



# Quantitative Investing

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## What is quantitative investing?

**Common definition:**

- Any strategy that relies on computers

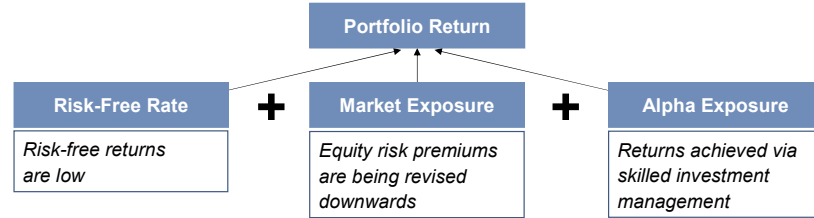
**Our definition:**

- Investing based on modern economic and financial theory



The equilibrium theory permeates investment decisions of GSAM's Quantitative Resources Group. The Black-Litterman Global Asset Allocation model is a demonstration of the usefulness of the equilibrium approach in modern portfolio management

## Sources of portfolio return



**Market risk:**

- Available at very low cost (low fees)
- Relatively low expected return per unit of risk

**Active risk:**

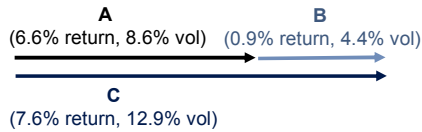
- Uncorrelated risk implies low impact on portfolio risk
- Skill-based
- Opportunities require deviations from equilibrium
- Active management fees

For illustrative purposes only.

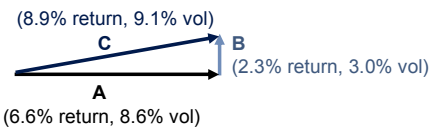
## Adding active risk can be more efficient means of achieving return target

While market risk is additive, active risk is not additive to market exposure, making it an attractive source of return

**Adding equity risk is expensive**



**Adding active risk is almost free**



Start with a 50% equity portfolio

Add 25% equities

OR

Add 3.0% active risk

**A = Old Portfolio Risk    B = New Investment Risk    C = New Portfolio Risk**

We have modeled equity using S&P 500 index. The active return is assumed to have an information ratio of 0.8. All numbers reflect GSAM Global Investment Strategies and GS IMD Investment Strategy Groups consensus estimates as of 30-Sep-03. Strategic long-term assumptions are subject to high levels of uncertainty regarding future economic and market factors that may affect actual future performance. Accordingly, such data should be viewed as hypothetical indications of a broad range of possible returns. These strategic assumptions should not be construed as providing any assurance or guarantee as to returns that may be realized in the future from investments in any asset or asset class described herein and may not be representative of how we will manage any of our portfolios or allocate funds to such asset classes. Goldman Sachs has no obligation to provide recipients hereof with updates or changes to this data as assumptions, economic and market conditions, models or other matters change. Important: Please see appendix for further disclosures.



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## Adding active risk can dramatically improve portfolio performance

	Total return	Expected excess return	Volatility	
Original portfolio (50% equity)	6.6%	1.8%	8.6%	
Additional market risk (25% equity)	0.9%	0.9%	4.4%	
Diversification benefit	-	-	(0.1%)	
<b>New portfolio</b>	<b>7.6%</b>	<b>2.8%</b>	<b>12.9%</b>	<b>0.21</b>
Original portfolio (50% equity)	6.6%	1.8%	8.6%	
3% active risk <sup>2</sup> (assumed IR = 0.75)	-	2.3%	3.0%	
Diversification benefit	-	-	(2.5%)	
<b>New portfolio</b>	<b>8.9%</b>	<b>4.1%</b>	<b>9.1%</b>	<b>0.45</b>

Sharpe Ratio<sup>1</sup> improves with addition of market independent return

### Adding exposure to active risk can boost long-run expected returns without meaningfully increasing fund volatility

<sup>1</sup> The Sharpe Ratio is the ratio of excess return to volatility and is a measure of the efficiency of return generation in a portfolio.  
<sup>2</sup> Information ratio (IR) is a measure of the efficiency by which active managers convert active risk into excess returns.  
 Expected excess returns and risk, as measured by the standard deviation of returns, are statistical estimates of hypothetical average returns of economic asset classes, derived from statistical models. Actual returns and risks are likely to vary from expected returns and risks. Expected return and risk models apply statistical methods and a series of fixed assumptions to derive estimates of hypothetical average asset class performance. Reasonable people may disagree about the appropriate statistical model and fixed assumptions. These models have limitations, as the assumptions may not be consensus views, or the model may not be updated to reflect current economic or market conditions. Accordingly, these models should not be relied upon to make predictions of actual future account performance. Goldman Sachs has no obligation to provide recipients hereof with updates or changes to such data. There is no guarantee that the above results can or will be achieved. Simulated performance results do not reflect actual trading and have certain inherent limitations. Please see additional disclosures.

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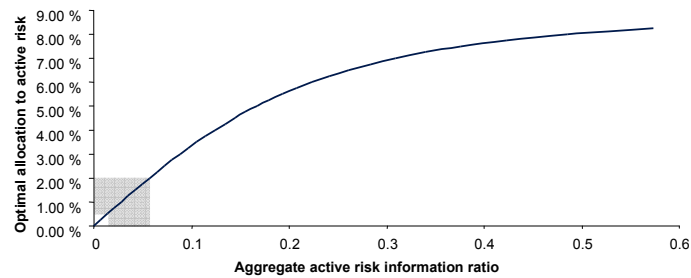


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## The Active Risk Puzzle: why do funds have such modest expectations?

Allocations to active risk of typical pension funds range between 50 and 200 bps

Optimal risk allocations reveal modest IR expectations



### Possible explanations:

- Funds may be unsure of their ability to select skilled managers
- Career risk
- Governance restrictions
- Active risk and strategic asset allocation have historically been linked

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## Issues in finding active risk

### Correlation:

- Active risk should be uncorrelated across sources (and, by definition, with equity index risk)

### Consistency:

- Highest possible active return per unit of active risk
- Confidence that strategy is sustainable

### Capacity:

- For any active manager, increasing AUM will cause information ratio to decline.

### Capital:

- Active risk in most plans constrained by capital allocation, rather than impact on portfolio risk
- High risk is not necessarily bad! Higher active risk per unit of capital is a good thing

### Cost:

- Maximize net expected return
- Performance fees align interests, but should not be paid for beta

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## The liquidity crunch of August 2007

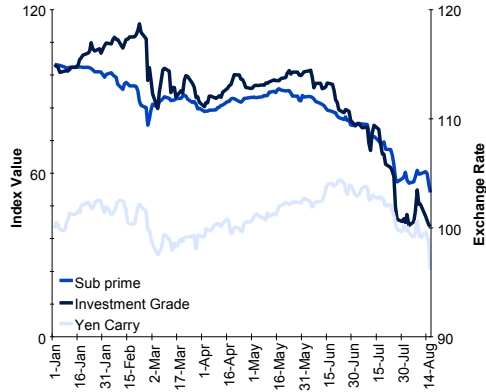


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## The liquidity crunch of August 2007 What happened?

- Sub-prime mortgage market disruption
  - Starts Jan 2007; substantial acceleration Jun 2007
- Spillover to investment-grade credit markets shortly thereafter
- Spillover to yen carry trade

Contagion – YTD 2007



For illustrative purposes only. Contagion graph source: ABX BBB-Tranch closing price, CDX Index USD/Yen exchange rate (PACE). Theme returns source: Goldman Sachs Asset Management (PACE).

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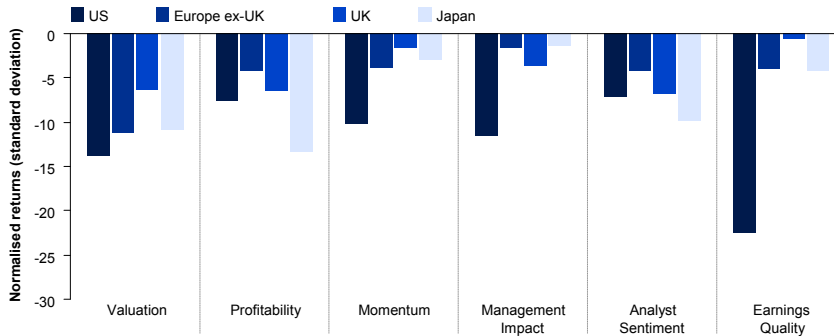


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## The liquidity crunch of August 2007 What happened?

- Spillover to US quant equity strategies, and then international quant strategies in early August

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



For illustrative purposes only. Contagion graph source: ABX BBB-Tranch closing price, CDX Index USD/Yen exchange rate (PACE). Theme returns source: Goldman Sachs Asset Management (PACE).

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## Market dynamics: contagion

- **Prisoner's dilemma developed**
  - Slow trading reduces costs
  - We're all better off if everyone is patient
  - Rush to liquidate → panic unwinding
- **Liquidity dried up**
  - Liquidity 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
- **Prisoner's dilemma accelerated the unwind**
- **Positive feedback loop develops**
  - Unstable equilibrium
  - Explosive dynamics



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## 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
- Some managers injected significant new capital into quant equity strategies

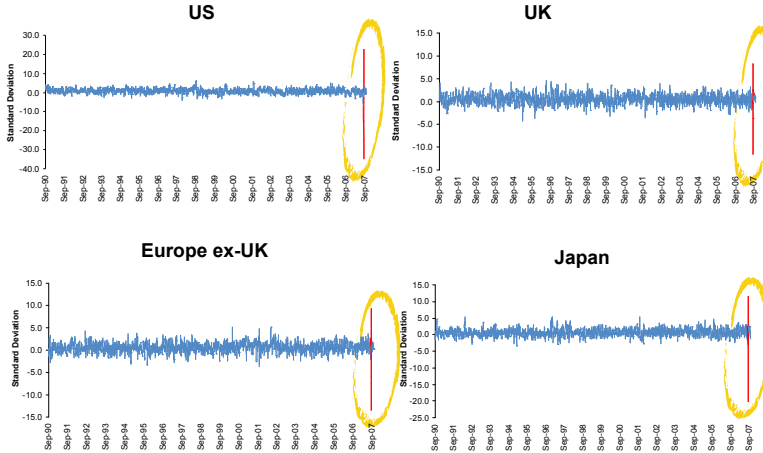
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### How unusual was the event? Cumulative 5-day standardized returns

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



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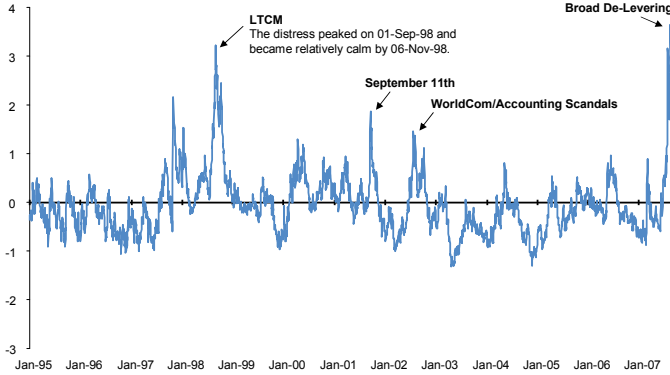
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### Disruptions tend to be short-lived

We recently developed the QIS Disruption Indicator to help us monitor the market's perception of risk

Currently, price of risk is at its highest level in last 10 years

QIS Disruption Indicator (01-Jan-95 to 30-Sept-07)



For illustrative purposes only. The QIS Disruption Indicator, which starts in June 1998, is a proprietary composite of various indicators of financial disruption, including equity market returns, implied volatility measures, quantitative forecasting signals, credit spreads and other signals. Each of these components was first normalized in an effort to make the underlying data sets comparable. We then calculated the average across all of the financial factors to arrive at the indicator.



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# Appendix



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## Risk and return assumptions Strategic long-term assumptions (Asset class return and volatility)

	Expected return	Volatilities
US Large Cap	8.3%	17.5%
US Small Cap	8.2%	20.3%
Intl Dev Equity	7.8%	16.0%
Emerging Markets Equity	8.4%	24.4%
US Fixed Income	4.9%	4.6%
US High Yield	5.7%	8.1%
Private Equity	11.0%	29.5%
Hedge Funds	8.5%	3.4%
Commodities	4.8%	18.6%

Estimates reflect the following indices: Russell 1000, Russell 2000, MSCI World ex US, MSCI EMF (unhedged), Lehman Aggregate, Lehman High Yield Index, CSFB/Tremont and Barclays CTA indices and GSCI (adjusted to reflect our long term assumptions; Private Equity risk characteristics are modeled using a beta of one against the MSCI World Index and an uncorrelated residual volatility of 25%. Expected returns based on a risk free rate assumption of 4.75%. Long-term expected volatilities and correlations based on daily and monthly excess returns over cash for each asset class over the longest period of time for which data are available, from 11/24/79 through 09/30/03. Indices are unmanaged, the figures for the index reflect the reinvestment of dividends but do not reflect the deduction of any fees or expenses which would reduce returns. Investors cannot invest directly in indices. All numbers reflect GSAM Global Investment Strategies strategic assumptions as of a certain date. Strategic long-term assumptions are subject to high levels of uncertainty regarding future economic and market factors that may affect future performance. They are hypothetical indications of a broad range of possible returns. Please see additional disclosures. Expected returns are estimates of hypothetical average returns of economic asset classes derived from statistical models. There can be no assurance that these returns can be achieved. Actual returns are likely to vary. Please see additional disclosures.



## Strategic long-term assumptions (Asset class correlations)

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	US Large Cap	US Small Cap	Intl Dev Equity	Emerging Markets Equity	US Fixed Income	US High Yield	Private Equity	Hedge Funds	Commodi- ties
US Large Cap	1.00								
US Small Cap	0.79	1.00							
Intl Dev Equity	0.79	0.74	1.00						
Emerging Markets Equity	0.66	0.74	0.75	1.00					
US Fixed Income	0.04	-0.03	-0.10	-0.13	1.00				
US High Yield	0.50	0.56	0.48	0.48	0.21	1.00			
Private Equity	0.50	0.43	0.49	0.38	-0.01	0.28	1.00		
Hedge Funds	0.35	0.44	0.32	0.37	0.18	0.41	0.19	1.00	
Commodities	-0.06	0.07	-0.02	0.10	0.03	-0.05	-0.03	0.27	1.00

Estimates reflect the following indices: Russell 1000, Russell 2000, MSCI World ex US, MSCI EMF (unhedged), Lehman Aggregate, Lehman High Yield Index, CSFB/Tremont and Barclays CTA indices and GSCI (adjusted to reflect our long term assumptions); Private Equity risk characteristics are modeled using a beta of one against the MSCI World Index and an uncorrelated residual volatility of 25%. Expected returns based on a risk free rate assumption of 4.75%. Long-term expected volatilities and correlations based on daily and monthly excess returns over cash for each asset class over the longest period of time for which data are available, from 11/24/79 through 09/30/03. Indices are unmanaged, the figures for the index reflect the reinvestment of dividends but do not reflect the deduction of any fees or expenses which would reduce returns. Investors cannot invest directly in indices. All numbers reflect GSAM Global Investment Strategies strategic assumptions as of a certain date. Strategic long-term assumptions are subject to high levels of uncertainty regarding future economic and market factors that may affect future performance. They are hypothetical indications of a broad range of possible returns. Please see additional disclosures. Expected returns are estimates of hypothetical average returns of economic asset classes derived from statistical models. There can be no assurance that these returns can be achieved. Actual returns are likely to vary. Please see additional disclosures.

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## Active returns and risk: traditional managers

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	Historical median information ratio	Assumed information ratio	Assumed tracking error
<b>Public Equity</b>			
US Large Cap Equity	0.39	0.15	3.3%
Enhanced Index	0.82	0.25	1.8%
US Small Cap Equity	1.04	0.35	6.3%
EAFE Equity	0.85	0.25	5.3%
Emerging Markets Equity	0.69	0.25	7.3%
<b>Fixed Income</b>			
US Investment Grade Bonds	0.32	0.25	0.8%
High Yield	1.49	0.35	2.3%

Our source for TE was a GSAM analysis based on Nelsons Institutional Database (Monthly returns data from Jan-90-Mar-03) and reflects the following number of managers: US Large Cap -5, US Small Cap -4, EAFE Equity -4, Emerging Equity -3, US Investment Grade Bonds -3, High Yield -3. The historical median information ratio reflects single manager median historical characteristics. There can be no assurance that the targeted tracking error stated above can be achieved. Please be advised that the targets shown above are subject to change at any time and are current as of the date of this presentation only. Please see appendix for further information.

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Tracking Error is one possible measurement of the dispersion of a portfolio's returns from its stated benchmark. More specifically, it is the standard deviation of such excess returns. Tracking error figures are representations of statistical expectations falling within "normal" distributions of return patterns. Normal statistical distributions of returns suggests that approximately two thirds of the time the annual gross returns of the accounts will lie in a range equal to the benchmark return plus or minus the tracking error if the market behaves in a manner suggested by historical returns. Targeted tracking error therefore applies statistical probabilities (and the language of uncertainty) and so cannot be predictive of actual results. The tracking error that will actually be achieved may inherently lie outside of the range suggested by a "normal" statistical distribution of returns. The actual tracking error is the result of many factors (including but not limited to market volatility, company specific anomalies, instability of correlation between benchmark holdings, timing differences between the calculation of the portfolio value and the valuation of the benchmark by the index provider. In addition, past tracking error is not indicative of future tracking error and there can be no assurance that the tracking error actually reflected in your accounts will be at levels either specified in the investment objectives or suggested by our forecasts.

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### Effect of Fees on Performance

The following table provides a simplified example of the effect of management fees on portfolio returns. For example, assume a portfolio has a steady investment return, gross of fees, of 0.5% per month and total management fees of 0.05% per month of the market value of the portfolio on the last day of the month. Management fees are deducted from the market value of the portfolio on that day. There are no cash flows during the period. The table shows that, assuming that other factors such as investment return and fees remain constant, the difference increases due to the compounding effect over time. Of course, the magnitude of the difference between gross-of-fee and net-of-fee returns will depend on a variety of factors, and the example is purposely simplified.

Time Period	Gross Return	Net Return	Differential
1 year	6.17%	5.54%	0.63%
2 years	12.72%	11.38%	1.34%
10 years	81.94%	71.39%	10.55%

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