August 2007 Quant Equity Turbulence:
An Unknown Unknown Becomes a Known Unknown

September 15, 2008

LEHMAN BROTHERS
Quant Equity Funds Use Computer Models to Trade Stocks

• Quant equity funds typically hold hundreds of stocks long and short
  • Portfolios generally not concentrated: largest positions only 2-3%

• Usually neutral to equity market moves
  • Some funds allow other systematic exposures
  • Recent growth in long-biased, “130/30” funds

• Leverage of 2-4x per side is typical

• Some funds use price and trading volume only
  • Statistical Arbitrage (Stat Arb) funds use mean reversion over days or weeks
  • Black Box funds use pattern recognition over range of time scales

• Other funds use corporate accounting data
  • Equity Market Neutral (EMN) funds typically hold stocks for several months
Quant Equity Funds Endured a Turbulent August 2007

Differences in discretionary timing of portfolio leverage drove August dispersion

- Monthly cross-sectional returns of EMN funds from Lehman Brothers data base
- Month-end returns *understate* August volatility, as some funds partially recovered
- Similar results for other quant equity strategies

Median and Quartile Returns of Quant Equity Market Neutral Funds, Feb 2003 - Jan 2008

Source: LBAIM Peer Group database, contains data from TASS, Altvest and EurekaHedge
Past performance is not indicative of future results
Quant Equity Holdings Exhibit Large August Drawdowns

- We collected holdings data on 34 quant equity funds from public filings
  - 13-F filings across 4,200 US equities
  - No data on short positions; excludes prop desks and mixed quant/discretionary funds
- Holdings return distributions computed during August sub-periods
- Two proxies used for aggregate short exposure
  - Market weights and aggregate short interest weights used for shorts
- Net holdings returns exhibit drawdowns similar to those seen in quant equity funds

### Performance of Holdings of 34 Quantitative Equity Hedge Funds in August 2007

<table>
<thead>
<tr>
<th>Date Range</th>
<th>Holdings Returns</th>
<th>Market Return</th>
<th>Aggregate Short Interest Portfolio Return</th>
<th>4x Levered (Holdings - Market)</th>
<th>4x Levered (Holdings - Short Interest)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25%-ile</td>
<td>Median</td>
<td>75%-ile</td>
<td>25%-ile</td>
<td>Median</td>
</tr>
<tr>
<td>August 1 - 6</td>
<td>-2.2%</td>
<td>-1.3%</td>
<td>-0.8%</td>
<td>0.2%</td>
<td>-0.8%</td>
</tr>
<tr>
<td>August 7 - 9</td>
<td>-3.2%</td>
<td>-1.8%</td>
<td>-0.8%</td>
<td>-0.5%</td>
<td>1.3%</td>
</tr>
<tr>
<td>August 10 - 13</td>
<td>0.8%</td>
<td>1.9%</td>
<td>3.4%</td>
<td>0.1%</td>
<td>-0.6%</td>
</tr>
<tr>
<td>August 14 - 31</td>
<td>1.3%</td>
<td>1.5%</td>
<td>1.7%</td>
<td>1.5%</td>
<td>1.1%</td>
</tr>
</tbody>
</table>

Source: FactSet and LBAIM Analysis
Past performance is not indicative of future results
Large Losses Not Due to “Standard” Risk Factors

• Risk management at quant equity funds focused on controlling exposures
  • Concentration in individual stocks
  • Sector/industry exposure, market cap bias, value bias (multiple measures)
  • Often weighted toward recent data

• We formed aggregate net holdings portfolio to analyze exposures
  • Equal weight portfolio guards against omission/misclassification of funds

• Aggregate portfolio contains some factor exposures
  • Industry over-/underweights
  • Bias towards small-cap and mid-cap stocks

• Exposures did not contribute meaningfully to overall portfolio volatility
  • Negligible factor contributions to Aug 7-9 losses (Aug 10-13 gains)
  • Small-cap bias exerted indirect effect through reduced liquidity

• Such exposures exacerbated losses at some funds
Daily Equity Returns Indicate August Liquidation Event

- Returns of 4,200 US equities plotted as Aug 10-13 vs Aug 7-9
- Strong diagonal pattern: Stocks down Aug 7-9 recovered Aug 10-13 and vice versa
- Rapid rebound consistent with liquidity-driven trades, not fundamentals
- Stocks retraced 44% of their Aug 7-9 move during Aug 10-13 on average

Source: FactSet and Lehman Brothers Analysis
Past performance is not indicative of future results
Stocks’ Popularity in Quant Equity Holdings Drove August Returns

Despite their low historical correlations, funds had substantial overlap in positions

- Daily cross-sectional model for 4,200 stock returns
- Two factors use number of funds holding stock, market cap and short interest
- Explanatory power (r-squared) peaks at 14% on Aug. 10 - typically below 1%

Daily R-Squared of Two-Factor Model for Cross-Sectional Excess Stock Returns

Source: FactSet and Lehman Brothers Analysis
Past performance is not indicative of future results
Factor Sensitivities of Stocks Consistent with Liquidation

Stock returns consistent with rapid reduction in both long and short exposure
- Popular stocks in quant equity holdings lost then gained during August
- Unpopular stocks with high short interest gained then lost during August
- Trading volume also consistent with liquidation

Source: FactSet and Lehman Brothers Analysis
Past performance is not indicative of future results
What Triggered August De-levering?  I. Value-Biased Quant Equity Funds

- Some EMN funds have value-biased portfolios
- Worked well for several years, but July 2007 was worst month for value in five years
- May have led value-oriented funds to cut exposure
  - Risk models indicating higher value-at-risk post-July
  - Need for cash to meet anticipated investor redemptions
  - Prime broker-mandated leverage reductions

![Monthly Relative Performance of Value Stocks vs Growth Stocks (Fama-French HML Factor)](source)

-4.4% in July 2007, worst in 5 years

Source: Kenneth R. French Data Library
Past performance is not indicative of future results
What Triggered August De-levering?  II. Multi-Strategy Hedge Funds

• Some funds have both credit and quant equity portfolios
• Seizing of credit markets in July caused mark-to-market losses
  • Sowood lost 50% ($1.5bn) in July and sold its portfolio to Citadel
• Multi-strategy funds may have cut equity leverage due to credit losses
  • Either across-the-board cut or cash to meet credit margin calls
• Evidence that multi-strategy funds preceded EMN funds in Aug. 7-9 liquidation
Growth in Strategy Assets Created Potential for Liquidity Event


- At June 2007 peak, these funds had $205 bn in US equity market value
  - 23% of total hedge fund holdings (all styles) and 1% of equity market capitalization
- June 2008 total is $121 bn, due to lower leverage and redemptions (60% of max)
  - Mkt value stabilized in June 2008, but potential end-of-year redemptions loom

Sources: FactSet and LBAIM analysis
EMN Returns More Volatile Post-August 2007

- Median EMN fund volatility returned to levels last seen in internet bubble/collapse
  - August 2007 still worst month, but Jan 2008 perhaps 2nd worst since 2000
- Increased factor volatility and sector dispersion only partially explain increased vol
  - HML (value/growth) factor vol doubled since 2007, but far below 2002 level

Sources: TASS, Altvest and LBAIM analysis
EMN Suffered in Bad Months for Hedge Funds Overall

Strategy has provided little diversification to hedge fund portfolios in down months

• In four worst months for HFR composite, median EMN fund lost an average of 1%

• Somewhat surprising, given the lack of equity or credit market exposure in EMN

Performance of Equity Market Neutral (EMN) Funds in Difficult Months for Hedge Funds, 2007-8

<table>
<thead>
<tr>
<th>Month</th>
<th>HFR Composite Hedge Fund Index</th>
<th>LBAIM EMN Peer Group Median Fund Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug-07</td>
<td>-1.53%</td>
<td>-1.77%</td>
</tr>
<tr>
<td>Nov-07</td>
<td>-2.20%</td>
<td>-0.55%</td>
</tr>
<tr>
<td>Jan-08</td>
<td>-2.69%</td>
<td>-1.26%</td>
</tr>
<tr>
<td>Mar-08</td>
<td>-2.24%</td>
<td>-0.46%</td>
</tr>
</tbody>
</table>

1Data for HFR Composite hedge fund index available from www.hedgefundresearch.com
2Monthly median return among a set of 25-40 equity market neutral (EMN) hedge funds, as collected by LBAIM

Sources: HFR, TASS, Altvest and LBAIM analysis
Headline Events Mark Sharp Declines in Large-Cap Correlations

Sharp drops in correlations of long and short portfolios signal higher EMN volatility

- Bear Stearns collapse and Fannie/Freddie concerns dominate recent landscape
  - Aug 2007 quant equity turbulence a “non-event” for large cap portfolios
  - Also observe a drop on January 22, 2008, date of emergency Fed rate cut

![Graph showing correlation of market portfolio and aggregate short interest portfolio (Rolling 60 Day)](image)

Sources: FactSet and LBAIM analysis

LEHMAN BROTHERS
August 2007 and January 2008 Dominate Mid-Cap Correlation Plot

Quant equity turbulence had dramatic effect on $2-10 bn stocks

- Sharp declines in long/short portfolio correlations indicate higher EMN fund vol
  - 60-day correlation measurement interval creates “ghost” increases in correlations
- Nonlinear relation between change in correlation and change in volatility
  - Aug 2007 volatility increased by 130%, while Jan 2008 volatility rose by only 30%

Sources: FactSet and LBAIM analysis

LEHMAN BROTHERS
Holdings Factors Give Mixed Picture on Jan 2008 Quant Deleveraging

- Short-interest factor correlation rises sharply on Jan 22
  - Consistent with short-covering by quant hedge funds driving up prices
- Long holdings factor falls slightly, but remains positive on Jan 22
  - Inconsistent with selling by quant funds driving down prices

Sources: FactSet and LBAIM analysis
Quant Sell-Off Likely Did Not Drive Markets in Jan 2008

- R-squared of two-factor holdings model peaks at 2.5% in Jan 2008
  - Compared with 14% at August 2007 peak
  - R-squared of 2.5% reached at other times in August 2007 and Jan 2008 – not uncommon
- Quant funds suffered in Jan 2008 and may have exacerbated event by deleveraging

Sources: FactSet and LBAIM analysis
Most Quant Fund Portfolios Smaller than Pre-August 2007

• 25 of 31 funds have lower total market value of equity holdings than in June 2007
  • Only 3 funds have substantially higher TMV
  • 8 funds have 0-20% of June 2007 TMV; another 6 funds have 20-40% of June 2007 TMV
• Funds with steepest declines in TMV at risk of liquidation

Sources: FactSet and LBAIM analysis
Conclusions and Open Questions

Conclusions

• Aug 2007 quant equity turbulence due to simultaneous fund de-levering
• Growth of strategy assets created potential for liquidation risk
• Multi-strategy funds likely played role in triggering de-levering event
• Unanticipated “new” risk, rather than previously-known risks led to losses

Open Questions

• What is risk of repeat scenario at current aggregate market value?
• Will investors (and leverage!) return to these strategies?
• Can quant equity funds reduce overlap without sacrificing performance?
• What is proper role of human discretion in a systematic equity fund?
Disclosure

While hedge funds offer you the potential for attractive returns and diversification for your portfolio, they also pose greater risks than more traditional investments. An investment in hedge funds is only intended for sophisticated investors. Investors may lose all or substantial portion of their investment. You should consider the risks inherent with investing in hedge funds:

**Leveraged and Speculative Investments:** An investment in hedge funds is speculative and involves a high degree of risk. Hedge funds commonly engage in swaps, futures, forwards, options and other derivative transactions that can result in volatile fund performance. Leveraging may increase risk.

**Limited Liquidity:** There is no secondary market for investors’ interests in hedge funds (and none is expected to develop), there may be restrictions on transferring interests in hedge funds, and hedge funds may suspend or limit the right of redemption under certain circumstances. Thus, an investment in hedge funds should generally be regarded as illiquid.

**Absence of Regulatory Oversight:** Hedge funds are not required to be registered under the U.S. Investment Company Act of 1940; therefore hedge funds are not subject to the same regulatory requirements as mutual funds.

**Dependence Upon Investment Manager:** The General Partner or manager of a hedge fund normally has total trading authority over its respective fund. The use of a single advisor applying generally similar trading programs could mean the lack of diversification and consequently, higher risk.

**Foreign Exchanges:** Selective hedge funds may execute a portion of their trades on foreign exchanges. Material economic conditions and/or events involving those exchanges may affect future results.

**Fees and Expenses:** Hedge funds often charge high fees; such fees and expenses may offset trading profits.

**Complex Tax Structures:** Hedge funds may involve complex tax structures and delays in distributing important tax information.

**Limited Reporting:** While hedge funds generally may provide periodic performance reports and annual audited financial statements, they are not otherwise required to provide periodic pricing or valuation information to investors.

**Business and Regulatory Risks of Hedge Funds:** Legal, tax and regulatory changes could occur during the term of a hedge fund that may adversely affect the fund or its managers.

In addition to these risk considerations, there are specific risks that may apply to a particular hedge fund. Any investment decision with respect to an investment in a hedge fund should be made based upon the information contained in the confidential Offering Memorandum of that fund. The information contained herein is therefore is not intended to be complete or final and is qualified in its entirety by the offering memorandum and governing document for each fund.

THIS DOCUMENT IS FOR INFORMATIONAL PURPOSES ONLY AND IS NOT AN OFFER OR SOLICITATION WITH RESPECT TO THE PURCHASE OR SALE OF ANY SECURITY. THIS SUMMARY IS INTENDED ONLY FOR THE PERSON TO WHOM IT HAS BEEN DISTRIBUTED, IS STRICTLY CONFIDENTIAL AND MAY NOT BE REPRODUCED OR REDISTRIBUTED IN WHOLE OR IN PART NOR MAY ITS CONTENTS BE DISCLOSED TO ANY OTHER PERSON UNDER ANY CIRCUMSTANCES. THIS SUMMARY IS NOT INTENDED TO CONSTITUTE LEGAL, TAX, OR ACCOUNTING ADVICE OR INVESTMENT RECOMMENDATIONS. PROSPECTIVE INVESTORS SHOULD CONSULT THEIR OWN ADVISORS ABOUT SUCH MATTERS.

We do not represent that this information is accurate or complete and it should not be relied upon as such. Opinions expressed herein are subject to change without notice. The products mentioned in this document may not be eligible for sale in some states or countries, nor suitable for all types of investors.

Lehman Brothers Inc. and/or its affiliated companies may make a market or deal as principal in the securities purchased through a program or product recommended herein or in options or other derivatives based thereon. In addition, Lehman Brothers Inc., its affiliated companies, shareholders, directors, officers and/or employees, may from time to time have long or short positions in such securities or in options, futures or other derivative instruments based thereon. One or more directors, officers, and/or employees of Lehman Brothers Inc. or its affiliated companies may be a director of an issuer of securities purchased through the programs or products mentioned herein. Lehman Brothers Inc. or its affiliated companies may have managed or co-managed a public offering of securities for any issuer of securities purchased through the programs or products mentioned herein within the last three years. Securities transactions for certain products or programs mentioned herein may be executed through Lehman Brothers Inc., which receives compensation for such transactions.

©2008 Lehman Brothers Inc. All rights reserved. Member SIPC