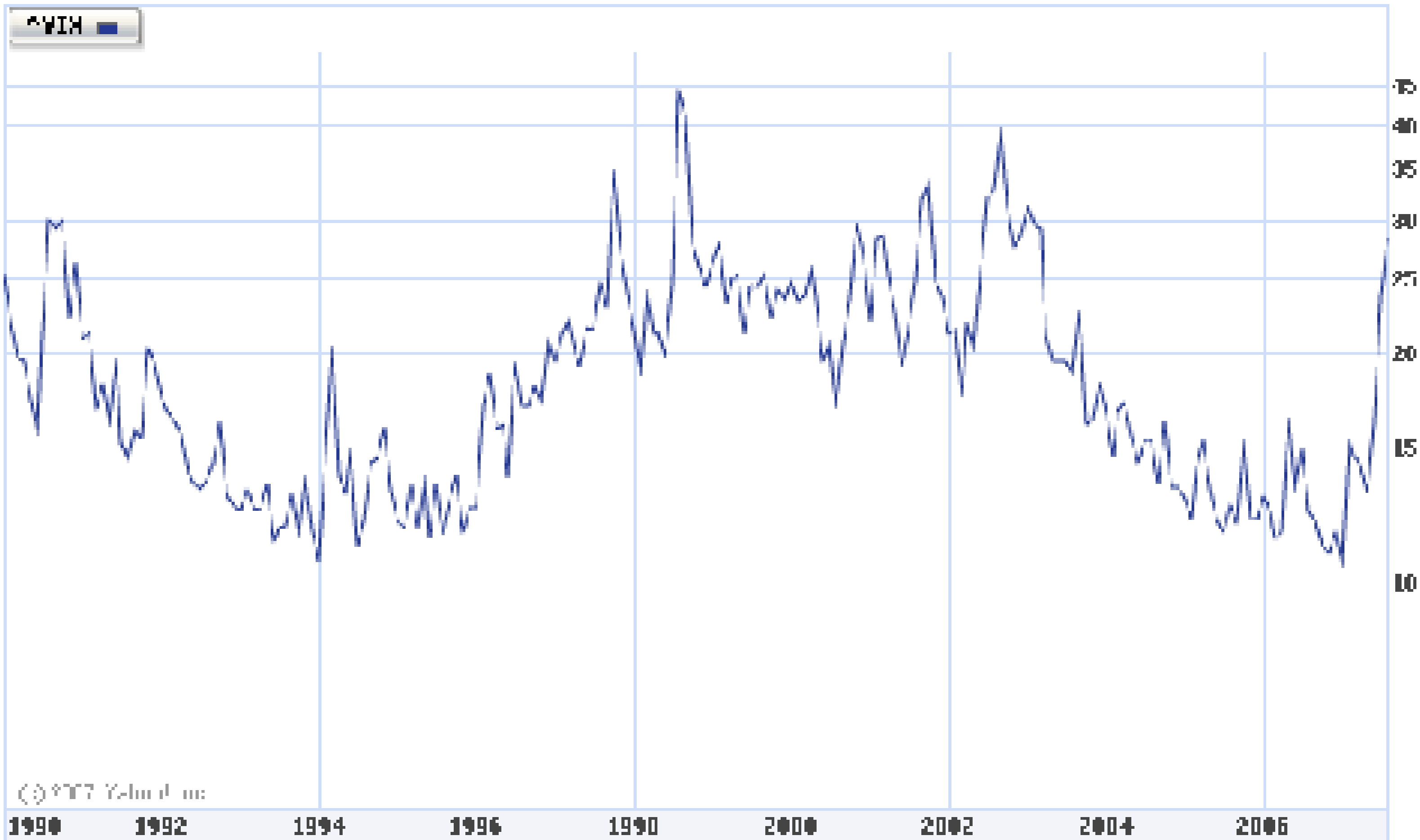
VIX

July 10 - August 10

VIX
1990 – August 10, 2007



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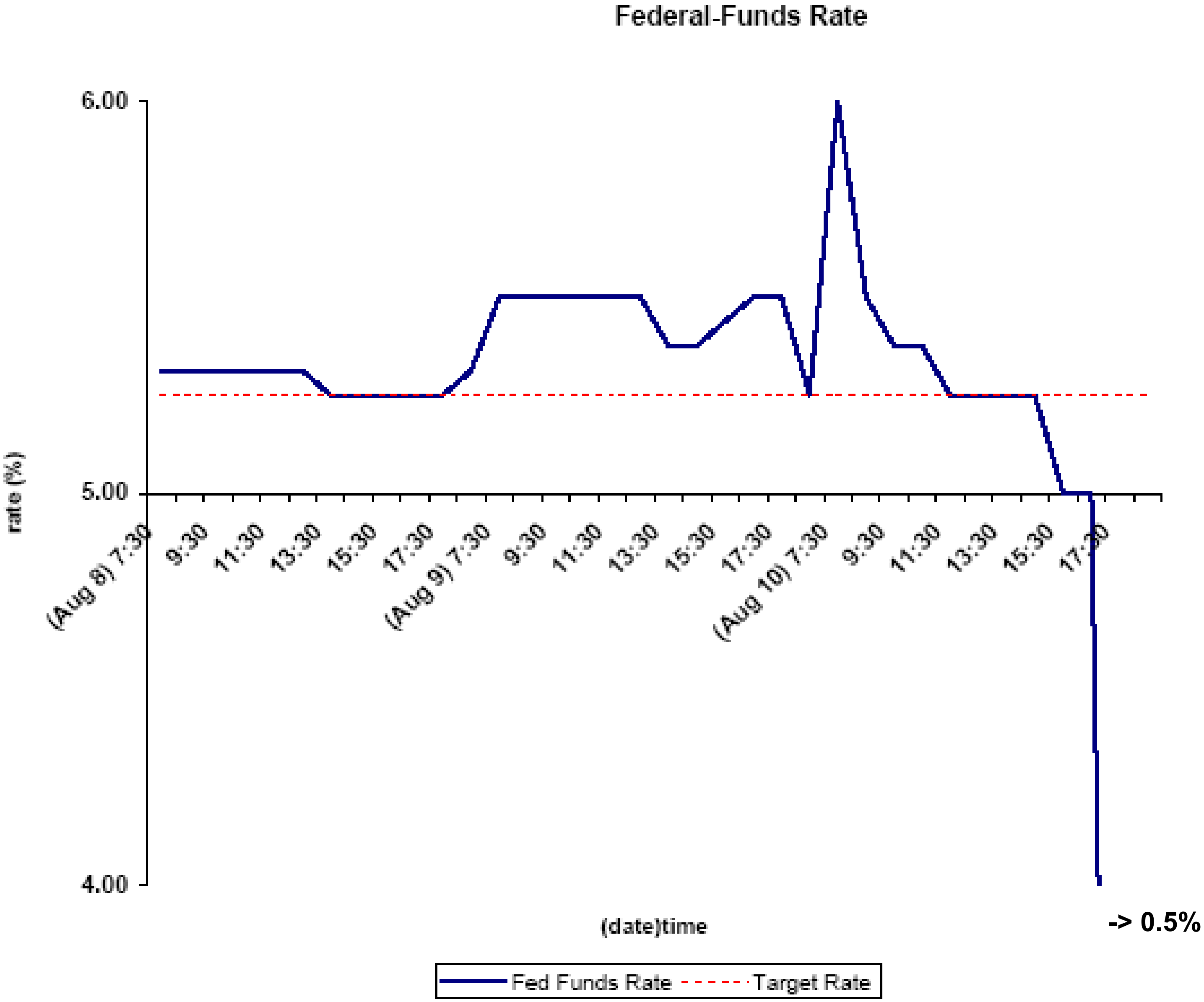
Federal Funds Rate
August 8-10, 2007



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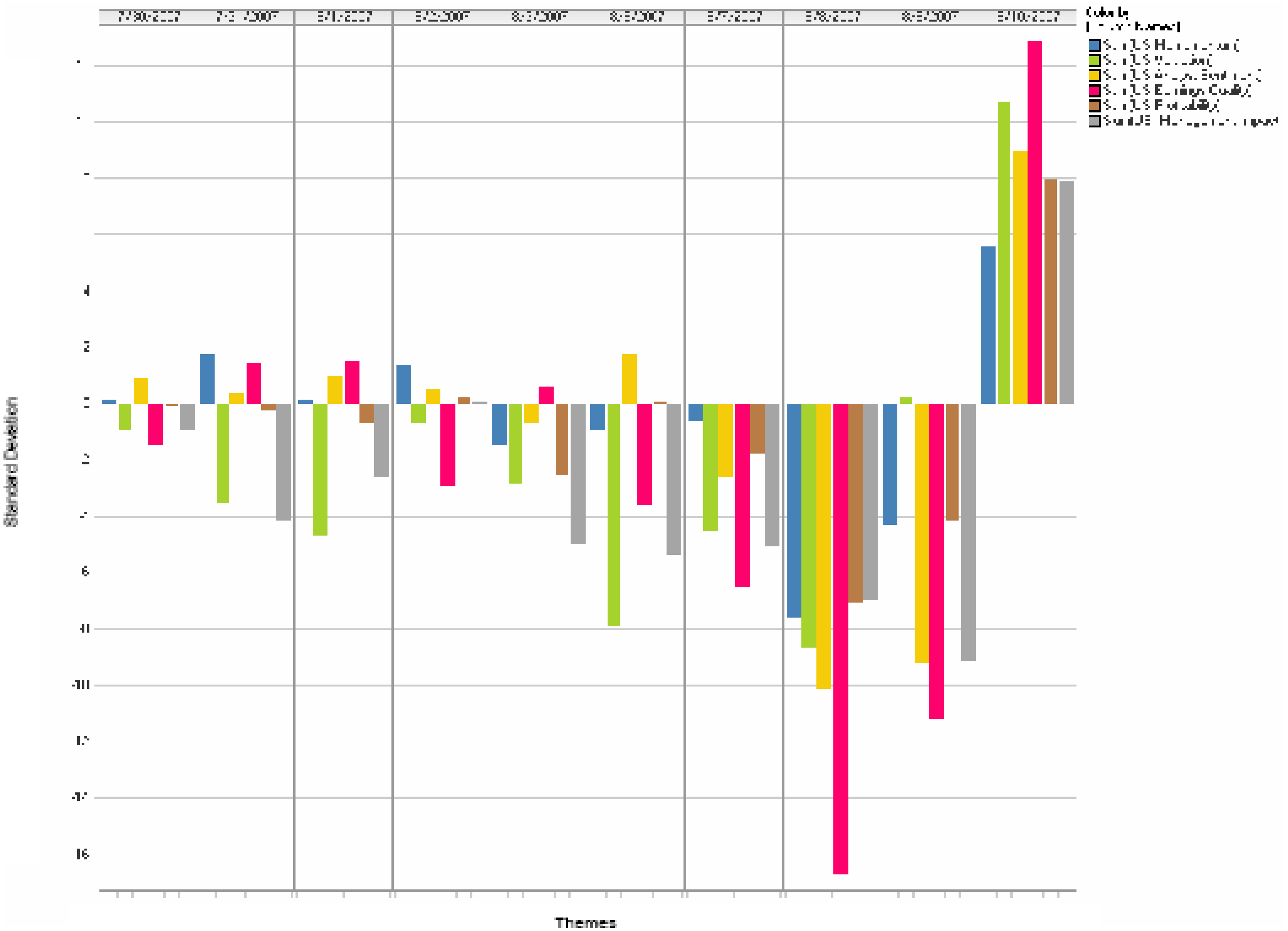
US Theme Returns -- *August 1-10*



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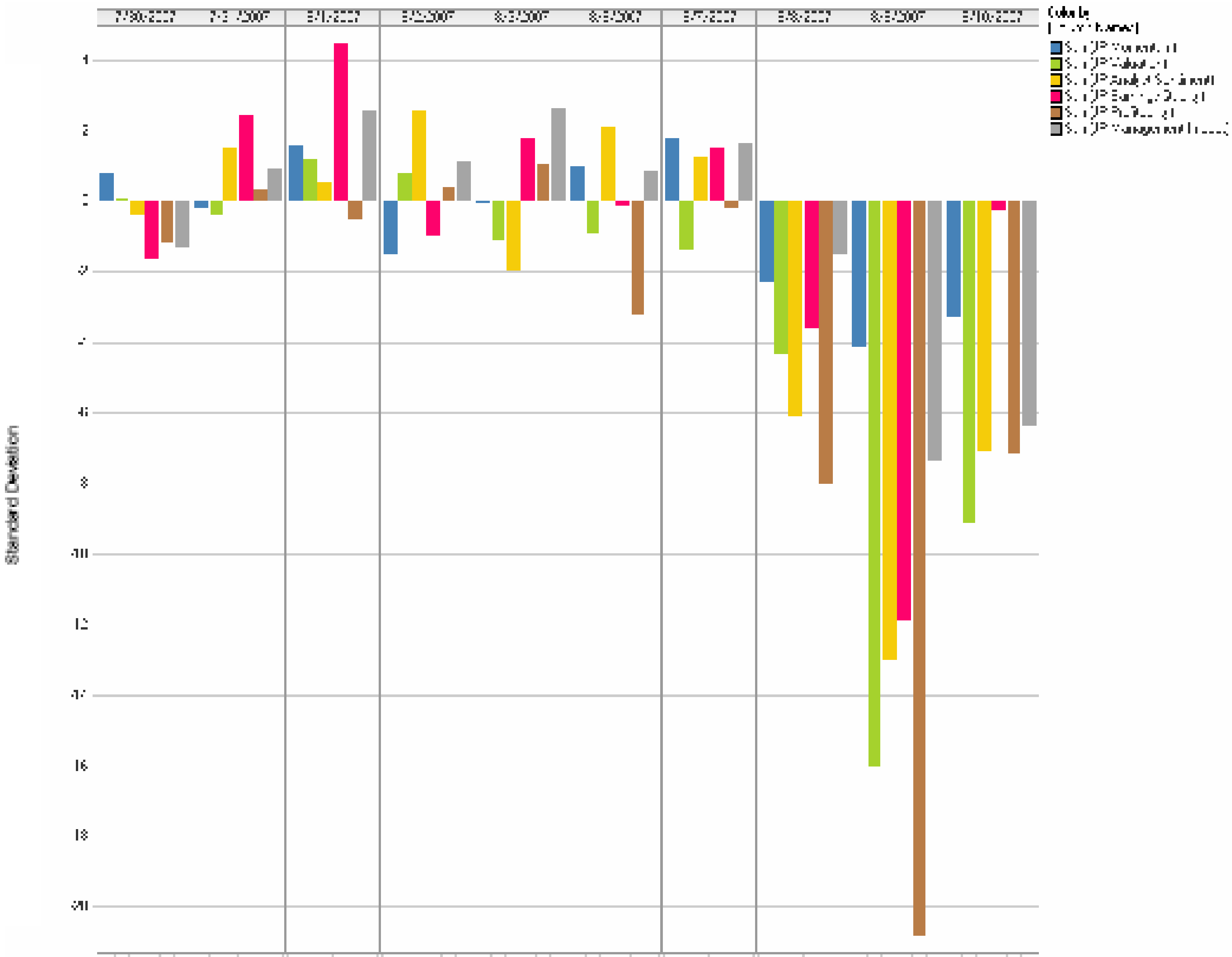
Japan Theme Returns -- *August 1-10*



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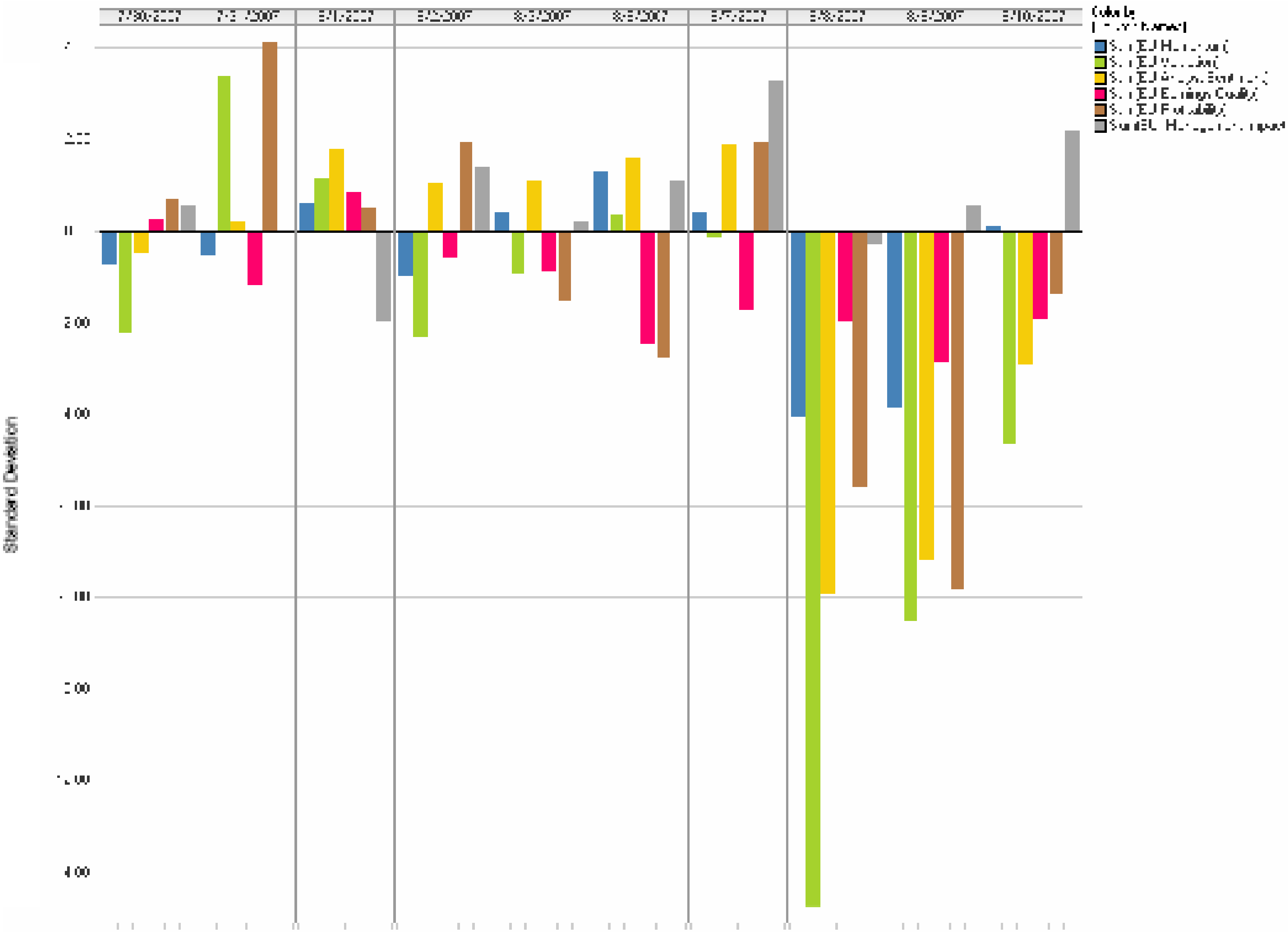
EU Theme Returns -- *August 1-10*



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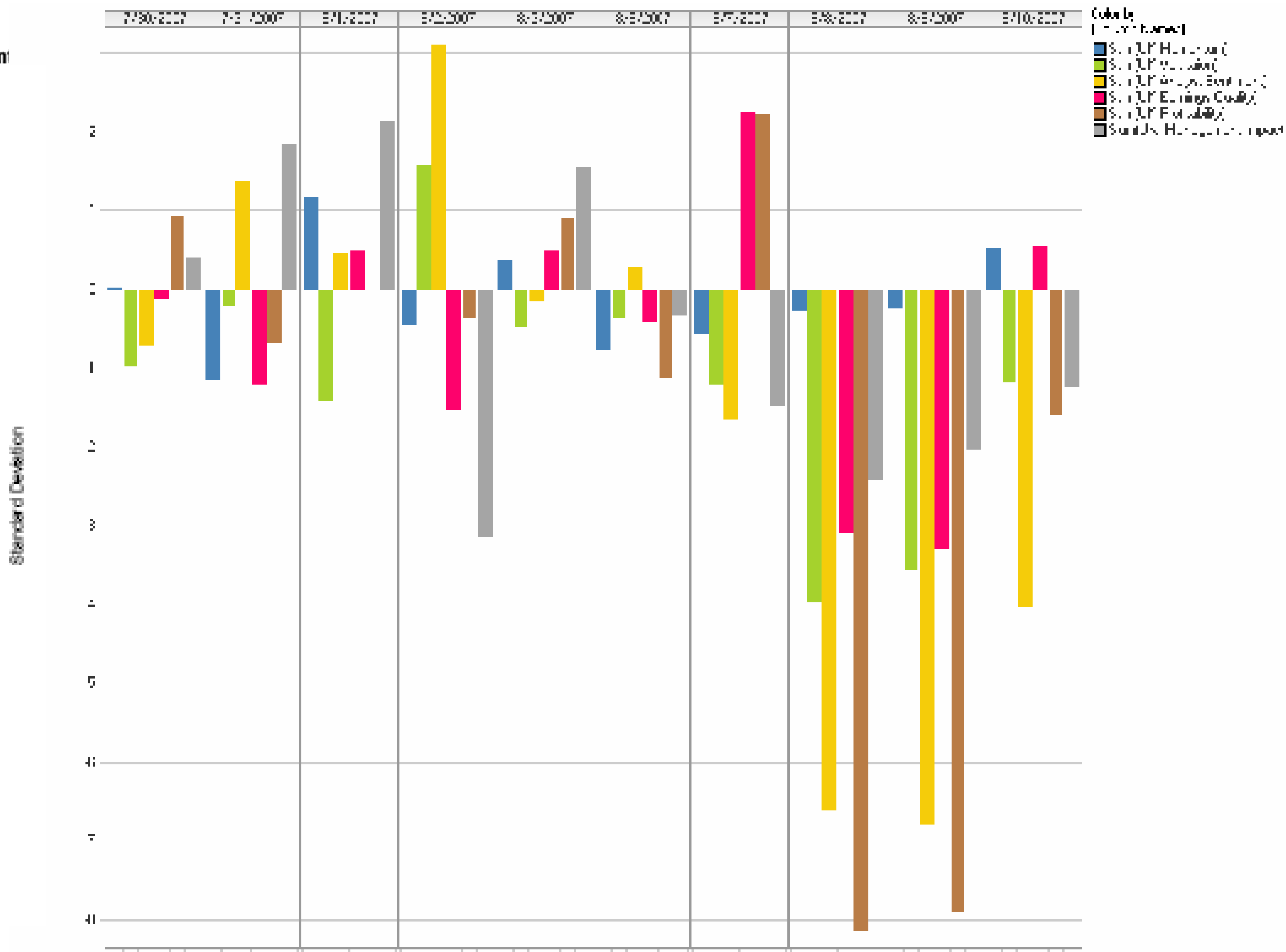
UK Theme Returns -- *August 1-10*

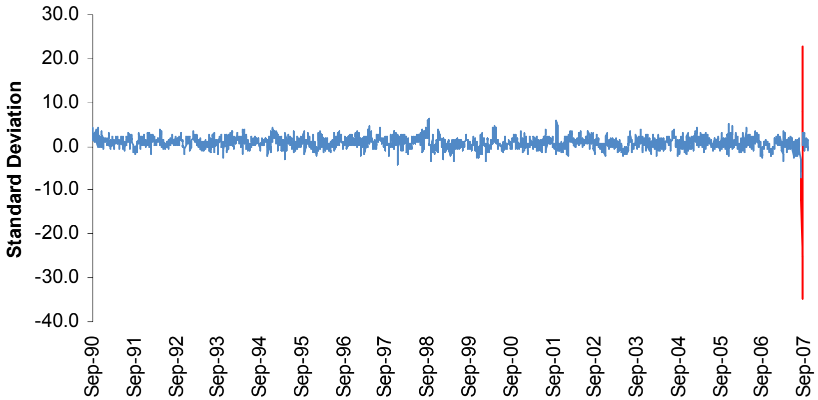


How unusual was the event?

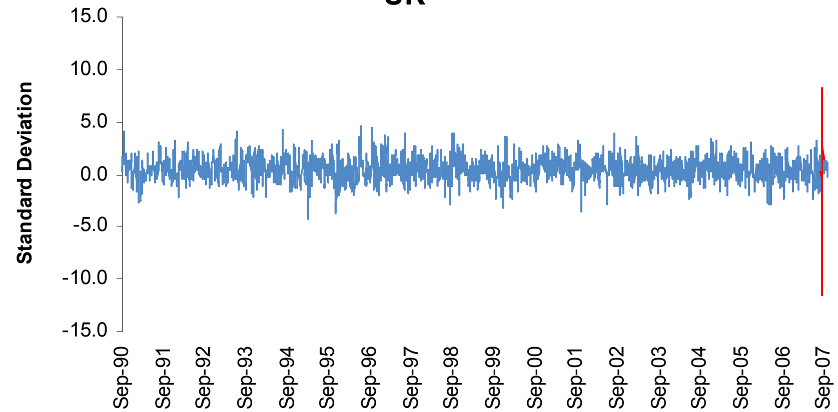
Cumulative 5-day standardized returns

Our models in all major regions experienced extraordinary drawdowns at virtually the same time

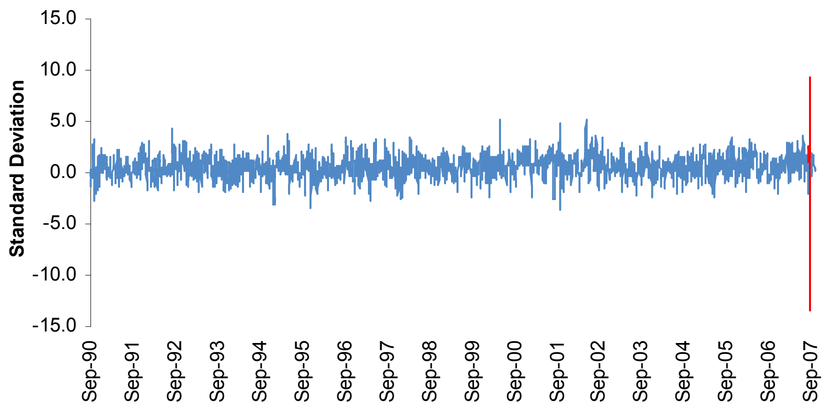
US



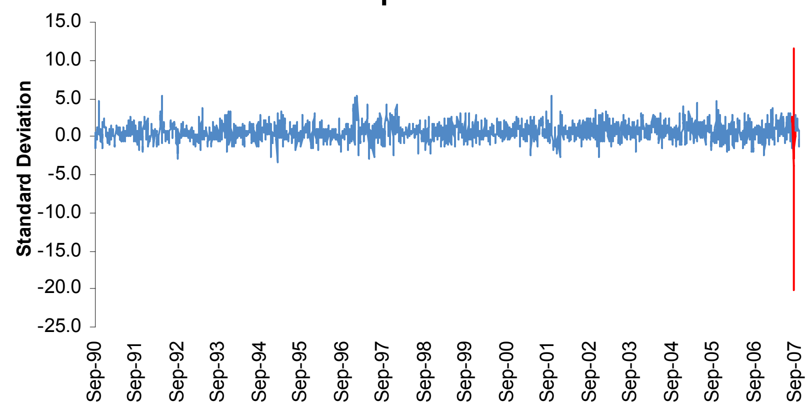
UK



Europe ex-UK



Japan



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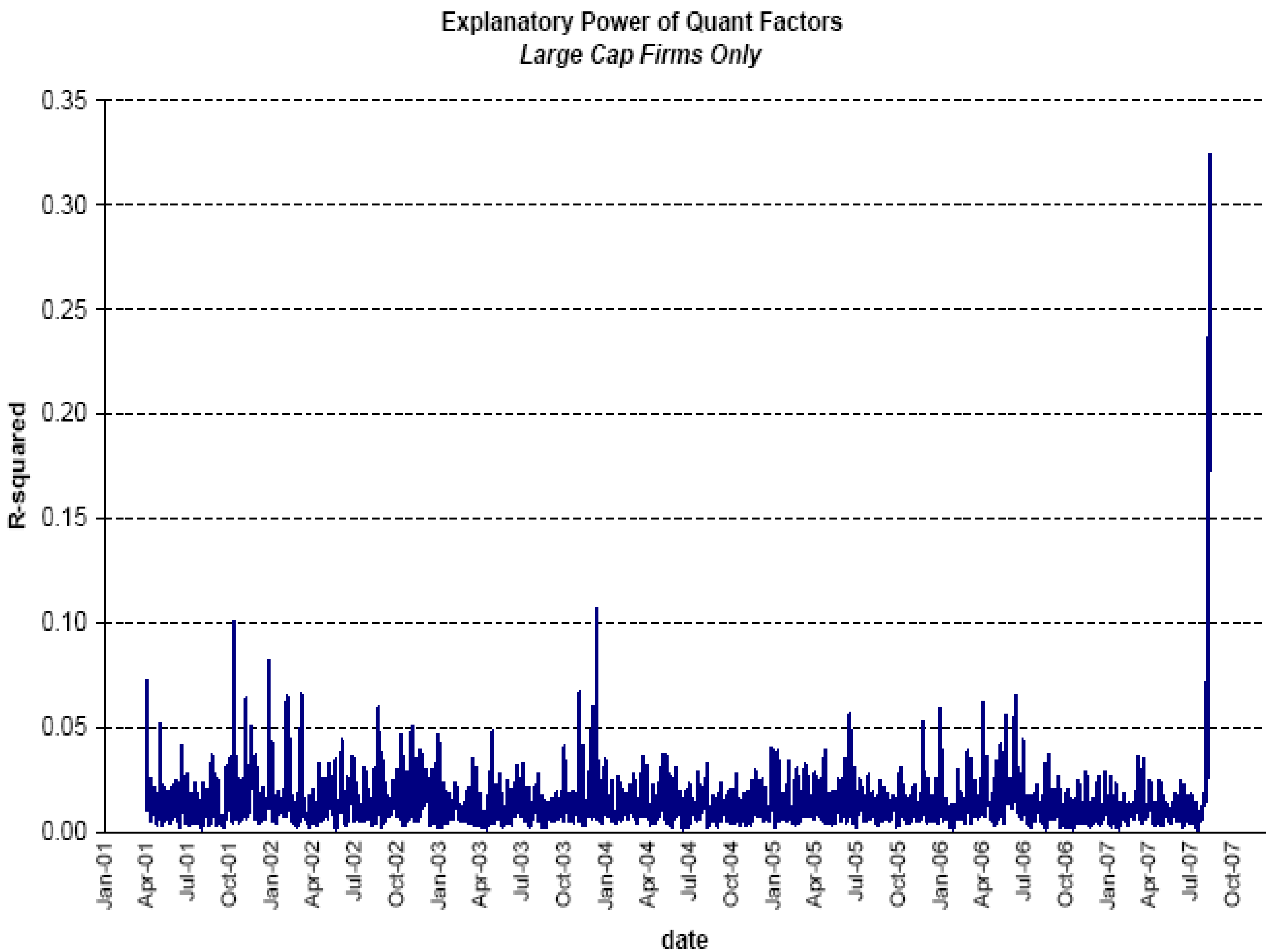
Cross-Sectional Regression R^2s



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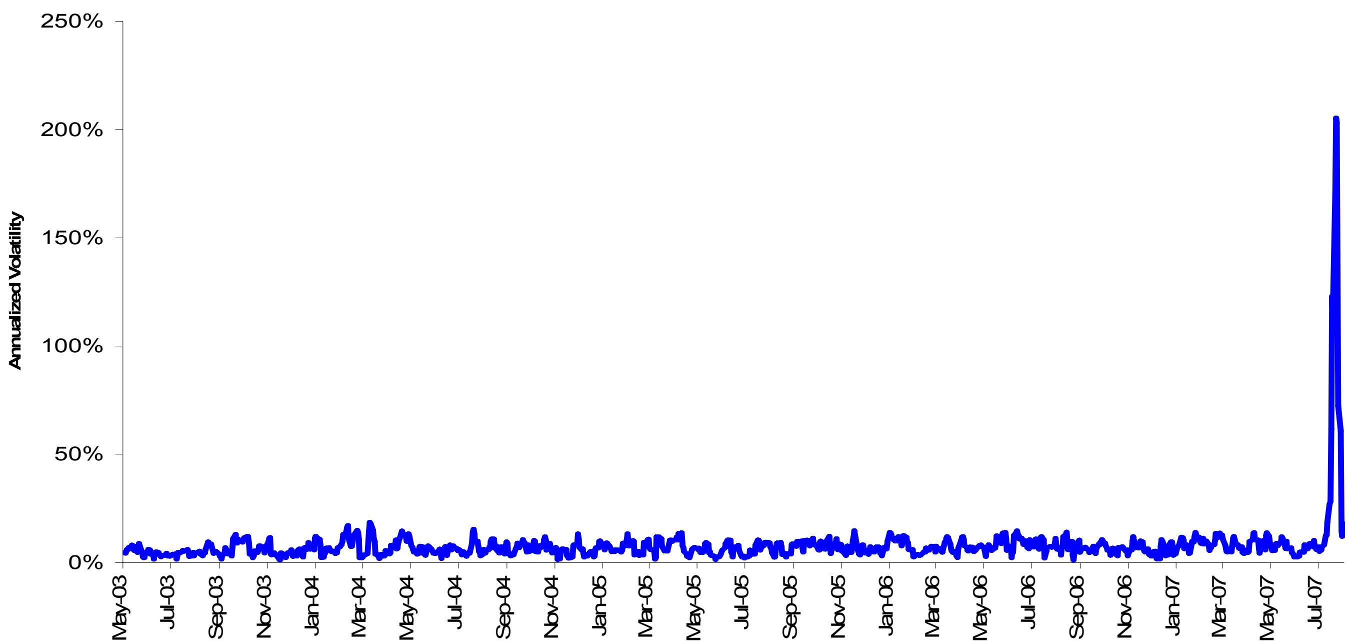
History provided no warning

- Recent events were well outside the range of prior experience
- Although we've seen occasional blow-ups in some factors in some regions, we had never seen this happen simultaneously to virtually all factors in every major region
- This produced a 20-sigma drawdown for our Global Equity Opportunities Fund and a huge spike in volatility

Rolling 5-Day volatility of the Global Equity Opportunities Fund, Plc



Since inception as of August 24, 2007. The inception date of the Global Equity Opportunities Fund, Plc is May 1, 2003. Past performance is not indicative of future results, which may vary. Please note that the above data is calculated using two day overlapping gross returns. The returns presented herein are gross and do not reflect the deduction of investment advisory fees, which will reduce returns.

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Market dynamics: how it started

- **Multi-strategy hedge funds**
  - Hidden losses in illiquid mortgage and credit positions
  - Looking to reduce risk and raise cash
- **Quant equity strategies**
  - Viewed as liquid
  - Required relatively large margin balances (good source of cash)
  - Were not performing well

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Market dynamics: contagion

- **Prisoner's dilemma developed**
  - Slow trading reduces costs
  - We're all better off if everyone is patient
  - But if others rush to liquidate, I better get out first → panic unwinding
- **Liquidity dried up**
  - Liquidity is normally provided by stat-arb strategies and brokers
  - When small price discrepancies become large imbalances, liquidity providers pull back
  - Normal, slow summer schedules may have contributed

Market dynamics: positive feedback

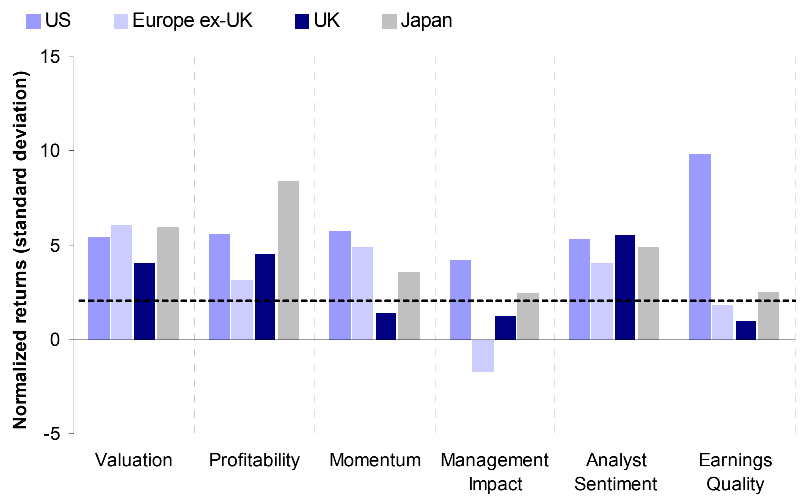
- **Prisoner's dilemma accelerated the unwind**
- **Positive feedback loop develops**
  - — Unstable equilibrium
  - — Explosive dynamics

Market dynamics: opportunity

What ends the stampede?

- Supply and demand
  - — Prices move farther away from fundamental values
  - — Higher risk is offset by higher expected returns
  - — Liquidity returns as new sources of capital seek to participate
- Goldman and others injected significant new capital into quant equity strategies

Theme returns by region (August 10 - August 31, 2007)*



*Theme returns are shown as of August 10 - 31 for the US and as of August 13 – 31 for Europe ex-UK, UK and Japan.

What made this event unique?

Market dislocations occur regularly

- The unwinding of “crowded trades” can create large losses, but they are not uncommon
  - However, they usually involve concentrated positions in relatively illiquid assets
- What made this event unique was:
  - A crowded trade in a diversified portfolio of normally liquid assets
  - It hit all quant factors in all major markets at almost the same time
  - Without looking at quantitative factors you might have missed it

We didn't foresee this scenario

We saw the growth of quant AUM, but

- Didn't see how far these strategies had extended into statistical arbitrage desks and hedge-funds
- We felt our proprietary factor specifications and weighting would provide differentiation
  - Supported by historical correlations plus low exposures of other quant managers to our factors
- Our individual equity positions were small, liquid, and diversified – we didn't foresee a significant liquidation event focused on similar portfolios

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What we’ve learned

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Lessons learned

Did our process fail?

- It was designed to give us efficient exposure to our factors, which it did.
- These factors moved sharply against us as quant portfolios were de-levered
- In fact, the event is only understandable in the context of quantitative models (a factor story)
- Our process was not designed to anticipate or protect us from 20-sigma events

Other Lessons:

- The risks, rewards, and impacts on market behavior of popular alpha strategies are more dynamic than ever
- In integrated markets with sophisticated risk sharing mechanisms, spillover of de-levering from one strategy to another is likely to be more common
- Sound quant strategies should do very well when they are new, and perhaps even better as they gain popularity, but can become risky and less profitable when they get too popular

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Did we have an adequate margin of safety?

- **In most funds, we did**
- **In the Global Equity Opportunities Fund, we had enough cash to withstand a 30% drawdown (a 10-sigma monthly event)**
  - — Seemed more than adequate, but wasn’t
- **After several days of large losses, we had two options to reduce leverage:**
  1. Unwind in an illiquid market
  2. Raise cash from outside investors
- **We felt the 2nd option was more prudent, and beneficial to all investors.**

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Quant investing

Is it broken?

- No, in fact we believe near-term opportunities are especially attractive
- Academic finance continues to identify and explain market anomalies
- But, as knowledge diffuses, these strategies become more crowded
- In finance, unlike most other fields, what we predict reacts to our predictions, especially when they become widely-held.
- Innovation and adaptation will remain the keys to success

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Implications for the future

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Implications for quantitative equity research

- **Superior research will continue to differentiate the best managers**
- **We have re-prioritized our research agenda in light of recent events**
  - **Risk management:**
    - Can we anticipate, or at least prepare for, sudden changes in risks/correlations?
    - Can we identify and hedge transient risks (e.g., low quality rally)?
  - **Alpha models**:
    - Identify over-used (common) factors
    - Continue to develop more proprietary factors
    - Re-allocate risk between common and proprietary factors
    - Focus more on less-followed or difficult-to-analyze data (barriers to entry)
- **Although we will continue to share the philosophy and intuition behind our process with outside investors, we won't be able to reveal specific calculations or other details. This is solely to protect our clients' interests.**

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Implications for our process

Issues Raised	Action Items
Capacity: There is more money chasing these strategies than we appreciated.	We will be more conservative on capacity estimates going forward, while continuing to search for innovative/proprietary strategies.
“Crowded” factors: Commonly-used factors are riskier and may be less effective in the future.	These events will help us to better identify over-used factors and either avoid them or better hedge their risks.
“Crowded” positions: Stocks that are widely held by hedge funds and other quants can experience severe pricing pressure in times of stress.	Going forward we will need to consider this risk during portfolio construction.
Leverage: Allows us to increase risk without changing the underlying portfolio’s expected IR, but can be hard to reduce in periods of market turmoil.	We will need to keep leverage at levels that can withstand turmoil, and adjust risk as needed using our underlying positions.
Factor timing: Many factor returns are now riskier and can have sudden and severe drawdowns.	We have accelerated our research efforts into factor timing and risk forecasting.
Trading: During liquidity events, anonymous trading and minimizing impact are even more important.	We will make even greater use of algorithmic trading, short-term timing factors, and opportunistic trading in the future.
Risk management: Even the most adaptive risk model cannot predict sudden and dramatic changes in risk.	Can we forecast market disruptions using structural models of contagion?

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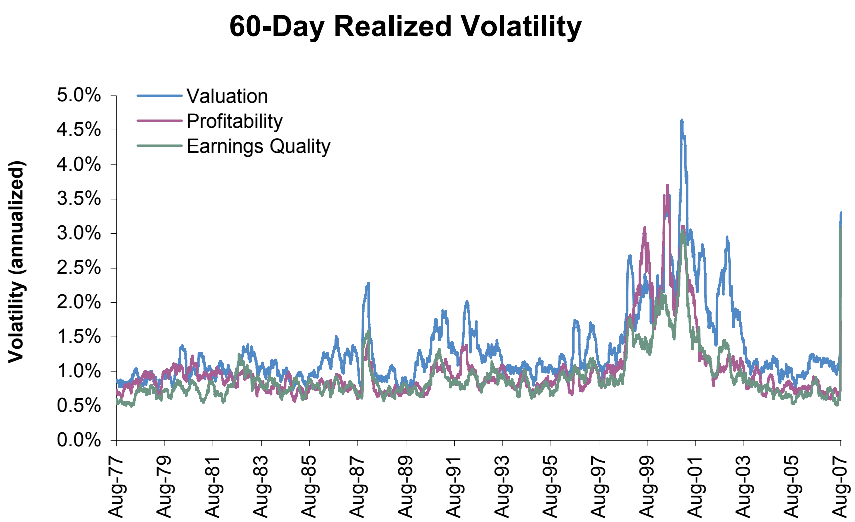
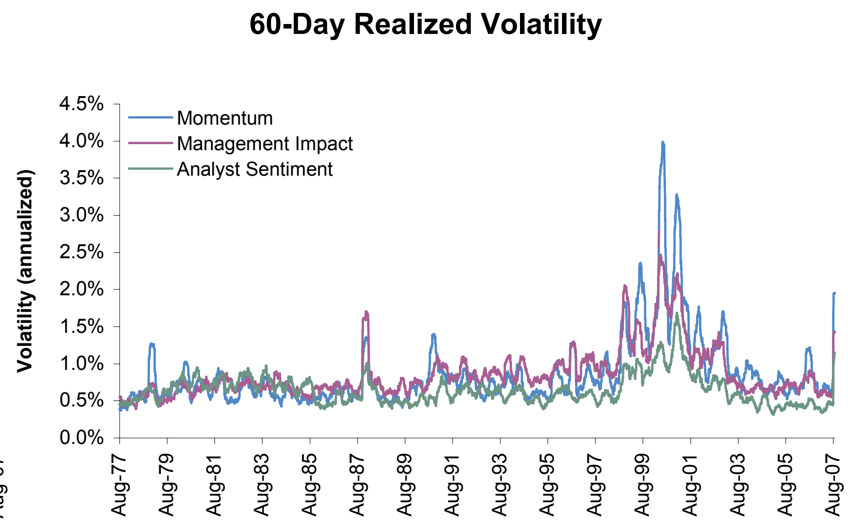
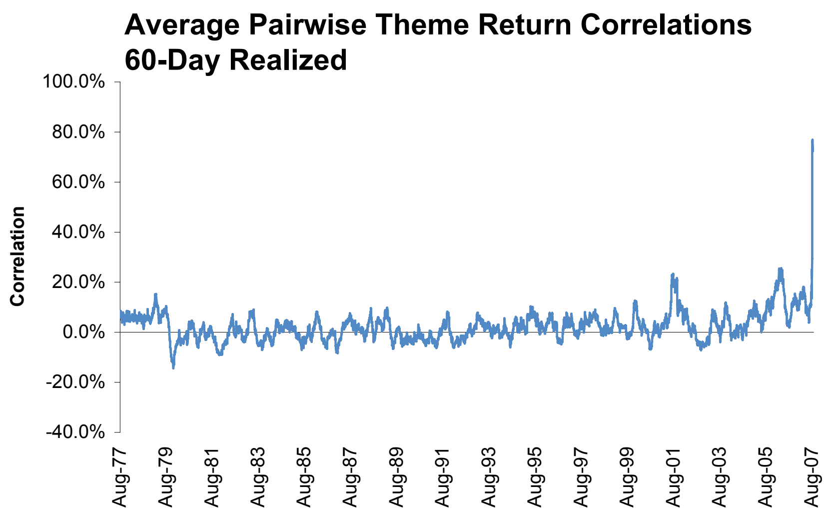
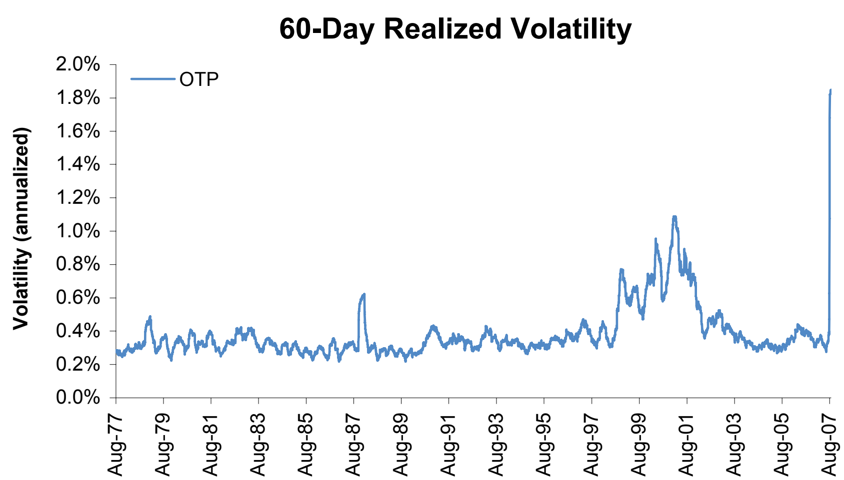
Appendix

Factor risks
US









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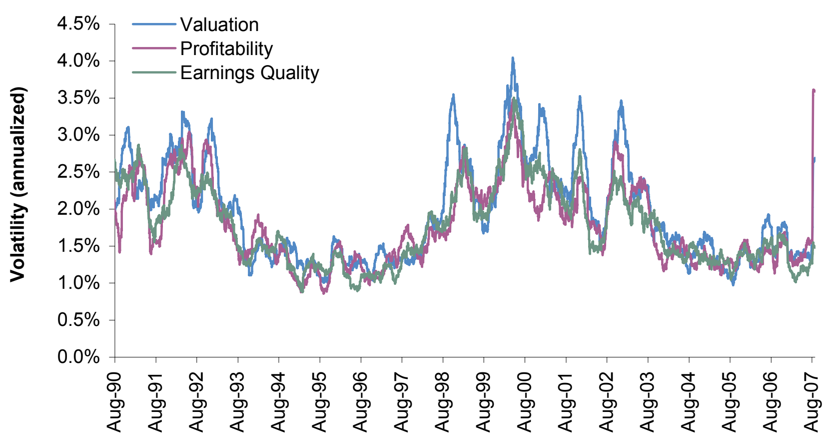
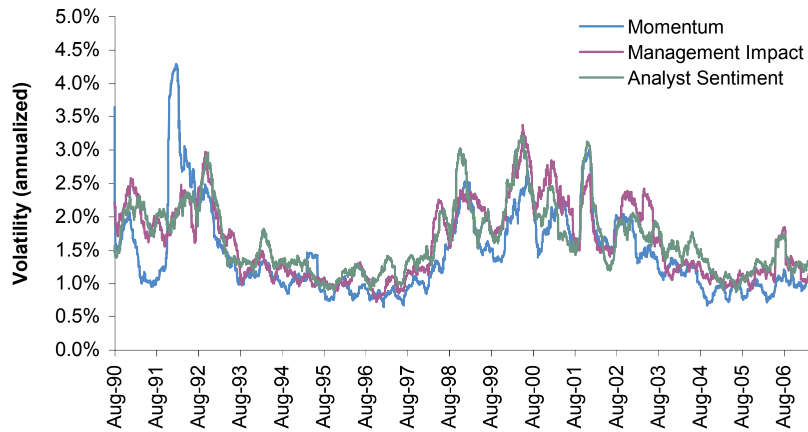
Factor risks
UK

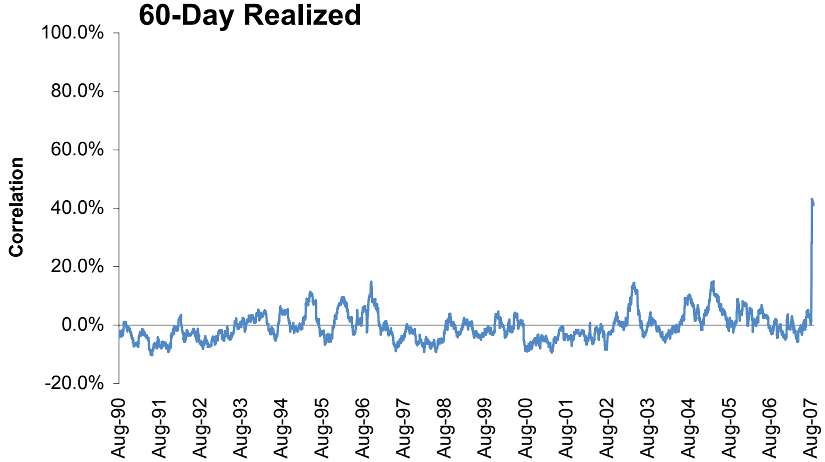
60-Day Realized Volatility



60-Day Realized Volatility



Average Pairwise Theme Return Correlations
60-Day Realized



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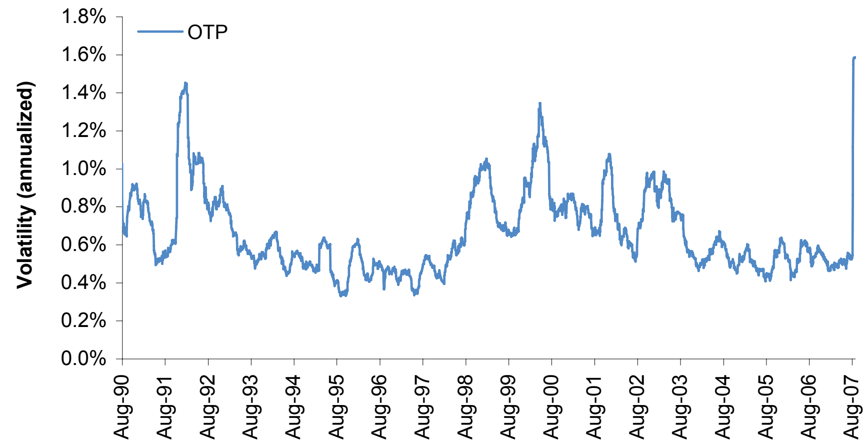

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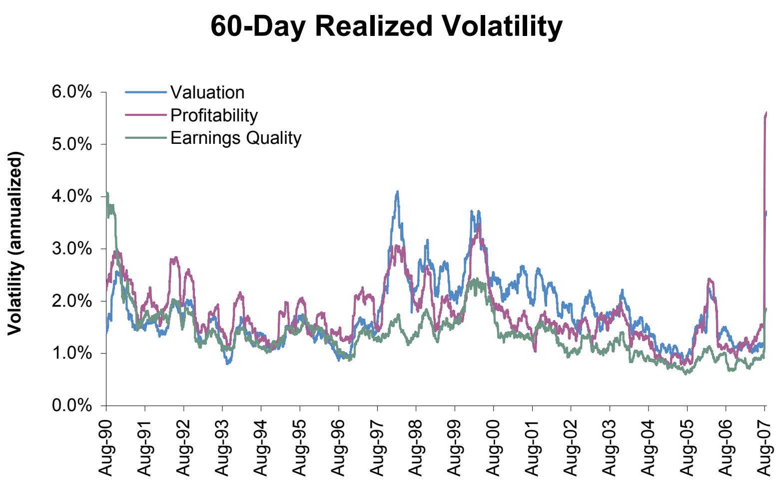
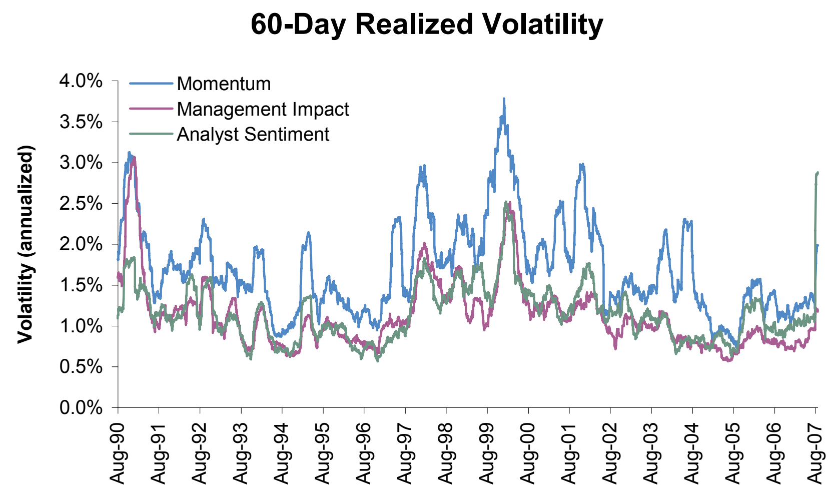
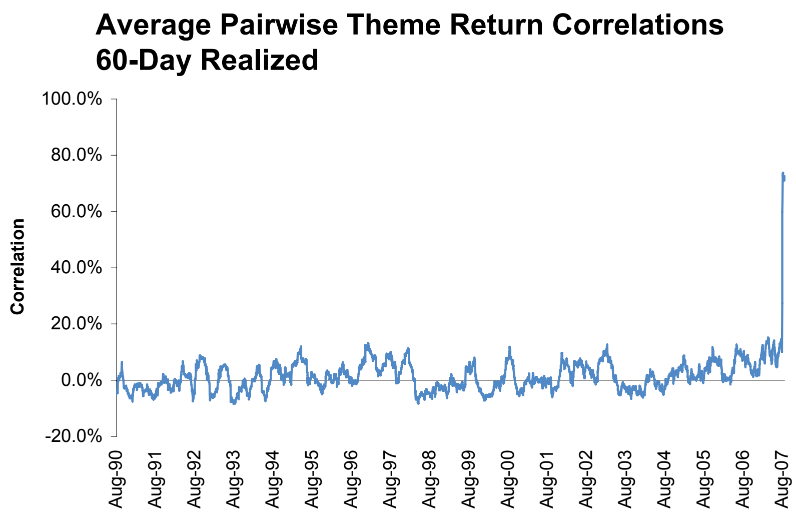
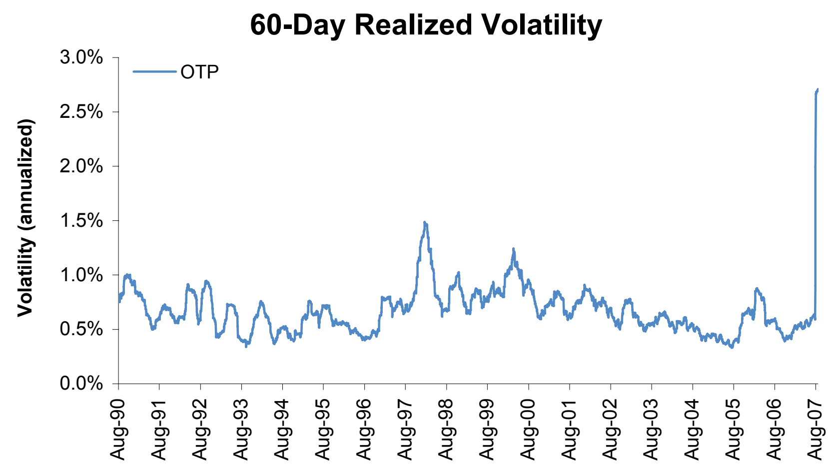
Factor risks
Japan

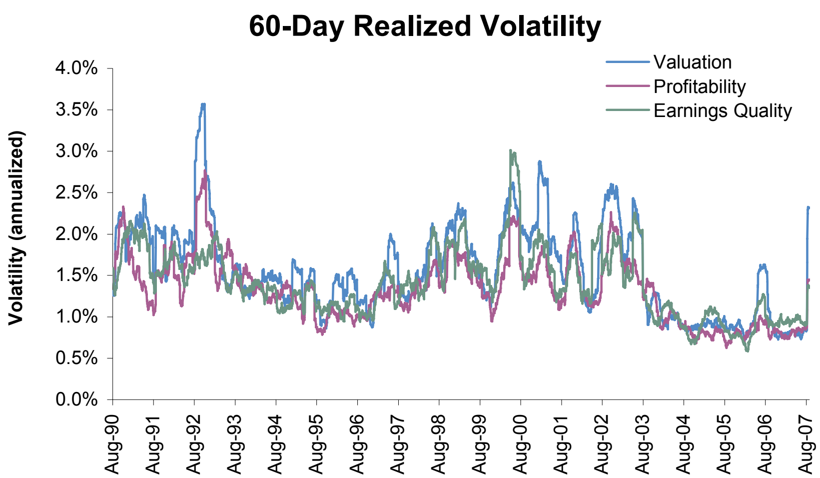


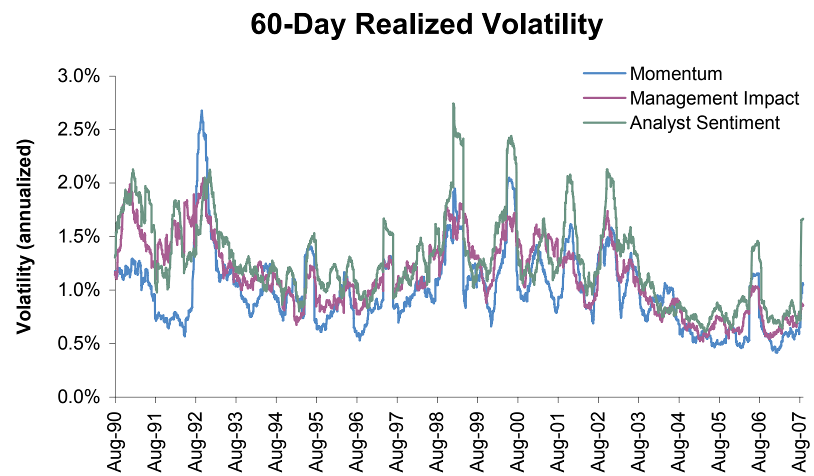


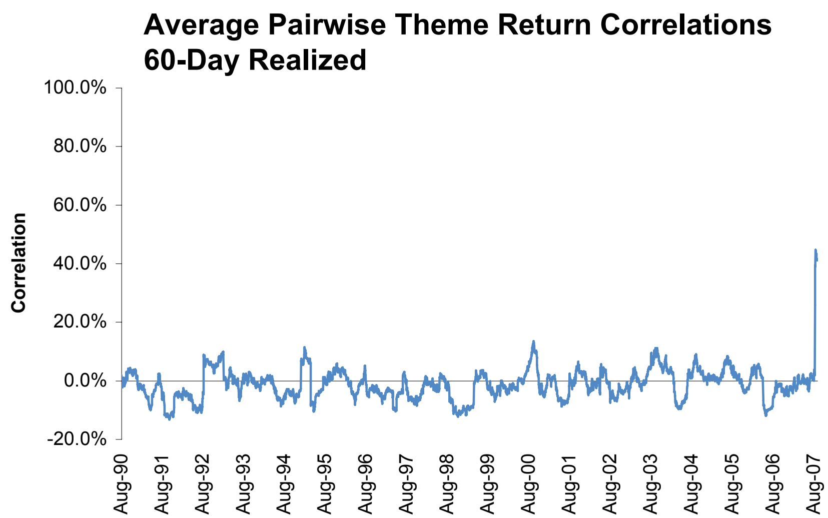


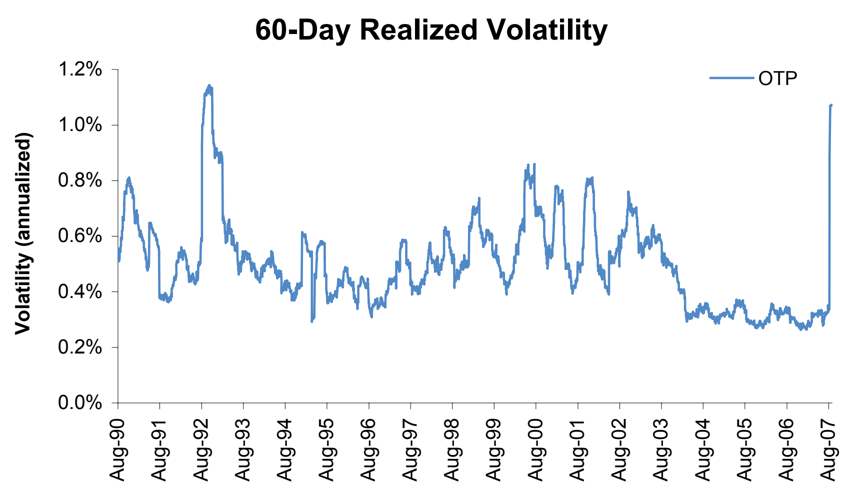


Factor risks
Europe









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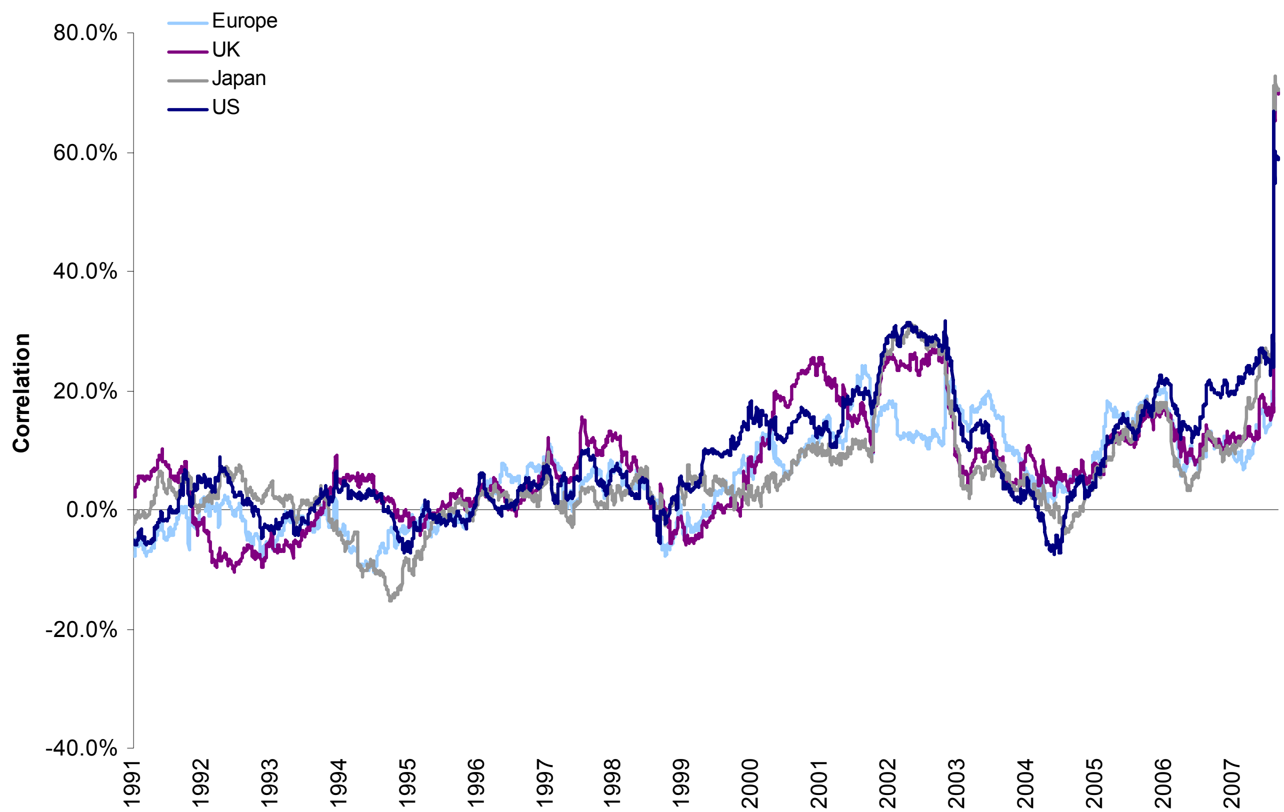
Regional performance correlation



252 day realized OTP average pairwise return correlations using 3-day overlapping daily returns

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