Revolution Capital Management

Understanding Risk

This page is intentionally left blank.

Version 11.1/1.6

Important Notices

By accessing this presentation herein, the reader hereby agrees to the following conditions:

- The reader will not disclose the information or data herein in any fashion (including but not limited to verbal, written or electronic means) to any outside party for any purpose whatsoever.
- The reader intends to use the data for internal research purposes only.
- The reader qualifies as a "Qualified Eligible Person" (QEP) as defined in CFTC Regulation 4.7.
- The reader acknowledges that the information contained herein abides by NFA Compliance Rule 2-29 regarding the use of hypothetical performance results.

This document is not a solicitation for investment. Such an investment is offered only on the basis of information and representations that are made in the appropriate offering documents. No representation is made that an investor will achieve similar results. Futures trading is speculative and involves substantial risk.

Notice Regarding Hypothetical Results

PERFORMANCE RESULTS HAVE MANY INHERENT LIMITATIONS, SOME OF WHICH ARE DESCRIBED BELOW. NO REPRESENTATION IS BEING MADE THAT ANY ACCOUNT WILL OR IS LIKELY TO ACHIEVE PROFITS OR LOSSES SIMILAR TO THOSE SHOWN. IN FACT, THERE ARE FREQUENTLY SHARP DIFFERENCES BETWEEN HYPOTHETICAL PERFORMANCE RESULTS AND THE ACTUAL RESULTS SUBSEQUENTLY ACHIEVED BY ANY PARTICULAR TRADING PROGRAM.

ONE OF THE LIMITATIONS OF HYPOTHETICAL PERFORMANCE RESULTS IS THAT THEY ARE GENERALLY PREPARED WITH THE BENEFIT OF HINDSIGHT. IN ADDITION, HYPOTHETICAL TRADING DOES NOT INVOLVE FINANCIAL RISK, AND NO HYPOTHETICAL TRADING RECORD CAN COMPLETELY ACCOUNT FOR THE IMPACT OF FINANCIAL RISK IN ACTUAL TRADING. FOR EXAMPLE, THE ABILITY TO WITHSTAND LOSSES OR ADHERE TO A PARTICULAR TRADING PROGRAM IN SPITE OF TRADING LOSSES ARE MATERIAL POINTS WHICH CAN ADVERSELY AFFECT ACTUAL TRADING RESULTS. THERE ARE NUMEROUS OTHER FACTORS RELATED TO THE MARKETS IN GENERAL OR TO THE IMPLEMENTATION OF ANY SPECIFIC TRADING PROGRAM WHICH CANNOT BE FULLY ACCOUNTED FOR IN THE PREPARATION OF HYPOTHETICAL PERFORMANCE RESULTS AND ALL OF WHICH CAN ADVERSELY AFFECT ACTUAL TRADING RESULTS.

PAST PERFORMANCE IS NOT NECESSARILY INDICATIVE OF FUTURE RESULTS.

Defining risk

Risk

-noun

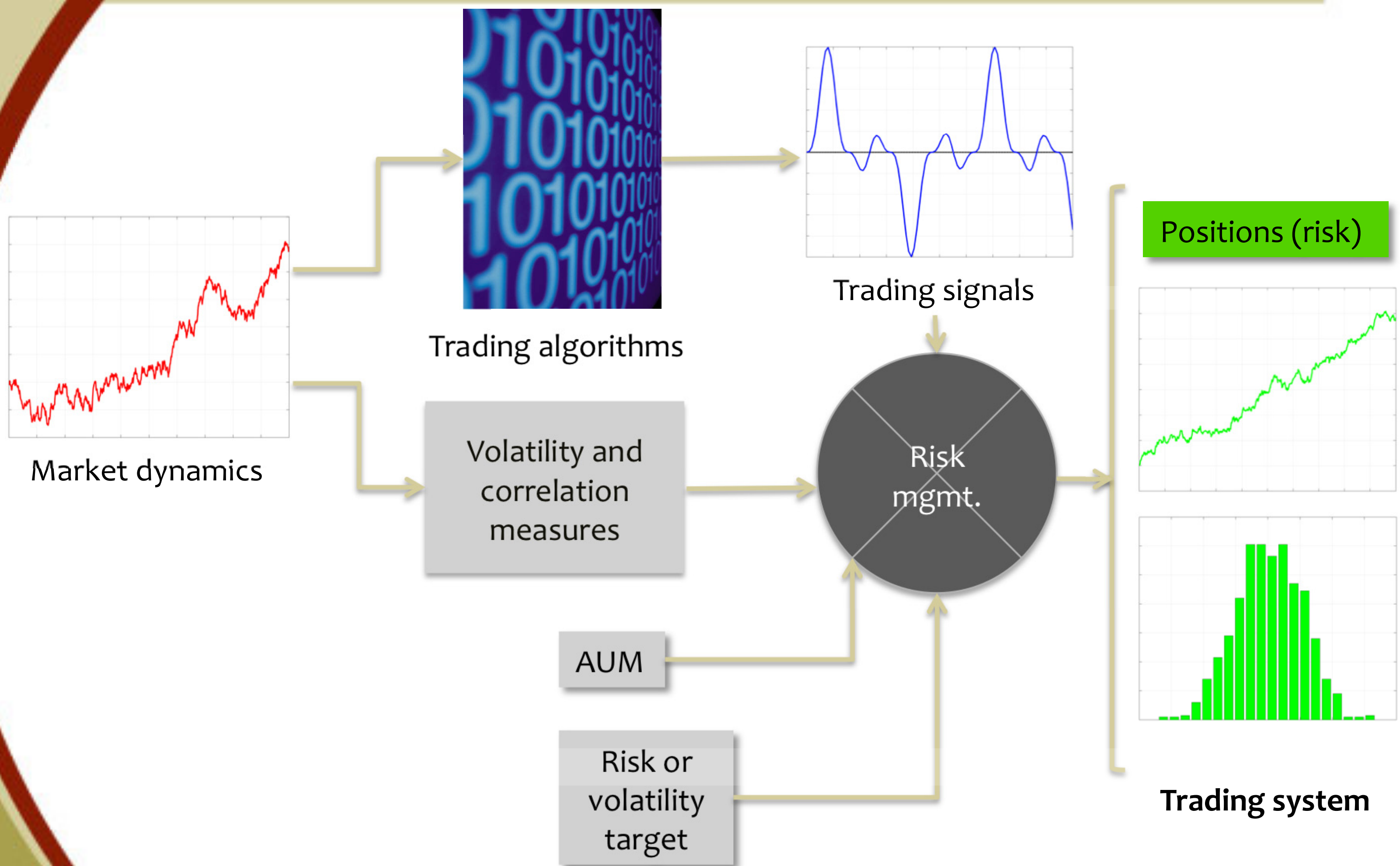
exposure to the chance of injury or loss.

We more specifically define it as the probability of a loss of a chosen magnitude, or more comprehensively as the probability distribution for all loss magnitudes.

Goals

- Identify and understand all of the inputs to our risk.
- Characterize the extent to which risk is embedded in the trading system itself, and why.
- Understand ways to mitigate and/or control risk, if possible.

The flow of risk



Price dynamics

- We have characterized the fat-tailed distributions of prices.
- We have measured the "trendiness" of price movements over different time scales and across all markets/sectors.

Volatility and correlation

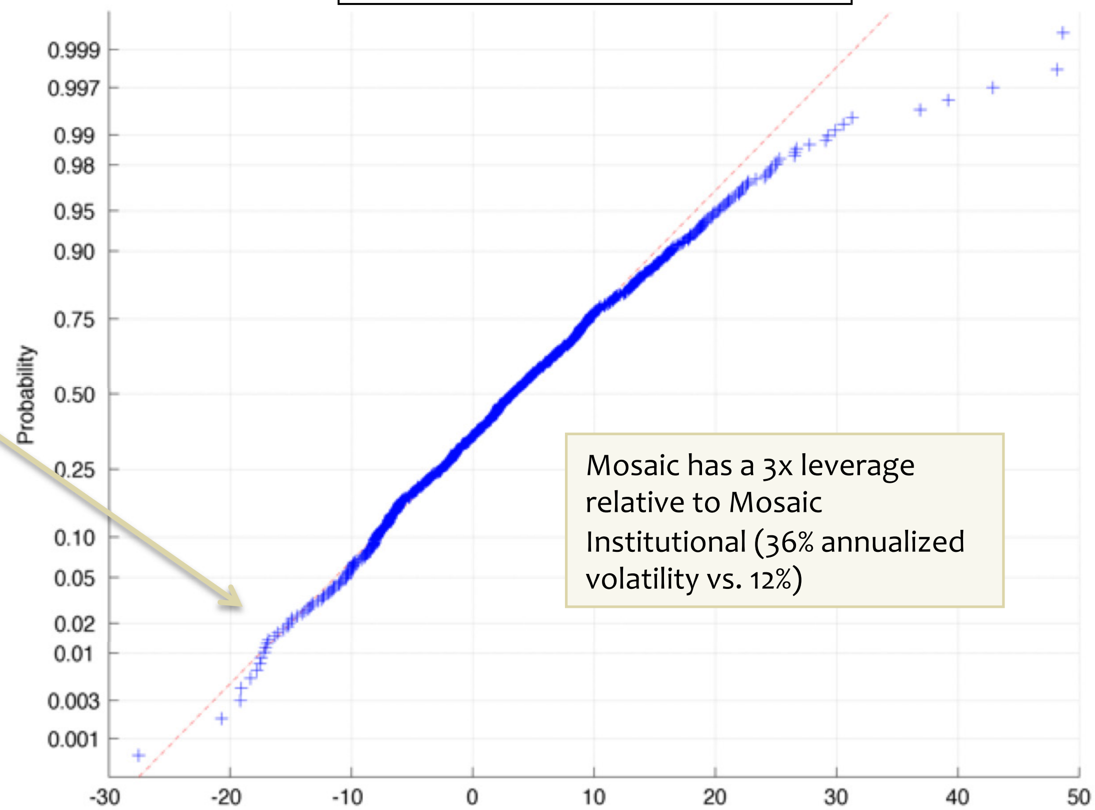
- We can separate volatility into two components: “predictable” and “unpredictable”.
- Using particular time scales for measuring volatility maximizes the predictable component and minimizes the unpredictable component.
- We have measured the impact of the clustered volatility/correlation spikes that periodically course through the markets as a whole; these limit one’s ability to diversify risk away via additional markets.

Risk and volatility targeting

- Volatility targeting and risk targeting have a one-to-one relationship, i.e. a given volatility of returns necessarily implies a particular risk (specific probability of a chosen drawdown).
- However, while it is relatively easy to accurately target a particular volatility (e.g. 1% daily RMS deviation of returns), it is more difficult to accurately estimate the equivalent risk being assumed.
- We examine tail statistics in detail in order to accurately understand the risk of a particular volatility target (and for Mosaic, we directly target the risk, which is a 1% probability of a -20% return or worse in any rolling one-month period).

Risk and volatility targeting

21-day rolling returns



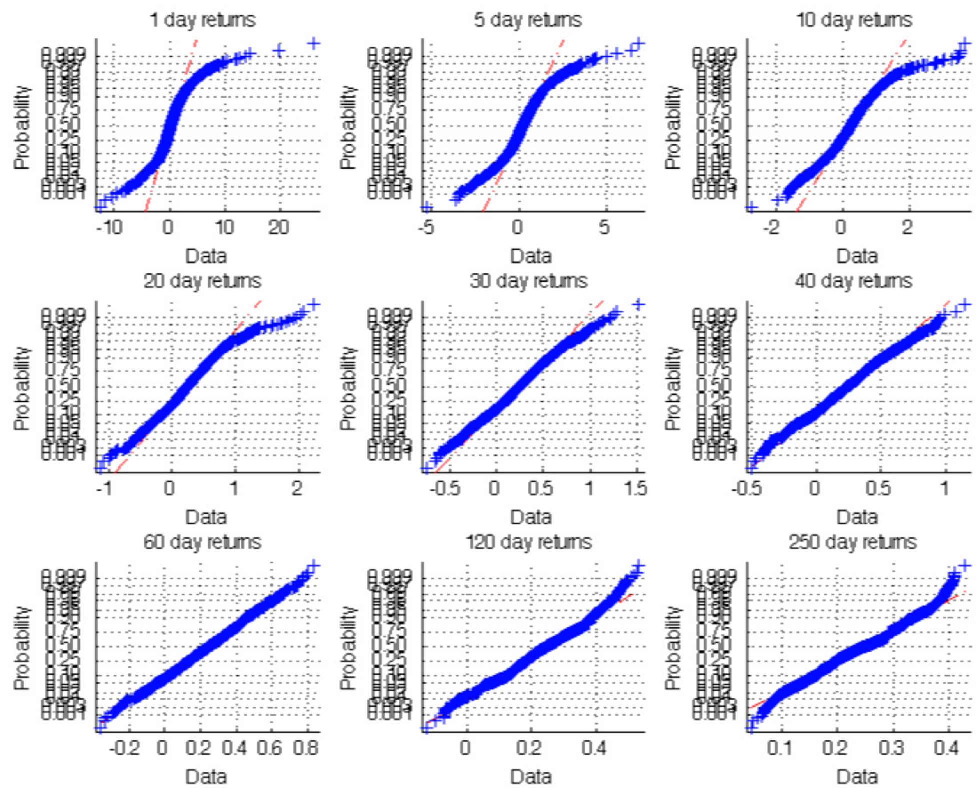
21-day return (%)

Tail of distribution is very close to target of 1% probability of 20%+ drawdown in rolling one-month period

Mosaic has a 3x leverage relative to Mosaic Institutional (36% annualized volatility vs. 12%)

Risk and volatility targeting

Considerable effort is expended understanding how quickly (if at all) return statistics approach Gaussian behavior [red dashed lines show Gaussian fit, blue symbols are from Mosaic model]



Goals

- Identify and understand all of the inputs to our risk.
- Characterize the extent to which risk is embedded in the trading system itself, and why.
- Understand ways to mitigate and/or control risk, if possible.

REVOLUTION Capital Management

The trading system

- Two simple examples explain all possible systems:
  1. Initially, risk $1. Add profits, if any, to risk at each iteration. Randomly stop if winning to preserve gain for that trade. Trade is always exited when net profit is -$1.

Iteration	1	2	3	4	5	6	7	8
Risk	1	2	4	8	16	32	64	128
Net profit if iteration is a success	1	3	7	15	31	63	127	255
Net profit if iteration is not a success	-1	-1	-1	-1	-1	-1	-1	-1

The trading system

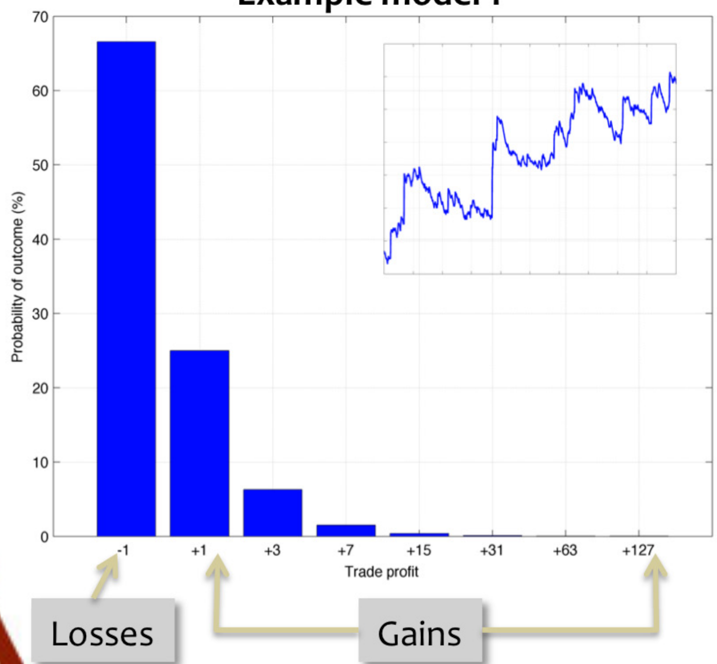
2. Initially, risk $1. Double risk at each losing iteration. Randomly stop if losing to avoid further loss for that trade. If iteration is a success, keep $1 net profit and exit trade.

Iteration	1	2	3	4	5	6	7	8
Risk	1	2	4	8	16	32	64	128
Net profit if iteration is a success	1	1	1	1	1	1	1	1
Net profit if iteration is not a success	-1	-3	-7	-15	-31	-63	-127	-255

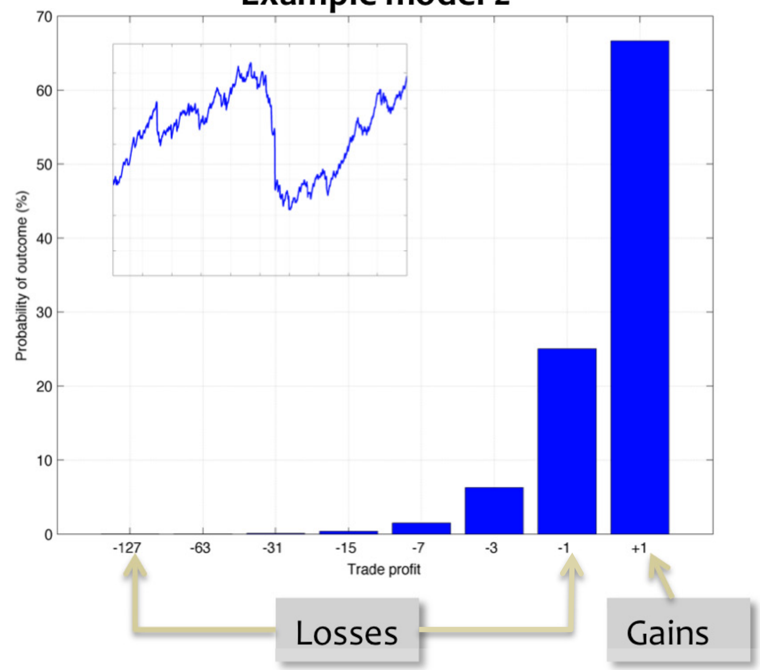
THE TRADING SYSTEM

- The two examples are symmetric. The first has a positive skew of trade profits while the second has a negative skew.

Example model 1



Example model 2



The trading system

- What is the relevance of the example models to systematic trading strategies?
  - Example 1 represents trend following: lots of small losses, occasional large gains, the ability to add to exposure without adding net risk.
  - Example 2 represents mean reversion: lots of small gains, occasional large losses, the necessity to add to net risk before accruing profits.
  - In the limiting case, these examples represent option buying and selling, respectively (zero risk vs. infinite risk).

The trading system

- The trading system itself determines many of the risk characteristics of the final program. ***Opportunity and risk are necessarily coupled***.
  - Even for a given trading paradigm, ***details matter***. For instance, we have characterized how the distribution of trading signals affects the final distribution of profits (one representative study involves "what-if" scenarios to look at effects of different signal discretizations).

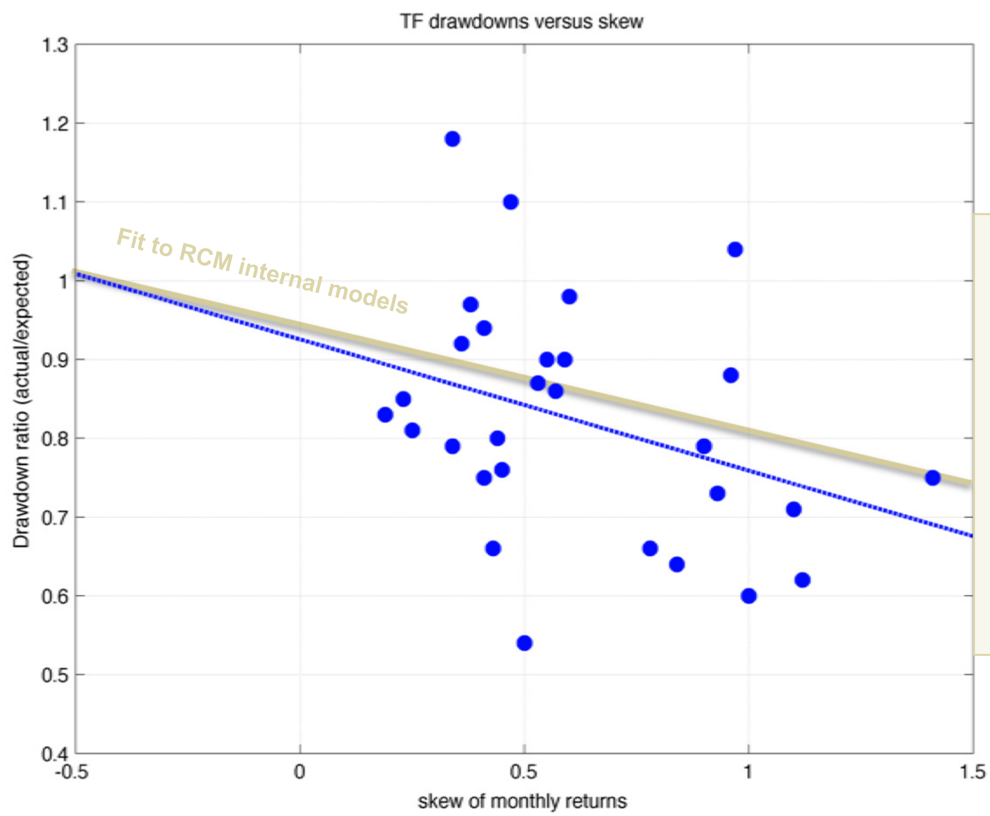
- From competitive analysis, we can determine that trend-following systems indeed fit the profile of returns exhibited by example model 1.

Trend-following competitive analysis

•30+ CTAs examined

• Each program's expected drawdown is computed based on monthly results, Sharpe ratio, length of track record, and volatility.

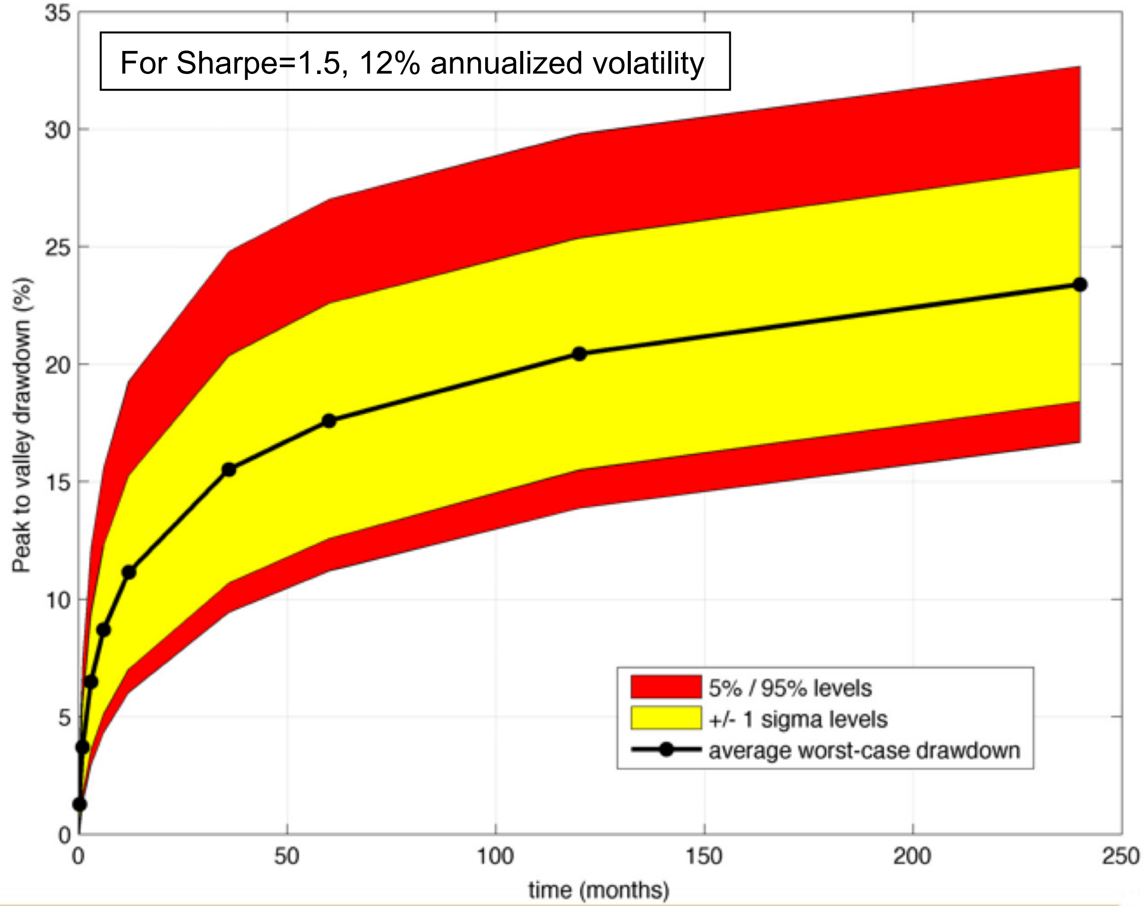
•Results were further validated with internal TF models



Trend followers tend to have smaller than expected drawdowns, and the drawdown is negatively correlated to their return skew.

Drawdown expectations

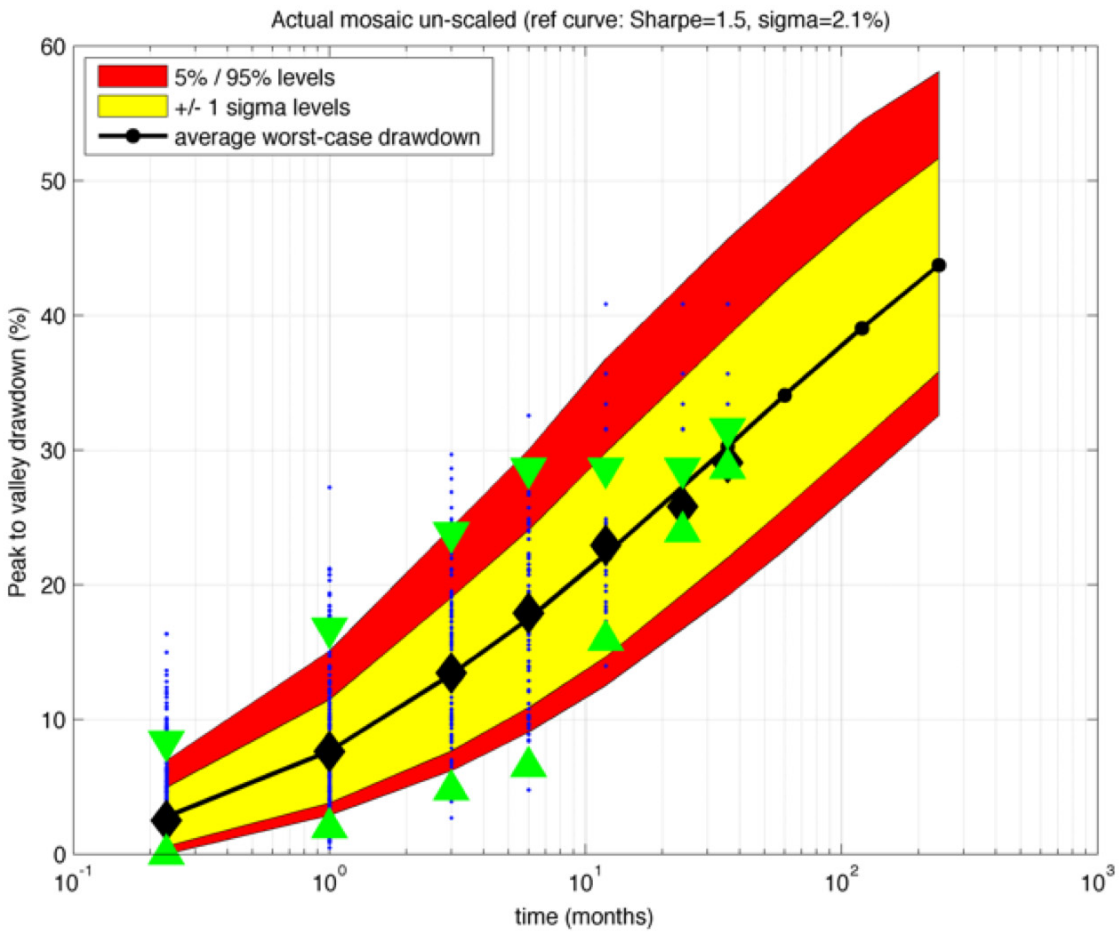
This shows distributions of worst observed peak-to-valley drawdown in any N-month period.



- RCM uses Gaussian-based Monte Carlo simulations as the starting point for risk estimation.
- We have no expectation for under-drawing since we don't exploit trend following.
- Gaussian simulations are reasonably accurate for 20+ days.
- **These simulations help tie together volatility and risk.**

Drawdown realizations

3.5 years of empirical data shows excellent agreement with Monte Carlo expectations



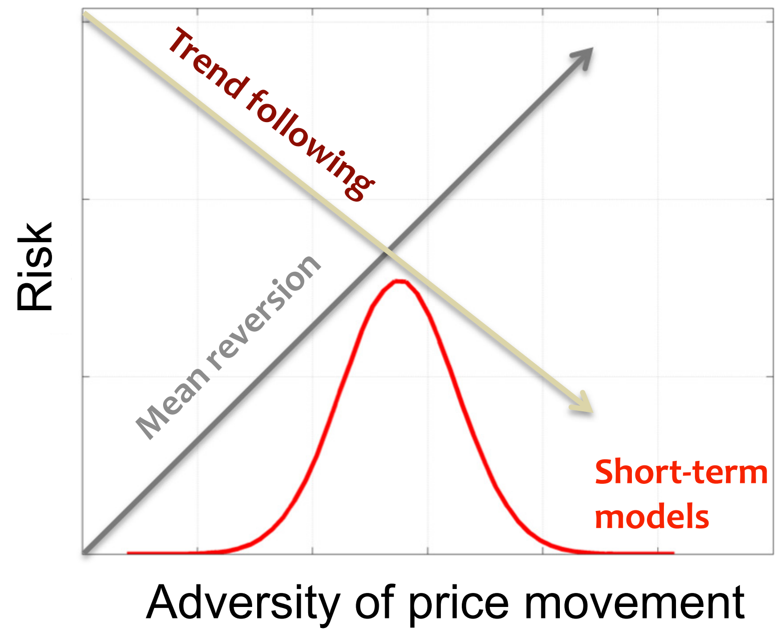
- **Blue** dots: empirical samples
- **Black** diamonds: empirical means
- **Green** triangles: empirical 5% and 95% levels

Trading system summary

- Positive skew of (monthly) returns is an inherent property of multi-strength, multi-time-scale trend following models.
  - Initial risk is fixed.
  - Additional exposure is taken ***after*** profits accrue, thus avoiding additional risk by using profits rather than initial capital.
  - Exposure generally decreases if adverse price movements occur.
- Competitive analysis of largest CTAs shows a clear inverse relationship between drawdown ratio (actual/expected) and skew of monthly returns.
- Those whose returns are most positively skewed (similar to example model 1) have the smallest relative drawdowns.
  - A corollary to this is that more highly-skewed distributions generate higher Sortino ratios (Sortino=mean/downside volatility) for a given Sharpe ratio (Sharpe=mean/volatility). Thus, intermittency of returns is the "cost" of a high Sortino ratio.
- [continued on next page]

Trading system summary (cont'd)

- Short-term models (unless momentum-based) look for price anomalies. Hence, returns have properties of both trend-following and mean-reversion models.
- [continued on next page]



Trading system summary (cont'd)

- RCM's short-term systems tend to follow Gaussian drawdown expectations (daily returns are not Gaussian, but over 20+ days, the fat-tailed effects average out).
- Trend followers generally do better than expected (in the sense their drawdowns are less than theory would suggest).
- However, the price to be paid is consistency of returns. As systems develop a larger return skew, it is a mathematical necessity that the bulk of the returns come in isolated chunks. Thus, intermittency increases for highly-skewed systems (the "no free lunch" principle).

Goals

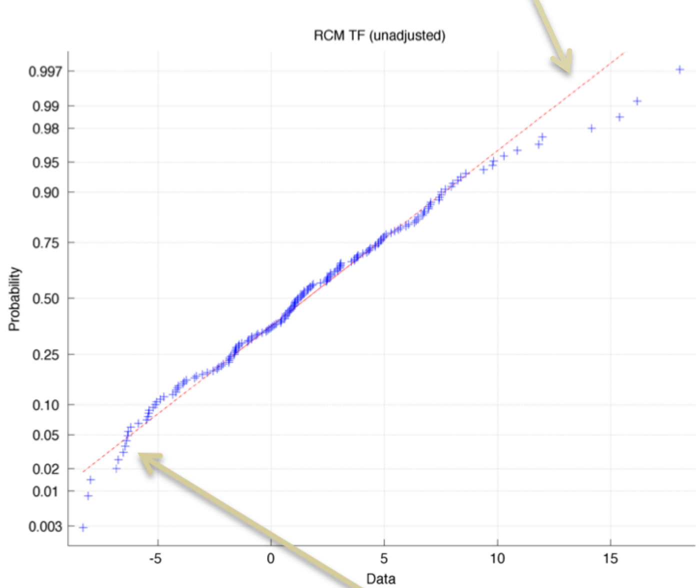
- Identify and understand all of the inputs to our risk.
- Characterize the extent to which risk is embedded in the trading system itself, and why.
- Understand ways to mitigate and/or control risk, if possible.

Risk mitigation

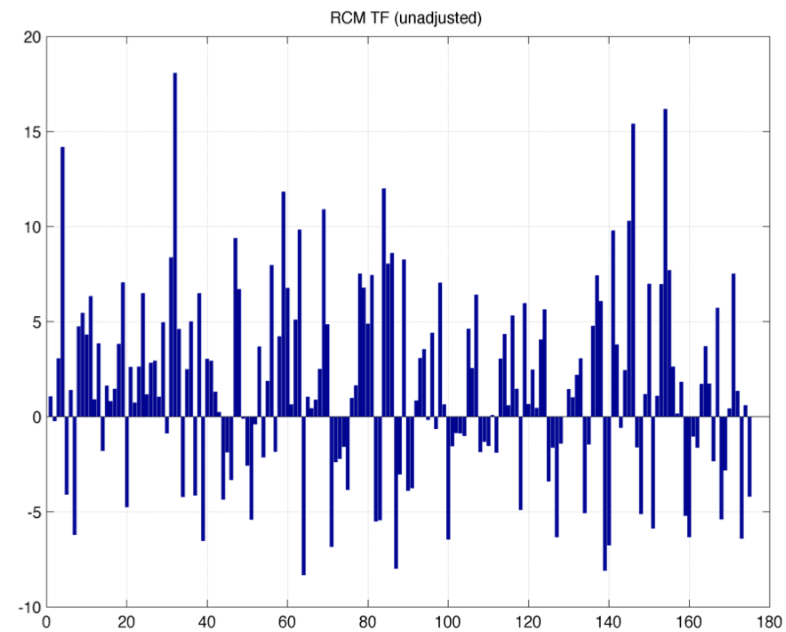
- Multiple studies have been performed to examine the efficacy of metrics based on signal strengths, cross-market correlations, market volatilities, and/or changes in market volatilities for mitigating risk.
- On the following pages, we examine three risk mitigation strategies:
  - Intra-month performance-based de-leveraging
  - Drawdown-based de-leveraging
  - Risk-based de-leveraging

INTRA-MONTH PERFORMANCE-BASED DE-LEVERAGING

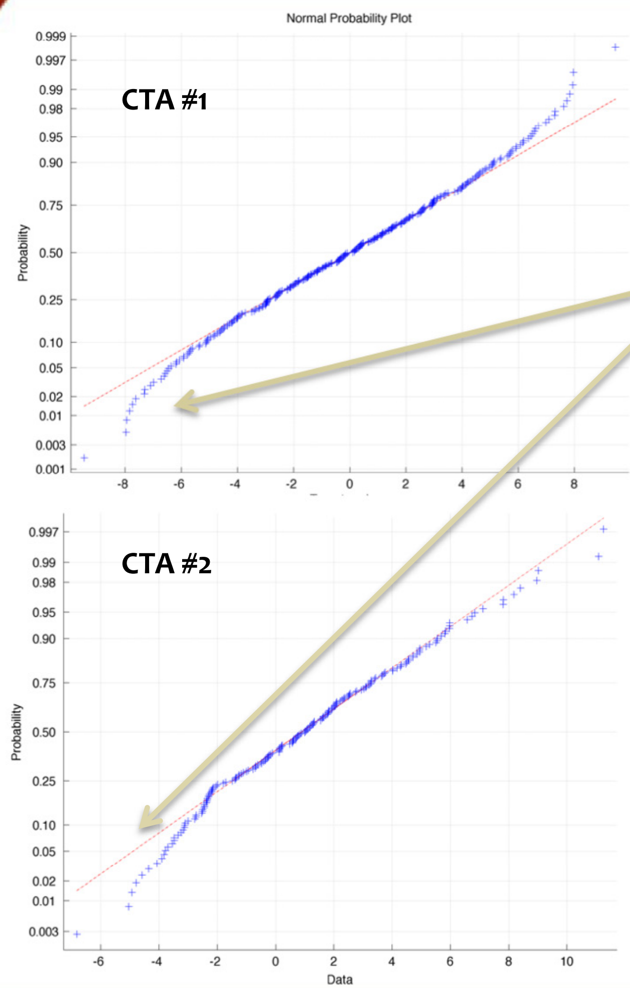
Fat-tailed upside distribution



Gaussian downside distribution

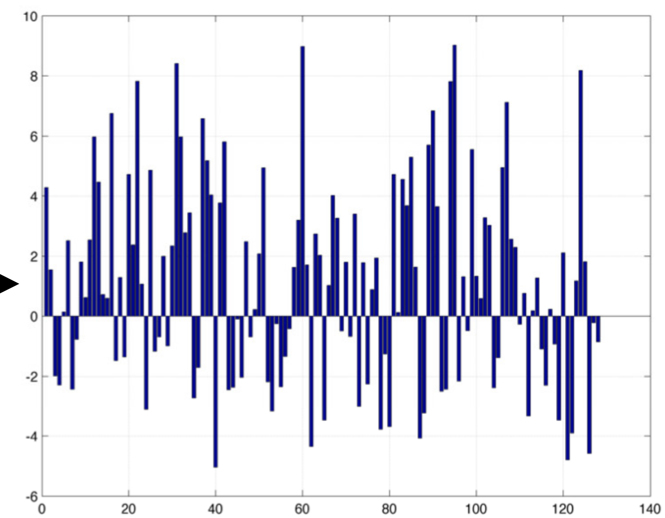


INTRA-MONTH PERFORMANCE-BASED DE-LEVERAGING



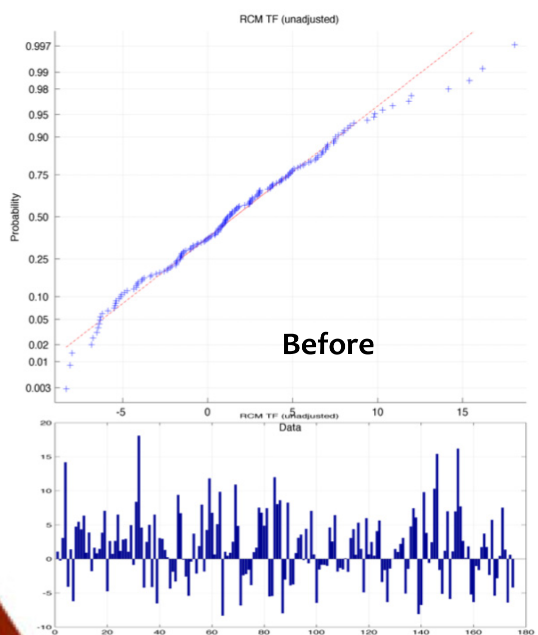
Narrow-tailed upside distribution

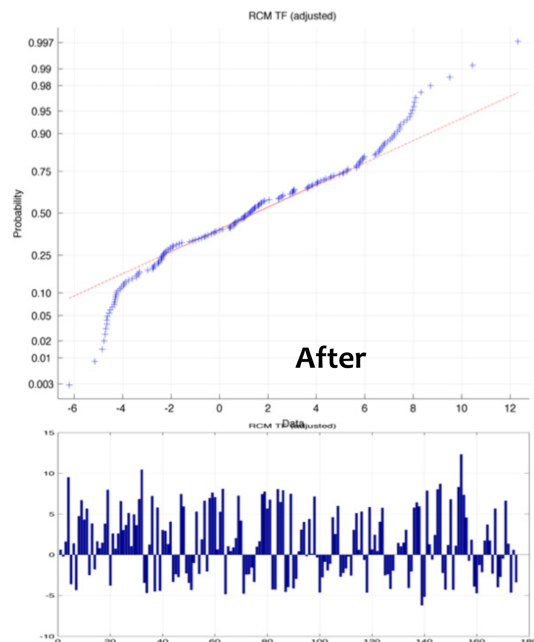
Narrow-tailed downside distribution



Intra-month performance-based de-leveraging

- How can we narrow the tails of a trend-following system?
- Intra-month de-leveraging provides a mechanism:
  - If return is greater than X%, de-lever by half.
  - If return is less than –Y%, de-lever by half.





Intra-month performance-based de-leveraging

- For a trend-following system, the effect of intra-month de-leveraging is to:
  - Narrow the tails of the monthly return distribution.
  - Keep Sharpe ratio unchanged or even slightly improved.
  - Provide better consistency for performance based on month boundaries.
- For short-term systems, risk-adjusted performance is drastically degraded (sometimes up to 25%) because of the tendency of mean reversion in the performance.
- Thus, this isn't an option for RCM's programs.

Drawdown-based de-leveraging

- Some CTAs employ drawdown-based leverage reduction strategies.
- Typically, this consists of some rule set for reducing target volatility during drawdowns, with the intent to bound the magnitude of the drawdown.
- The following slides examine the efficacy of a candidate rule set in more detail.

Sample leverage reduction strategy*

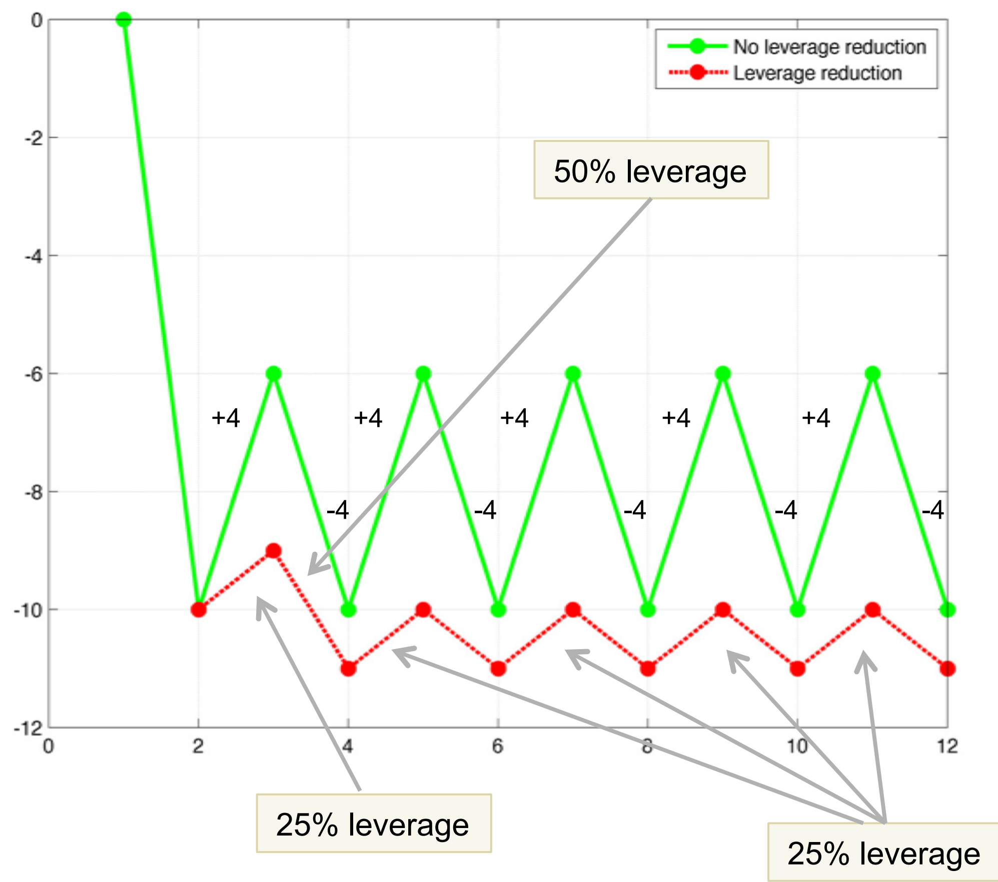
- When the drawdown reaches 6% from the previous peak, reduce leverage by 25% so that the current leverage is now 75% of normal.
- When the drawdown reaches 8% from the previous peak, reduce leverage by an additional 25% so that the current leverage is now 50% of normal.
- When the drawdown reaches 10% from the previous peak, reduce leverage by an additional 25% so that the current leverage is now 25% of normal.
- If at 25% of normal leverage, revert back to 50% of normal leverage when the drawdown becomes less than 9%.
- If at 50% of normal leverage, revert back to 75% of normal leverage when the drawdown becomes less than 7%.
- If at 75% of normal leverage, revert back to 100% of normal leverage when the drawdown becomes less than 5%.

*This follows directly from the currently-utilized strategy of a large CTA; applicable for a 12% annualized volatility.

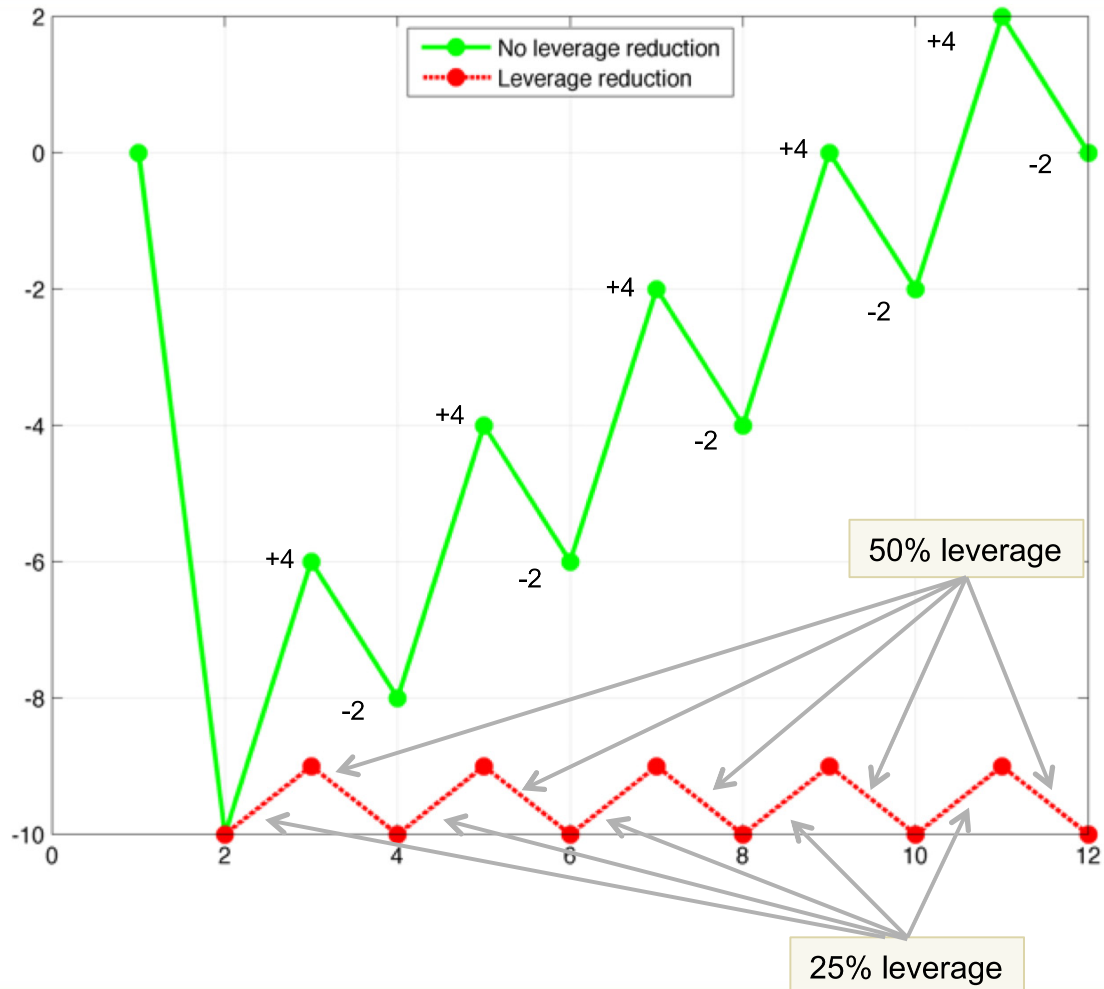
Summary of findings

- Leverage reduction is employed ostensibly to reduce downside volatility (see ***Scenario 1***).
- However, numerical studies show that its benefits may be minimal or non-existent.
- There are 2 primary caveats:
  - Recovery from drawdowns is necessarily slower (see ***Scenario 2***) and may result in a drawdown "trap".
  - Maximum peak to valley drawdown may be reduced, but this is not guaranteed (see ***Scenario 3***). In fact, under certain scenarios, a recovery could turn into a drawdown spiral.

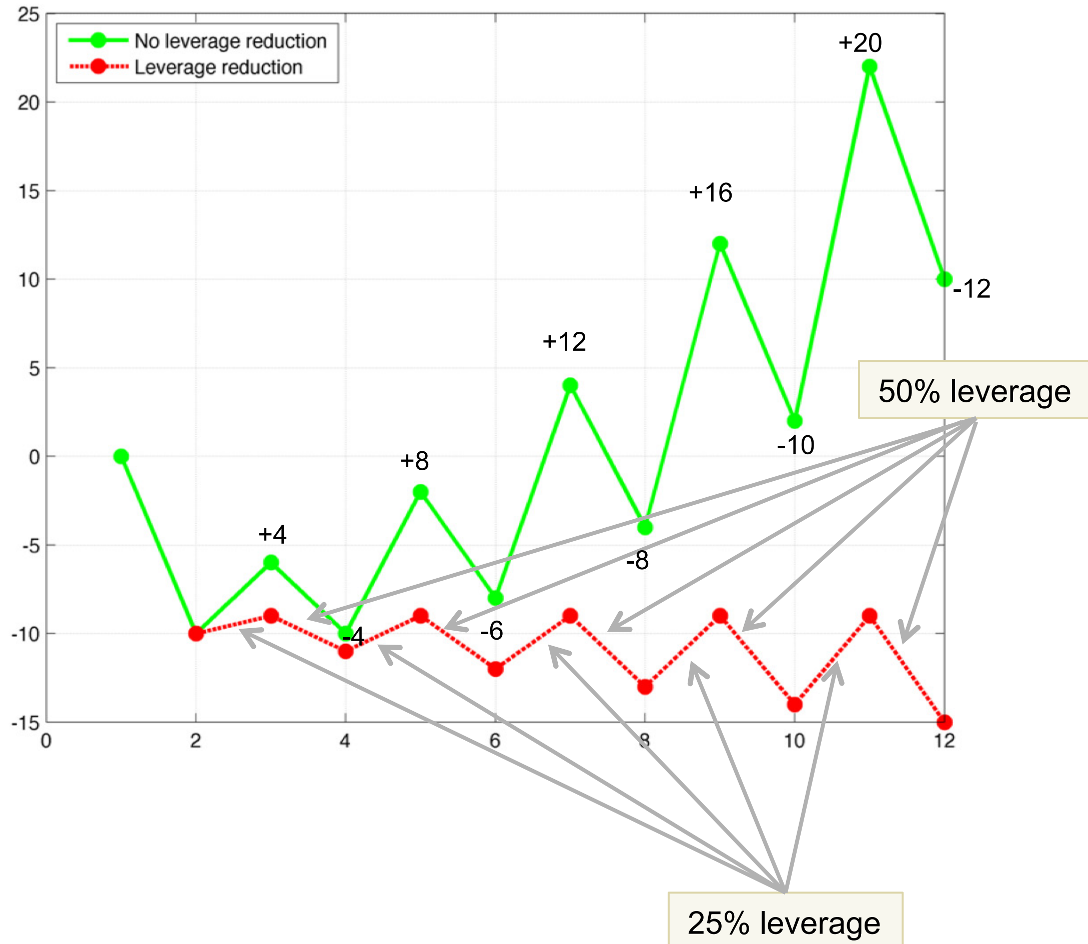
Scenario 1 – Volatility reduced during drawdown



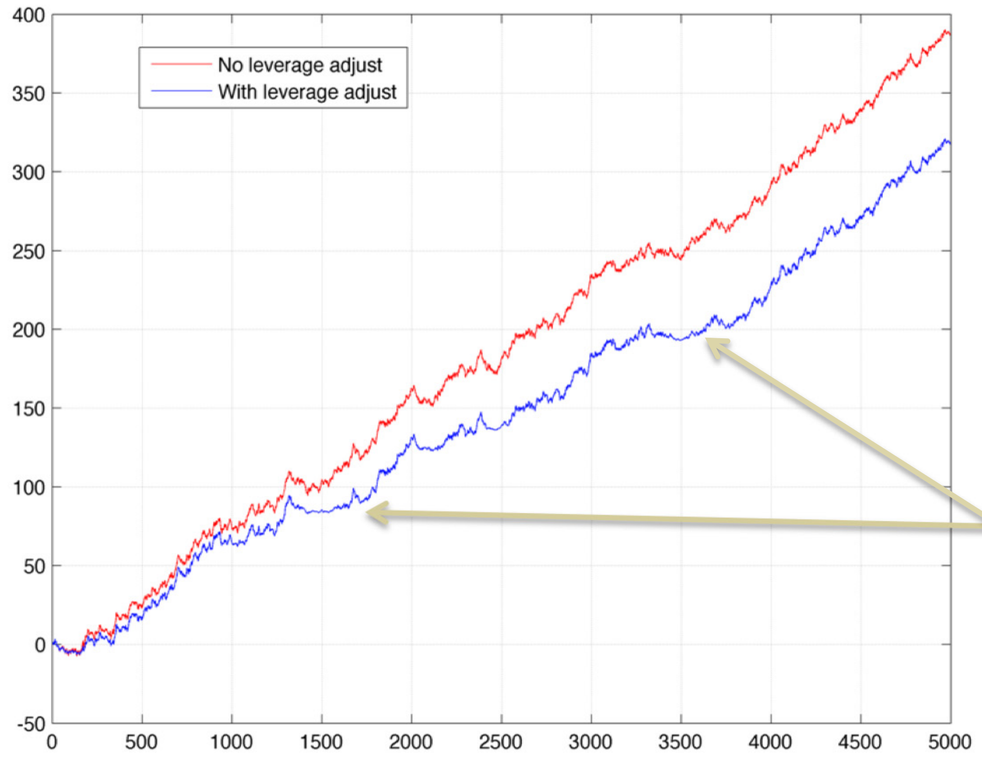
Scenario 2 – Drawdown "trap"



Scenario 3 – Drawdown "spiral"



Monte Carlo Study 1 (Gaussian data)

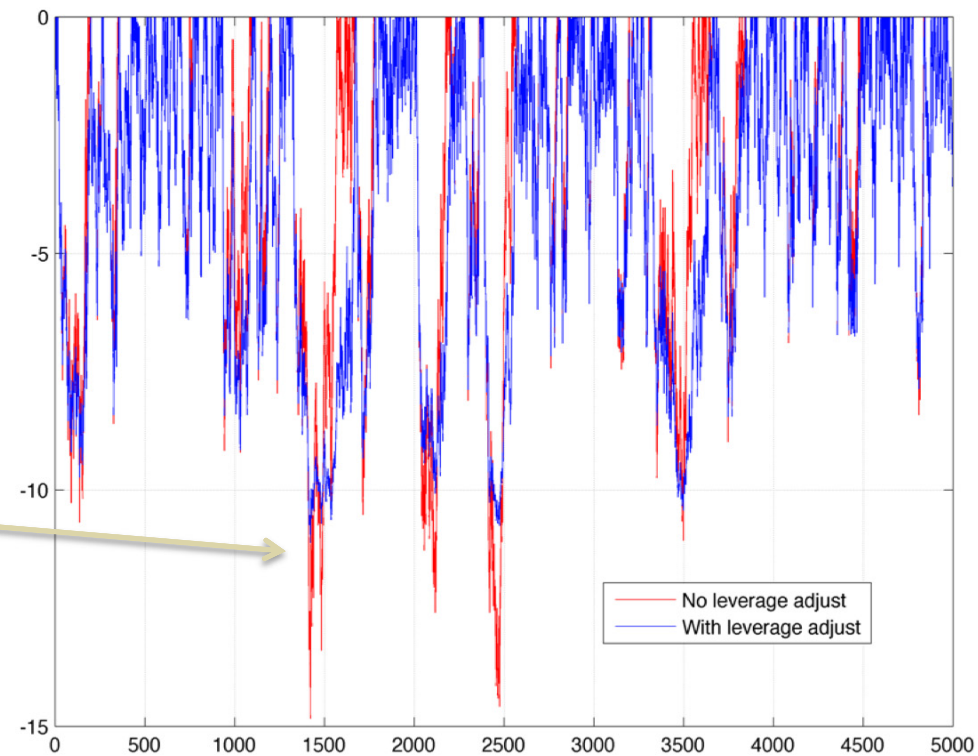


Performance is reduced if leverage adjustments are done…

Examples of a drawdown "trap"

Sharpe w/o adjust: **1.51**
Sharpe with adjust: **1.39**

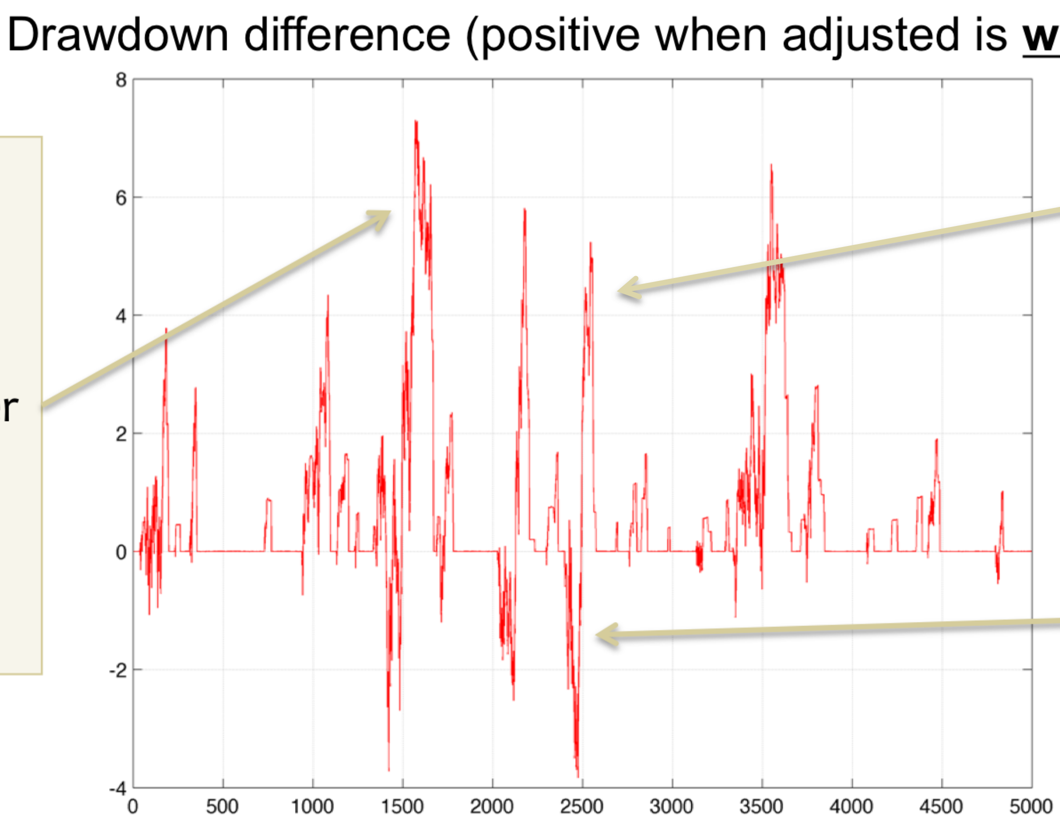
Monte Carlo Study 1 (Gaussian data)



Drawdowns appear more limited, but…

Monte Carlo Study 1 (Gaussian data)

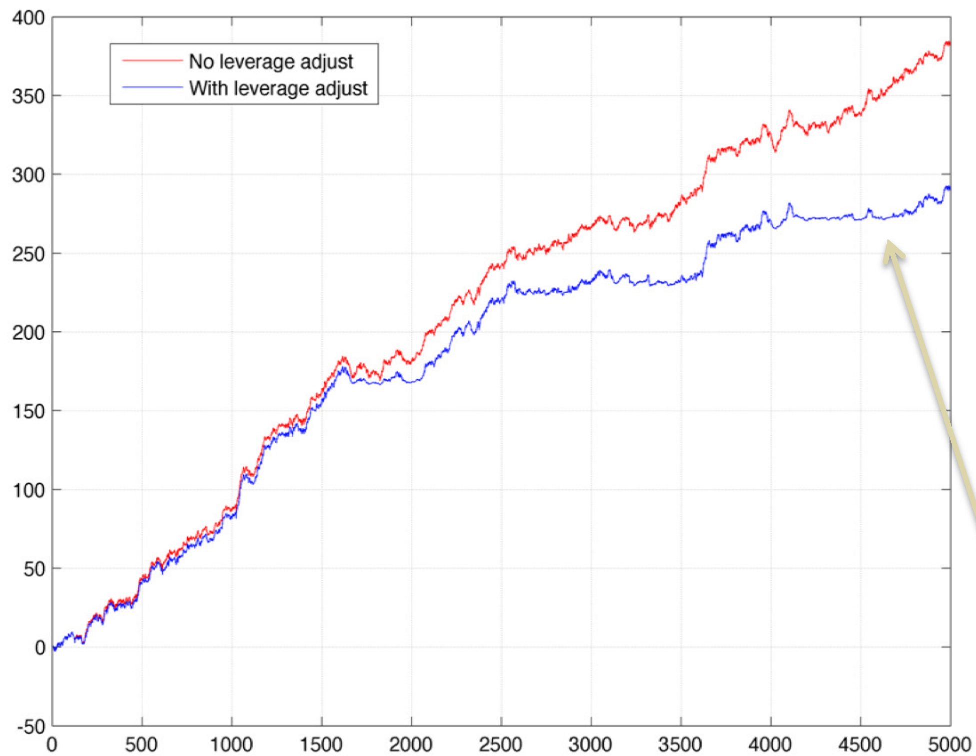
…with leverage adjustments, more time is spent in larger drawdowns than if no adjustments are done.



Subsequent price paid

Initial benefit

Monte Carlo Study 2 (Fat-tailed data)



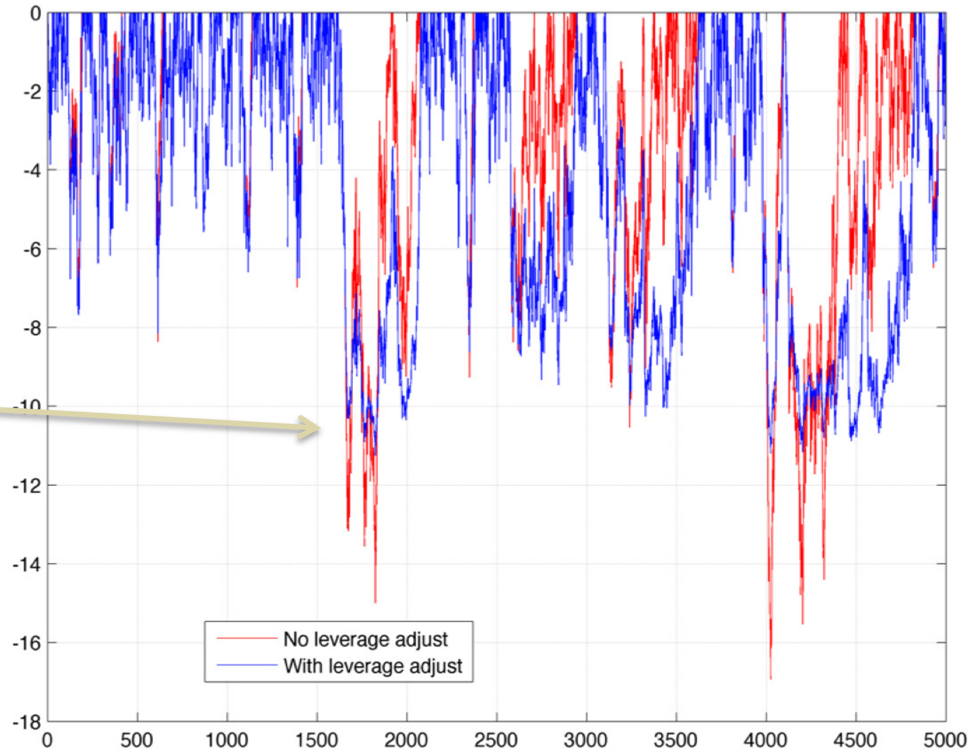
Performance is reduced if leverage adjustments are done…

Example of a drawdown "trap"

Sharpe w/o adjust: **1.51**
Sharpe with adjust: **1.35**

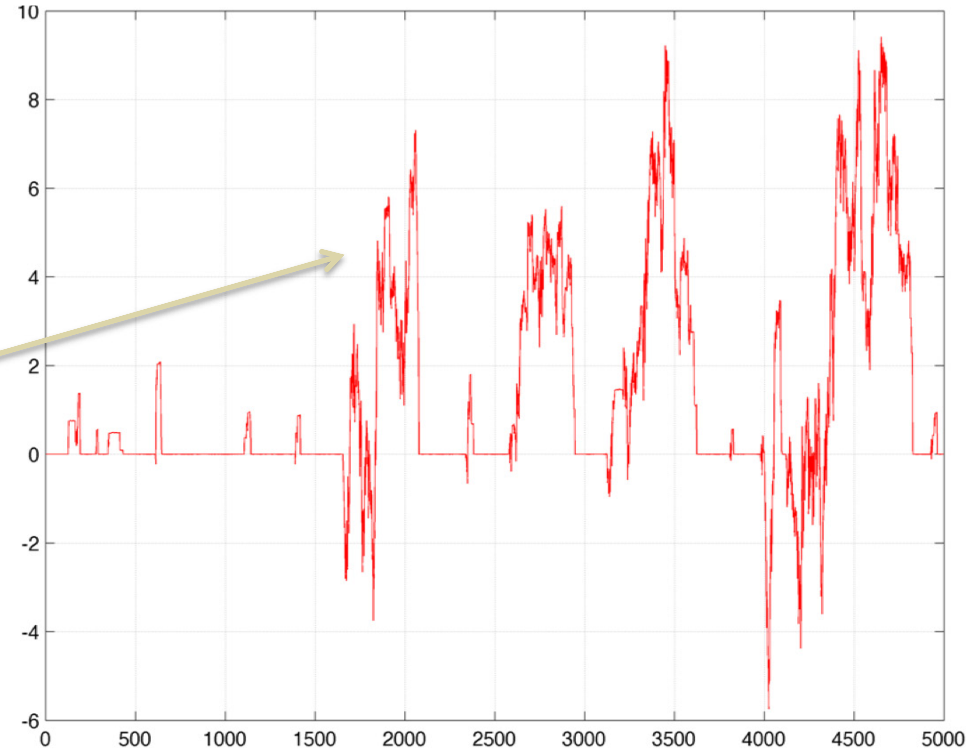
Monte Carlo Study 2 (Fat-tailed data)

Drawdowns appear more limited, but…



Monte Carlo Study 2 (Fat-tailed data)

Drawdown difference (positive when adjusted is **worse**)

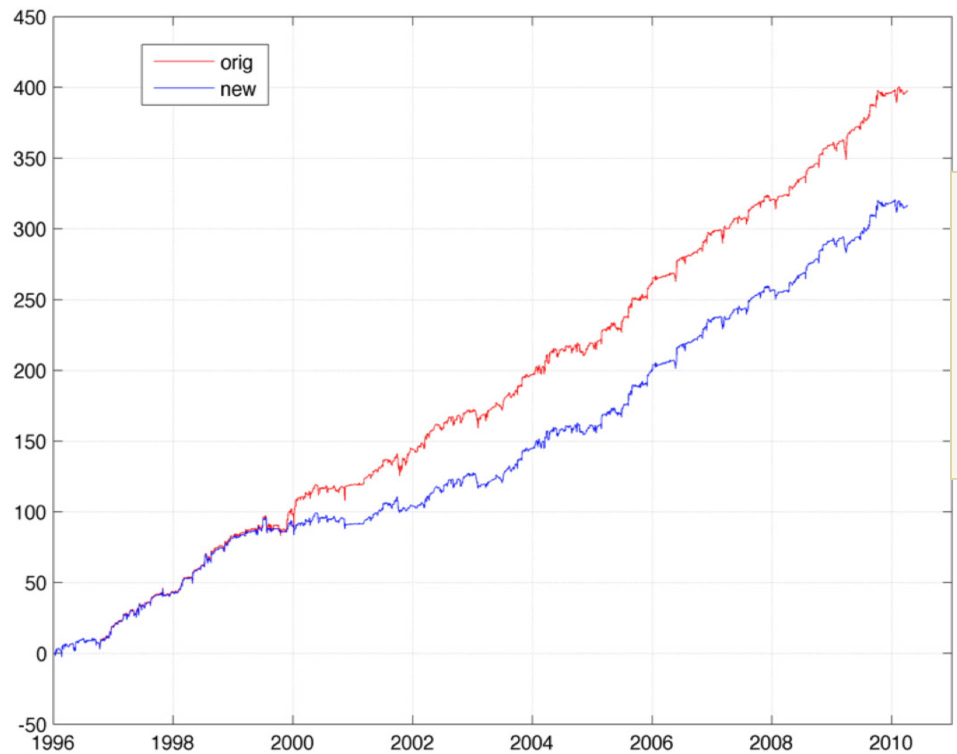


…with leverage adjustments, more time is spent in larger drawdowns than if no adjustments are done.

Does this apply to real systems?

What happens when we test the leverage reduction algorithm on the Global Stock Index program?

GSI (PRE-FEE SIMULATIONS)

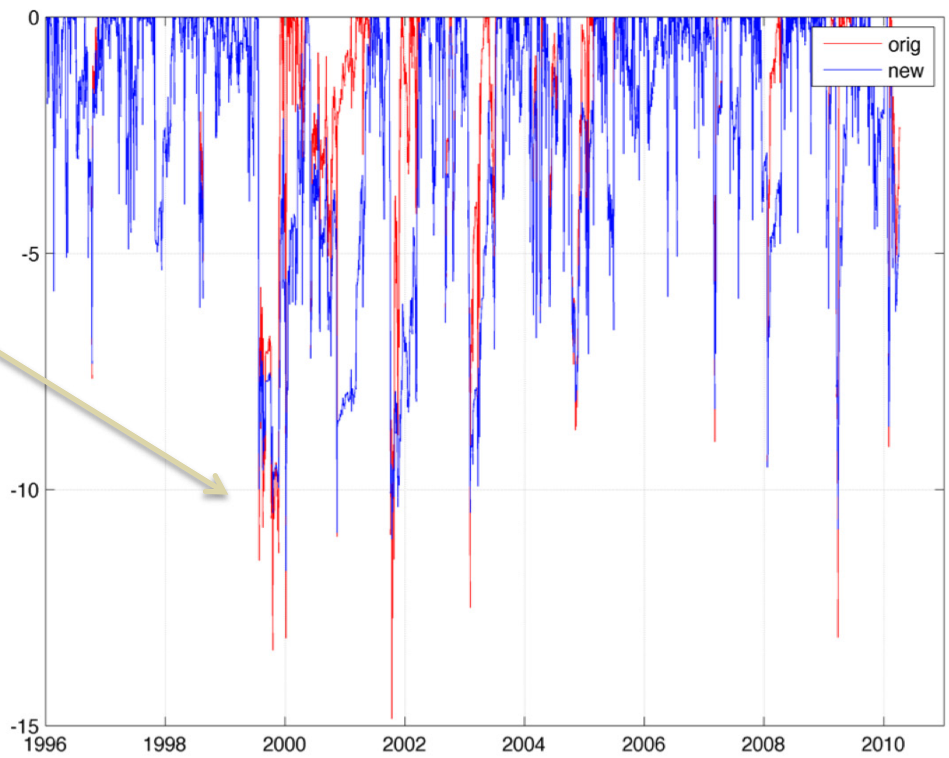


Performance is reduced if leverage adjustments are done…

Sharpe w/o adjust: **1.68**
Sharpe with adjust: **1.51**

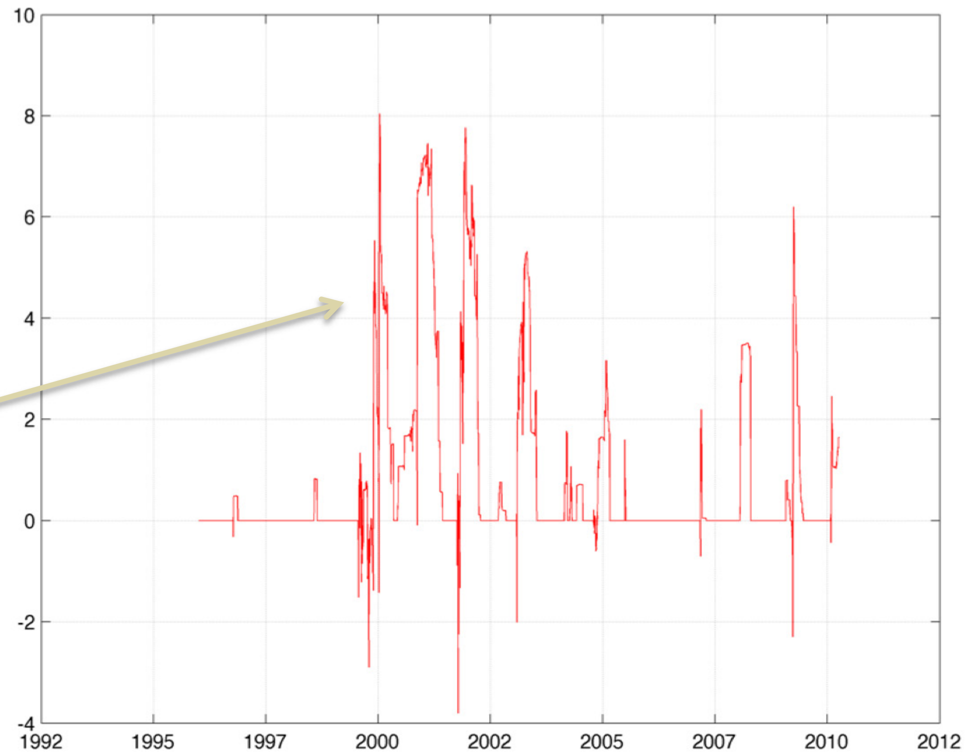
GSI (pre-fee simulations)

Drawdowns appear more limited, but…



GSI (pre-fee simulations)

Drawdown difference (positive when adjusted is **worse**)



…with leverage adjustments, more time is spent in larger drawdowns than if no adjustments are done.

Academic findings

- Grossman and Zhou 1993* theoretically examined strategies for controlling drawdowns (e.g. how to prevent a drawdown greater than X%, where X is chosen by the manager).
- They draw two primary conclusions:
  - The risk exposure needs to be proportional to the amount by which the NAV exceeds the minimum allowable value (i.e. risk ***must*** decrease in a drawdown until there is essentially no exposure as one reaches the X% maximum allowed value).
  - There is a ***cost*** to controlling the drawdown, which is that the risk adjusted return (e.g. Sharpe ratio) is ***strictly lower*** in the case where drawdown control is implemented.
- These theoretical predictions thus agree very well with our simulation results.

*Grossman, S. and Z. Zhou, **Optimal Investment Strategies for Controlling Drawdowns**, in *Mathematical Finance*, Vol. 3, No. 3, July 1993, 241—276.

Summary of drawdown-based de-leveraging study

- We are unable to find any systems (real or random) where leverage reduction has a ***long-term*** benefit (though one might observe isolated situations where it is beneficial).
  - This is not surprising, since theoretically speaking, leverage reduction should only help when negative returns have a long-lived positive correlation (i.e. losses imply more losses). [See Kaminski and Lo 2010**]
  - The Sharpe and Sortino ratios are reduced when leverage reduction is employed. The Calmar ratio (using the maximum observed drawdown over the evaluation period) is, however, modestly improved.
  - ***However***, this improvement comes at the expense of increased drawdown length when leverage reduction is employed ("no free lunch").
  - Another way to quantify the trade-off is to compute the "effective" drawdown versus the "nominal" drawdown. In the previous example, when the nominal drawdown is 10%, the effective drawdown is 15.67% (and this effective value is close to the observed values when no reduction is done).

Kaminski, K. and A. Lo, **When do stop-loss rules stop losses?, working paper, 2010.

Risk-based de-leveraging

- All of our systems employ ***opportunistic, risk-based*** de-leveraging.
- We use a proprietary measure of short-term cross-market correlations, including a noise-reduction algorithm to enhance the discrimination power of the metric.
- As short-term correlations rise beyond a pre-defined threshold, position sizes are reduced by a commensurate amount.
- This has the effect of keeping risk constant as correlations rise and fall.
- Performance effect is neutral based on Sharpe ratio, and fat tails (kurtosis) of N-day returns are measurably narrowed.
- Preferred over drawdown-based de-leveraging because it is tied to risk and not recent performance (forward looking vs. backward looking).

Conclusions

- We have examined and characterized the flow of risk through the entire trading system.
- Many inputs affect the system's risk properties, but a primary determinant is the system itself and how it accumulates or sheds risk.
  - Trend-following systems are intrinsically risk averse (loss-limiting) and thus often have positively-skewed (monthly) returns.
  - Pattern-recognition systems search for anomalies; often, the system will take on more risk in the face of adverse price movements (until the capitulation point).
  - RCM's diversified short-term systems tend to follow Gaussian expectations for drawdowns (a result of the Central Limit Theorem*, applicable for 20+ day returns).
- Various risk-mitigation strategies can be and are employed by various CTAs. RCM uses a risk-based de-leveraging strategy that is appropriate and effective for short-term trading systems. Other techniques that have been shown to work for longer-term systems are not useful for our programs.

*Roughly, the Central Limit Theorem says that a random variable comprised of lots of other random inputs, whether they themselves are Gaussian or not, will approach a Gaussian distribution.