Modern approaches to managing market risk using VaR limits

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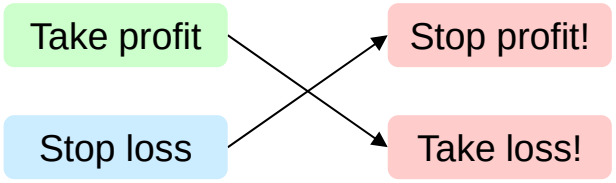
Presentation outline

1. Trading strategy as a ‘shadow’ part of market risk
2. Common approaches to risk budgeting in financial firms
3. Do risk limits add value? Embedding stop-loss limits into VaR limits
4. Setting VaR limits based on portfolio insurance and quantile hedging
5. Agenda for future research

Trading strategy as a ‘shadow’ part of market risk

- In risk management, market risk is often reduced to adverse price movements under the assumption that positions are fixed (e.g. for calculating VaR)
- In the real world, trading losses are a product of BOTH price movements AND position changes!
- Consistent with Sharpe’s (1992) decomposition of a mutual fund’s return into two components:
  - “Style”, i.e. asset-class factors (e.g. large-cap stocks, growth stocks etc.)
  - “Selection”, i.e. an uncorrelated residual
- Trader’s actions require revising risk estimates and ‘contaminate’ trading desk’s P&L used in VaR backtesting
- Market VaR loses its information value in high-frequency trading
- Trader’s actions are the key risk factor for intraday time horizons



Trading strategy as a ‘shadow’ part of market risk

Trader’s risk profile

- Traders have greater participation in the upside than in downside of their trades (e.g. Allen 2001)
- Typical trader’s compensation is akin to a payoff on a long call option, hence risk-loving behavior due to positive vega
- Some of the largest traders’ bonuses:
  - Driss Ben-Brahmin (Goldman Sachs): about £50 in 2006 (unconfirmed)
  - Brian Hunter (Amaranth): above $100 m in 2005 (Petzel 2006)
  - Adam Levinson (Fortress): £156 m in 2008 (Antonowicz 2008)
- Risk of trading strategies (and their interactions) is not well controlled by risk managers due to information asymmetries
- Realized market risk may entail operational risk (e.g. internal fraud)

Trading strategy as a ‘shadow’ part of market risk

- Is trader’s talent more ‘portable’ than that of corporate and investment bankers? (e.g. Butcher 2011)
- Is trader’s market value negatively correlated with incurred losses?

“Even firing does not have that large an effect — the tendency is for firms to hire traders who have had spectacular blowups elsewhere, figuring they’ve learned a lesson (at someone else’s expense). Nick Leeson going to jail was an aberration (possibly due to different attitudes in Singapore than in the West).”

Steve Allen
Managing Director, J. P. Morgan
Courant Institute of Mathematical Sciences, New York University

Source: Allen (2001)

Was Mr. Leeson an exception?!

Rogue trader ‘hall of fame’

- Nick Leeson (Barings, 1995): Nikkei Index futures, £827 m loss, 6.5 years jail, Barings bankrupt
- Yasuo Hamanaka (Sumitomo, 1996): copper, $2.6 bn loss, 8 years jail
- John Rusnak (Allied Irish Bank, 2002): FX options, $691 m loss, 7.5 years jail
- Brian Hunter (Amaranth, 2006): natural gas futures, $6.69 bn loss, fund closed
- Jérôme Kerviel (Société Générale, 2008): European stock index futures, €4.9 bn loss, 5 years jail
- Kweku Adoboli (UBS, 2011): Equities ETF, $2.3 bn loss, under investigation

Risk management was responsible for failing to prevent or stop rogue trading!

Source: http://en.wikipedia.org/wiki/List_of_trading_losses

Trading strategy as a ‘shadow’ part of market risk

Some ways to curb trader’s risk appetite

- More symmetrical compensation schemes (e.g. ‘golden cuffs’, cash bonus clawback)
- Internal controls (e.g. regular audits, phone conversation recording)
- Pre-committing traders to loss limits by incenting them to share their forecasts with risk managers by formula, “Lack of Identification of Risk + Unexpected Loss = Disciplinary Action/Dismissal by Business” (Miller 2001)
- Risk limits
  - Position limits
  - Stop-loss limits
  - Limits on specific parameters (e.g. rate buckets, ‘the Greeks’, markets, liquidity)
  - VaR limits
  - CVaR limits
  - Limits based on stress testing

Risk budgeting in financial firms

- VaR has been largely supplanted by CVAR in portfolio optimization (e.g. Rockafellar and Uryasev 2002)
- VaR has been widely used for setting risk limits in the industry since the 1990s
- G-10 regulators require from IMA-compliant banks to use VaR models also for setting trading limits (Basel Committee 1996, 2006)

"The risk measurement system should be used in conjunction with internal trading and exposure limits. In this regard, trading limits should be related to the bank's risk measurement model in a manner that is consistent over time and that is well understood by both traders and senior management."

Source: Basel Committee (2006), §718(Lxxiv)-f

Risk budgeting in financial firms

Lax risk limits have been a major cause of Lehman Brothers' failure!

"Antoncic* said that in early 2007 … she believed she was being marginalized and did not fully participate in some of the risk decisions made from that point forward. These events occurred after Antoncic expressed her opposition to the large increase in the 2007 risk appetite limit and to the firm's bridge equity and leveraged loan business."

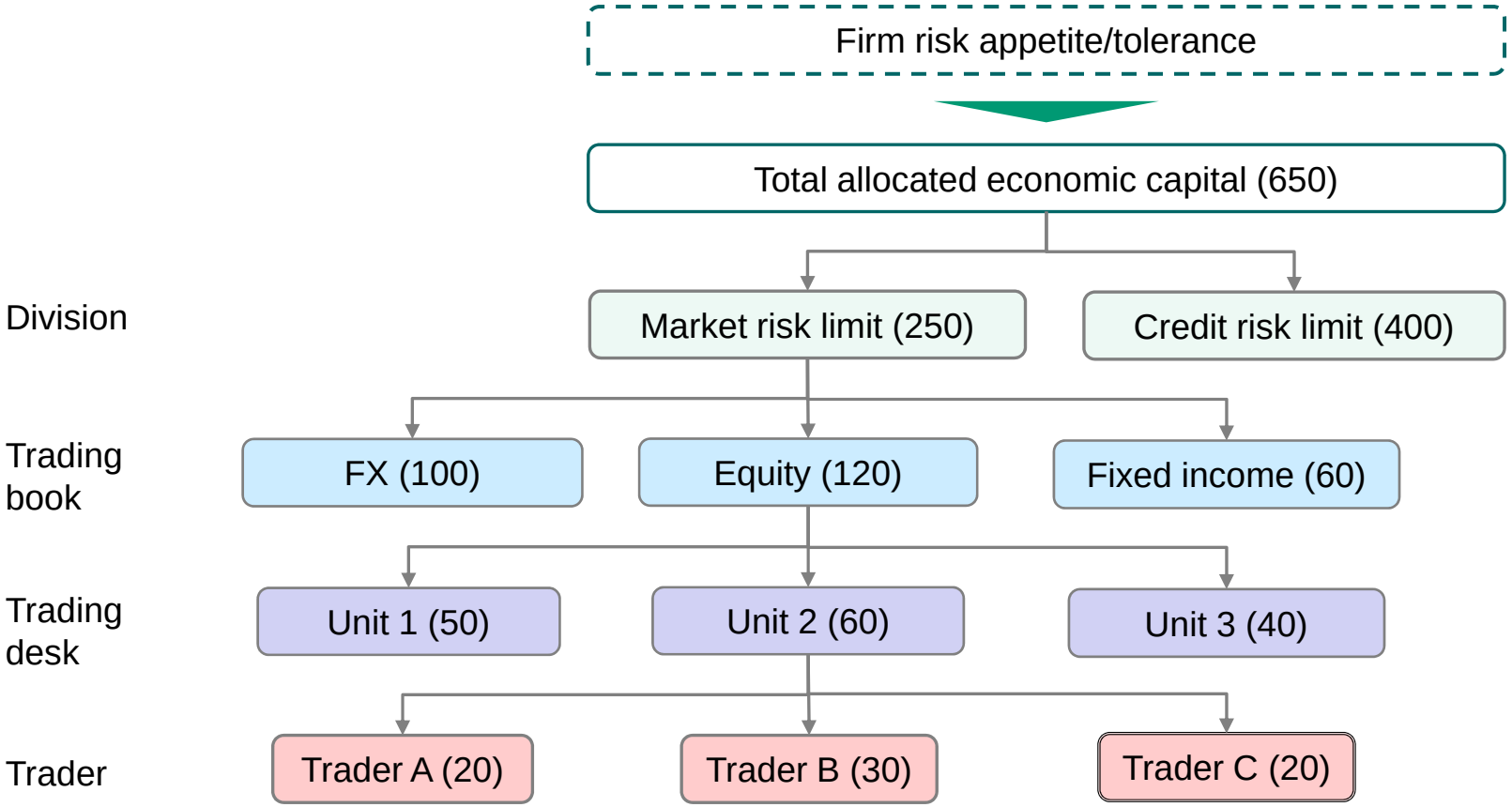
Anton Valukas
U.S. Bankruptcy Court Examiner

Source: U.S. Bankruptcy Court (2010)

* Madelyn Antoncic was Chief Risk Officer of Lehman Brothers in 2004–07

Risk budgeting in financial firms

Hierarchy of risk limits reflecting diversification benefits



Risk budgeting in financial firms

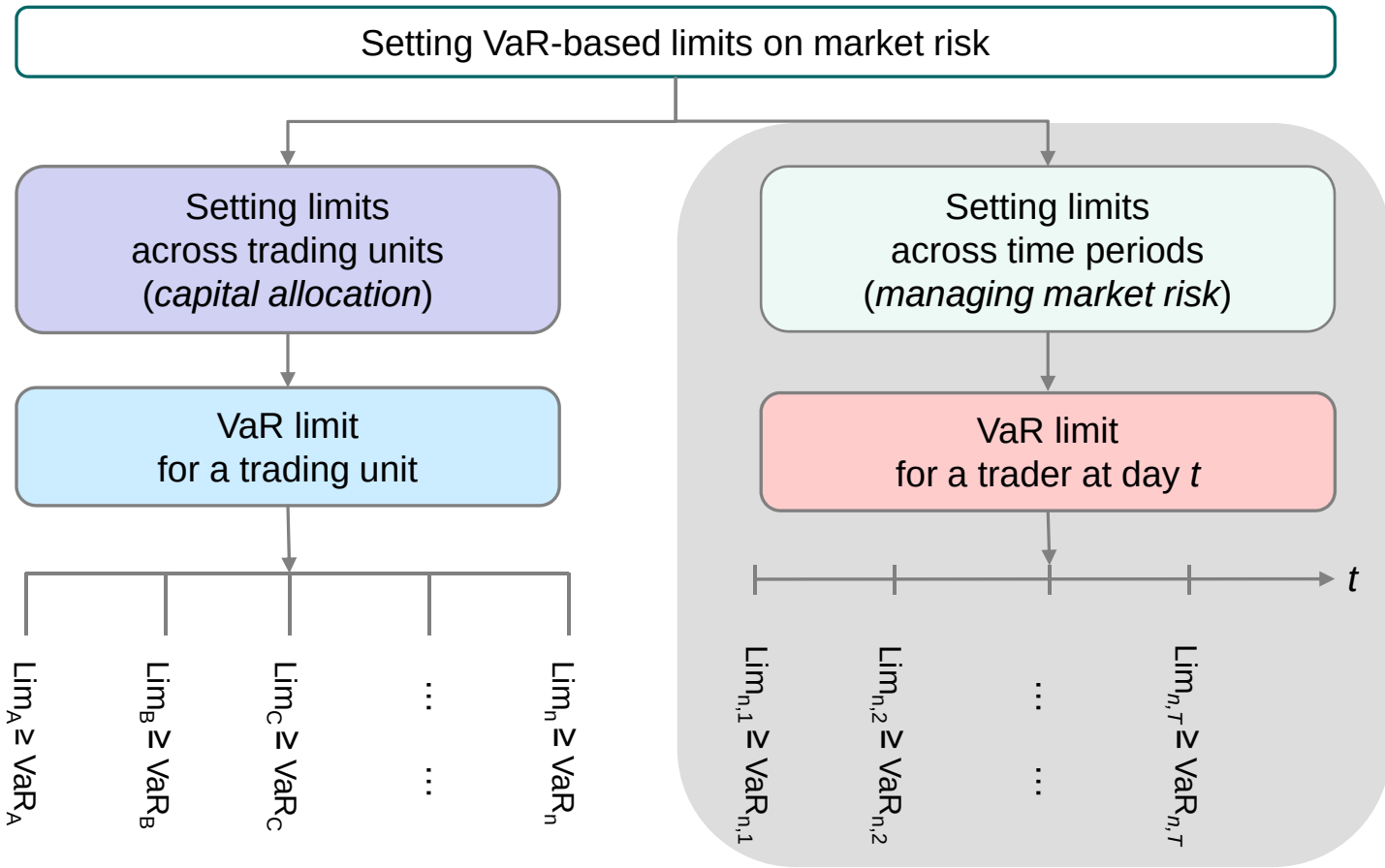
- Limit setting is driven by the economic capital allocation and should be conducted from top-down
- Economic capital is an internal solvency constraint on firm's value-maximization function (Beeck, Johanning, Rudolf 1997, Schroeck 2002)
- Economic capital is set according to firm's risk appetite as a probabilistic loss bound over a target time horizon, hence is typically measured with VaR
- Key assumption 1: Risk is consistently measurable at all levels
- Key assumption 2: Breach of limit must entail book closure and limit re-allocation
- Frequency: from quarterly to annually (e.g. Johanning 1998)

Issues and challenges

- Coherent accounting for risk diversification across all levels
- Consistent time scaling of limits
- Adjusting limits for trader's/desk's P&L
- Adjusting limits for model risk

Risk budgeting in financial firms

Divisional and temporal dimensions of setting VaR limits



Source: Straßberger (2002) – Focus of today's presentation

Embedding stop-loss limits into VaR limits

"One of the best ways to make money is not to lose it!" (Wall Street wisdom)

- Consider an example of two investment funds (Lo 2001)

D Fund A: no stop-loss limits
Lognormally distributed returns

Expected return	Volatility
10% p.a.	75% p.a.

C Fund B = Fund A,
Return B = max {Return A, –20%}

Expected return	Volatility
21% p.a.	67% p.a.

- Applications of truncated distributions:
  - Risk limits (lower tail truncation at stop-loss level)
  - Margin trading (lower tail truncation at margin call level)
  - Private equity fund (upper tail truncation at exit level)
  - Hedging (e.g. two-sided truncation at strike prices in bull/bear spreads)
- Example: truncated normal distribution (stop-loss limit at level z)

$$E(X \mid X > z) = m + s \times l(a) > m,$$

$$\sigma^2(X \mid X > z) = \sigma^2 \times (1 - d(a)) < \sigma^2(X),$$

where $a = (z - m) / \sigma$, $l(a) = N'(a) / (1 - N(a))$, $d(a) = l(a)\,(l(a) - a)$

Embedding stop-loss limits into VaR limits

Discrete management of VaR limits (Beeck, Johanning, Rudolf 1997)

Yearly risk limit = Annual VaR

Fixed limit =	**Loss-constraining limit** =	**Dynamic limit** =
= Yearly risk limit	= *f*(Yearly risk limit, Cum. loss)	= *f*(Yearly risk limit, Cum. P&L)

Daily risk limit = Yearly risk limit / $\sqrt{T}$

Daily position limit = *f* (Daily risk limit, Daily VaR)

- Applicable to single-factor linear position
- Serial correlation of daily returns ignored
- Daily position limit fully utilized
- Trading halted till year-end after yearly risk limit depleted

Embedding stop-loss limits into VaR limits

Deriving risk limits for delta-normal VaR (Beeck, Johanning, Rudolf 1997)

Limit type	Expected return = 0		
	Yearly risk limit	Daily risk limit	Daily position limit
Fixed limit	$YL = YL_0 = const$	$DL = \frac{YL}{\sqrt{T}} = const$	$V_t = \frac{DL}{k_a s_t}$
Loss-constraining limit	$YL_t = \begin{cases} YL_0, \sum_{s=1}^{t} \Delta V_{t-s+1} \geq 0, \\ YL_0 + \sum_{s=1}^{t} \Delta V_{t-s+1}, \sum_{s=1}^{t} \Delta V_{t-s+1} < 0 \end{cases}$	$DL_t = \frac{YL_t}{\sqrt{T}}$	$V_t = \frac{DL_t}{k_a s_t}$
Dynamic limit	$YL_t = YL_0 + \sum_{s=1}^{t} \Delta V_{t-s+1}$	$DL_t = \frac{YL_t}{\sqrt{T}}$	$V_t = \frac{DL_t}{k_a s_t}$

where ΔV – change in position value,

T – holding period assumed in risk limit allocation (e.g. 250 trading days)

Embedding stop-loss limits into VaR limits

Deriving risk limits for delta-normal VaR (Beeck, Johanning, Rudolf 1997)

Limit type	Expected return ≠ 0		
	Yearly risk limit	Daily risk limit	Daily position limit
Fixed limit	$YL = YL_0 = const$	$DL_t = YL\dfrac{\bar{m} - k_a \bar{s}}{\bar{m}\,T - k_a \bar{s}\sqrt{T}}$	$V_t = -\dfrac{DL_t}{m_t - k_a s_t}$
Loss-constraining limit	$YL_t = \begin{cases} YL_0, \sum_{s=1}^{t} \Delta V_{t-s+1} \geq 0, \\ YL_0 + \sum_{s=1}^{t} \Delta V_{t-s+1}, \sum_{s=1}^{t} \Delta V_{t-s+1} < 0 \end{cases}$	$DL_t = YL_t\dfrac{\bar{m} - k_a \bar{s}}{\bar{m}\,T - k_a \bar{s}\sqrt{T}}$	$V_t = -\dfrac{DL_t}{m_t - k_a s_t}$
Dynamic limit	$YL_t = YL_0 + \sum_{s=1}^{t} \Delta V_{t-s+1}$	$DL_t = YL_t\dfrac{\bar{m} - k_a \bar{s}}{\bar{m}\,T - k_a \bar{s}\sqrt{T}}$	$V_t = -\dfrac{DL_t}{m_t - k_a s_t}$

Embedding stop-loss limits into VaR limits

Advantages

- **J** Loss-constraining and dynamic limits produce positively-skewed distributions of P&L (Beeck, Johanning, Rudolf 1997; Lobanov, Kainova 2005)
- **J** Dynamic limit offers the highest potential for profit-making
- **J** Much lower frequency of losses exceeding yearly VaR than its confidence level
- **J** Conservative adjustments for model risk can be incorporated in parametric and non-parametric VaR limits (Lobanov, Kainova 2005)

Shortcomings (Straßberger 2002)

- **L** Annual VaR implies positions are fixed for a one-year horizon (unsuitable for proprietary trading)
- **L** Scaling with $\sqrt{T}$ leads to severe underutilization of economic capital (e.g. daily risk limit only 6.25% of yearly risk limit for T = 256 trading days)
- **L** Scaling with $\sqrt{(T-t)}$ leads to uneven distribution of limits over the year
- **L** Annual VaR almost never exceeded if trading halted after depletion of yearly limit!
- **L** Not extendable to portfolio case?

Setting VaR limits based on portfolio insurance

Continuous management of VaR limits (Straßberger 2002)

Yearly risk limit = VaR (Cumulative yearly loss)

Dynamic limit = *f*(Yearly risk limit, Cumulative P&L)

Daily position limit = *f* (Yearly risk limit, Daily VaR)

Risk-aversion scalar = *f*(Synthetic put strike, Daily position limit, *T*)

Daily risk limit = Yearly risk limit x Risk-aversion scalar

Setting VaR limits based on portfolio insurance

Continuous management of VaR limits (Straßberger 2002)

- Dynamic version of managing market risk through VaR limits
- Combination of portfolio insurance with synthetic put options (Rubinstein and Leland 1981) and 'quantile hedging' (Föllmer and Leukert 1999)
  - Max daily position limit derived from yearly risk limit and daily VaR parameters
  - Delta of European put option on single stock or portfolio continuously estimated
  - Synthetic put option replicated with short position in stock and long position in risk-free asset
  - Long stock + Long synthetic put = Net long position in stock + Long position in risk-free asset
  - Risk-aversion scalar = Net long position in stock / Max daily position limit
  - Portfolio insurance always applies to yearly risk limit
  - Put strike (i.e. the insurance bound) is set to achieve VaR confidence level
- Delta for portfolios of long and short positions calculated for changes in daily position limits (not stock price!)
- European barrier put options ensure min hedging cost (Föllmer and Leukert 1999)
  - Knock-out-drop-in put option with barrier price U equal e.g. to portfolio initial value
  - If $V_t > U$, delta = 0 and full yearly risk limit available for trader

Setting VaR limits based on portfolio insurance

Deriving risk limits for delta-normal VaR (Straßberger 2002)

Limit type	Expected return ≠ 0		
	Yearly risk limit	Daily position limit	Daily risk limit
Dynamic limit	$YL_t = YL_0 + \sum_{s=1}^{t} \Delta V_{t-s+1}$	$V_t^{\max} = \frac{YL_t}{m_t T - k_a s_t \sqrt{T}}$	$DL_t = a_t YL_t$

where $a_t = \frac{(1+d_t)V_t}{(1+d_t)V_t + M_t} = \frac{V_t \, \mathrm{N}(d_1)}{V_t \, \mathrm{N}(d_1) + K(1 - \mathrm{N}(d_2))}$;

$K \in [0; V_0 - YL_t]$ – strike price of European put option;

$d_1 = \frac{\ln(S_t / K) + (r + s^2/2)T^*}{s\sqrt{T^*}}$; $d_2 = d_1 - s\sqrt{T^*}$; $d_t = \mathrm{N}(d_1) - 1.$

Assumptions

- $T^* = 0.5T$; $r = 0$
- Daily risk limit fully utilized
- Trader has no extraordinary ability of predicting market movements!

Setting VaR limits based on portfolio insurance

Continuous management of VaR limits (Straßberger 2002)

- At $t = 0$: $V_0 > K$ and $d_t \approx 0$, $M_t \approx 0$, $a_0 \approx 1 \Rightarrow$ Daily risk limit = Yearly risk limit
- If $V_t > V_0$, then $V_t >> K$, and $d_t \approx 0$, $M_t \approx 0$, $a_0 \approx 1 \Rightarrow$ Yearly risk limit up due to positive P&L, Daily risk limit = Yearly risk limit
- If $V_t < V_0$, then $d_t < 0$, $M_t > 0$, $a_0 < 1 \Rightarrow$ Yearly risk limit down due to negative P&L, Daily risk limit < Yearly risk limit due to $a_0 < 1$
- If $K = V_0 - YL_t$, same as dynamic VaR limit as per Beeck, Johanning, Rudolf (1997)
- If $K < V_0 - YL_t$, $P(V_t > YL_t) < 1$ can be set equal to VaR confidence level
- Simulation required for estimating $K(P)$ (Lokarek-Junge, Straßberger, Vollbehr 2000)

$K = (V_0 - \text{VaR}(\alpha, T))$	x 1.00	x 0.95	x 0.90	x 0.85	x 0.75	x 0.50
$\hat{a}$	0.55%	1.86%	2.97%	3.58%	4.51%	5.00%
Insurance level (V_0=100)	76	72	68	65	58	51

Source: Lokarek-Junge, Straßberger, Vollbehr (2000)

Setting VaR limits based on portfolio insurance

Advantages

- J Smart and theoretically appealing marriage of VaR limits and quantile hedging
- J Higher daily risk limit available for trader
- J Yearly risk limit consistent with VaR definition
- J Consistent temporal management of daily risk limits
- J Risk aversion of firm management explicitly reflected in daily limit
- J Additional flexibility through setting barrier price
- J Applicable to portfolio of positions

Shortcomings

- L High transaction costs of continuous portfolio rebalancing
- L Top-down re-allocation of risk limits across firm required after adjustment of yearly limit in any single portfolio
- L Continuous re-allocation of risk limits unrealistic due to high cost
- L Relatively complex for understanding by senior management

Agenda for future research

- Investigate the distributions of intraday trader's P&L as a single asset and decouple it into 'market' and 'trader' components
- Study the usability of other risk measures (e.g. lower partial moment) for setting trading limits
- Develop method for allocating VaR and position limits in complex portfolios
- Model correlations between traders on desk and firm level (e.g. why do desks trading on correlated markets display low empirical correlations of returns? (Perold (2001))
- Investigate the distribution of unutilized desk risk limit under imperfect correlations between traders
- Find hands-on ways of enhancing risk limit utilization
- Engineer ways of incorporating traders' own risk forecasts into economic capital models
- ...
- **Develop actionable and incentive-compatible limit systems to ensure traders' buy-in!**

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QUESTIONS???