

MSCI

Valuing Liquidity

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Outline

- Introduction to Mark-to-Liquidity (MtL)
- Liquidity Risk of an equity portfolio
 - Exogenous risk
 - Portfolio Value as a function of its Liquidity Policy
 - examples
- Properties of MtL in illiquid markets
 - Non-additivity
 - Concavity
 - Granularity effect
 - The added value of Liquidity

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Mark-to-Liquidity: What It Means

- A portfolio value in an illiquid market depends
 - On **market illiquidity** – exogenous risk
 - On all **liquidity constraints** imposed on the portfolio – endogenous risk
- If the market is perfectly liquid or if the portfolio has no constraints, the value of the portfolio will not suffer any liquidity risk effect
- In all other cases **the presence of constraints in an illiquid market**, determines a nontrivial effect on the portfolio value
- Mark-to-Liquidity quantifies this effect systematically

The Value of a Portfolio with MtL

- MtL does not introduce **liquidity risk measures**, but rather a **liquidity-adjusted portfolio evaluation method**
- The value of a portfolio \mathbf{p} is expressed as a function

$$\mathbf{p} \mapsto V^L(\mathbf{p})$$

where L denotes a specific **Liquidity Policy (LP)**, namely the set of all constraints imposed on the portfolio

- The portfolio value is computed by seeking the optimal way to match the constraints given market conditions and by computing the corresponding minimal liquidation cost

A Three Stages Process

- Computing the value of a portfolio p in a given market, is a three stage process
 - **Modeling market (exogenous) liquidity**
 - **Describing the portfolio constraints**
 - **Solving the constrained optimization**
- This can be shown to be a convex optimization problem



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Example: An Equity Portfolio

- Analyzing a real case portfolio of stocks proposed by a client
- MtL applies to any other asset class. For the equity market, however, it's much easier to find liquidity data and there's a much more extensive literature on market impact

The Portfolio

Name			Sector	weight	
COMCAST CORP-CLASS A	CMCSA	US	Equity	Communications	7.53%
EXXON MOBIL CORP	XOM	US	Equity	Energy	4.69%
GOLDMAN SACHS GROUP INC	GS	US	Equity	Financial	4.04%
HEWLETT-PACKARD CO	HPQ	US	Equity	Technology	3.75%
INTEL CORP	INTC	US	Equity	Technology	3.48%
PROCTER & GAMBLE CO/THE	PG	US	Equity	Consumer, Non-cyclical	3.34%
CHEVRON CORP	CVX	US	Equity	Energy	3.32%
MICROSOFT CORP	MSFT	US	Equity	Technology	3.22%
WALT DISNEY CO/THE	DIS	US	Equity	Communications	4.82%
INTL BUSINESS MACHINES CORP	IBM	US	Equity	Technology	3.09%
NEWS CORP-CL A	NWSA	US	Equity	Communications	3.09%
ABBOTT LABORATORIES	ABT	US	Equity	Consumer, Non-cyclical	2.86%
CONOCOPHILLIPS	COP	US	Equity	Energy	2.09%
DISCOVERY COMMUNICATIONS-C	DISCK	US	Equity	Communications	2.00%
JOHNSON & JOHNSON	JNJ	US	Equity	Consumer, Non-cyclical	1.81%
TEXAS INSTRUMENTS INC	TXN	US	Equity	Technology	1.59%
LIBERTY GLOBAL INC-A	LBTYA	US	Equity	Communications	1.56%
DIRECTV-CLASS A	DTV	US	Equity	Communications	1.40%
TELEPHONE AND DATA SYSTEMS	TDS	US	Equity	Communications	1.25%
BROADCOM CORP-CL A	BRCM	US	Equity	Technology	1.22%
DEVON ENERGY CORPORATION	DVN	US	Equity	Energy	1.24%
SCHLUMBERGER LTD	SLB	US	Equity	Energy	1.22%
BROWN-FORMAN CORP-CLASS B	BF/B	US	Equity	Consumer, Non-cyclical	1.20%
AT&T INC	T	US	Equity	Communications	1.15%
OCCIDENTAL PETROLEUM CORP	OXY	US	Equity	Energy	1.15%
YAHOO! INC	YHOO	US	Equity	Communications	1.12%
CHIPOTLE MEXICAN GRILL INC	CMG	US	Equity	Consumer, Cyclical	1.10%
CBS CORP-CLASS B NON VOTING	CBS	US	Equity	Communications	3.33%
GANNETT CO	GCI	US	Equity	Communications	6.67%
OMNICOM GROUP	OMC	US	Equity	Communications	3.33%
NEWS CORP-CLASS B	NWS	US	Equity	Communications	1.67%
CHINA ARCHITECTURAL ENGINEER	CAEI	US	Equity	Industrial	5.00%
EFUTURE INFORMATION TECHNOLO	EFUT	US	Equity	Technology	3.33%
CHINA NATURAL RESOURCES INC	CHNR	US	Equity	Basic Materials	5.00%
CHINA TECHNOLOGY DEVELOPMENT	CTDC	US	Equity	Energy	1.67%
CHINA AUTOMOTIVE SYSTEMS INC	CAAS	US	Equity	Consumer, Cyclical	1.67%

Exogenous Liquidity Risk

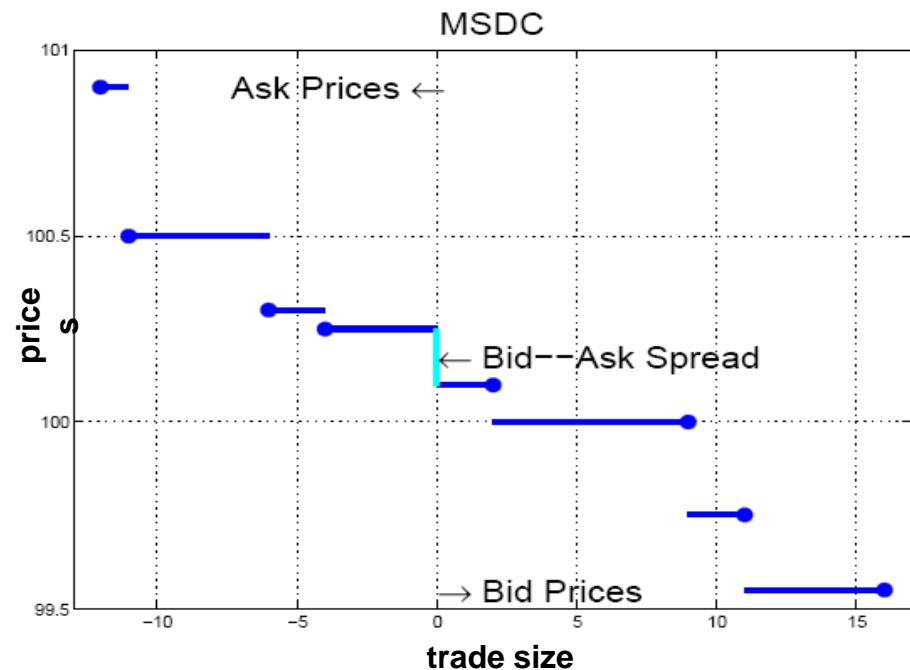
- The sample displays a wide range of liquidity (from very liquid like MSFT.US to very illiquid like CAEI.US)
- Stocks liquidity is compared based on public data **indicators**
 - Number of stocks issued
 - Average daily volume traded
 - Percentage bid-offer spread
 - Average daily turnover
 - Volatility (historical)

Liquidity Heat Map

Stock	Sector	Ticker	% bid-ask spread	Outstanding Shares	Mkt Cap (\$)	Avg Daily Volume	Avg daily turnover	Vol (120d)
COMCAST CORP-CLASS A	Communications	CMCSA US Equity	0.06%	2,063,073,000	35,959,362,390	20,268,490	0.98%	29.4%
EXXON MOBIL CORP	Energy	XOM US Equity	0.01%	4,721,273,000	315,239,398,210	26,911,172	0.57%	18.1%
GOLDMAN SACHS GROUP INC	Financial	GS US Equity	0.01%	526,251,100	92,088,679,989	12,049,916	2.29%	29.3%
HEWLETT-PACKARD CO	Technology	HPQ US Equity	0.02%	2,345,093,000	122,859,422,270	14,971,182	0.64%	20.8%
INTEL CORP	Technology	INTC US Equity	0.05%	5,524,000,000	117,550,720,000	58,714,996	1.06%	25.1%
PROCTER & GAMBLE CO/THE	Consumer, Non-cyclical	PG US Equity	0.02%	2,904,593,000	183,976,920,620	11,600,728	0.40%	14.3%
CHEVRON CORP	Energy	CVX US Equity	0.01%	2,008,353,000	148,136,117,280	11,068,801	0.55%	18.7%
MICROSOFT CORP	Technology	MSFT US Equity	0.03%	8,770,461,000	256,711,393,470	58,483,480	0.67%	21.1%
WALT DISNEY CO/THE	Communications	DIS US Equity	0.03%	1,939,515,000	65,381,050,650	12,511,876	0.65%	22.1%
INTL BUSINESS MACHINES CORP	Technology	IBM US Equity	0.02%	1,299,003,000	166,246,403,940	6,256,818	0.48%	17.8%
NEWS CORP-CL A	Communications	NWSA US Equity	0.07%	1,821,688,000	25,558,282,640	20,741,216	1.14%	33.1%
ABBOTT LABORATORIES	Consumer, Non-cyclical	ABT US Equity	0.02%	1,552,643,000	84,712,202,080	7,511,824	0.48%	15.4%
CONOCOPHILLIPS	Energy	COP US Equity	0.02%	1,486,838,000	76,884,392,980	10,415,717	0.70%	22.8%
DISCOVERY COMMUNICATIONS-C	Communications	DISCK US Equity	0.10%	141,711,300	4,072,782,762	905,777	0.64%	27.9%
JOHNSON & JOHNSON	Consumer, Non-cyclical	JNJ US Equity	0.02%	2,751,927,000	176,591,155,590	11,543,674	0.42%	11.6%
TEXAS INSTRUMENTS INC	Technology	TXN US Equity	0.04%	1,241,889,000	29,805,336,000	16,501,162	1.33%	27.1%
LIBERTY GLOBAL INC-A	Communications	LBTYA US Equity	0.04%	135,071,200	3,826,567,096	2,230,985	1.65%	37.6%
DIRECTV-CLASS A	Communications	DTV US Equity	0.03%	913,331,500	31,847,869,405	9,927,372	1.09%	22.9%
TELEPHONE AND DATA SYSTEMS	Communications	TDS US Equity	0.09%	49,804,910	1,708,308,413	339,286	0.68%	24.0%
BROADCOM CORP-CL A	Technology	BRCM US Equity	0.06%	438,600,000	14,320,290,000	9,856,374	2.25%	35.3%
DEVON ENERGY CORPORATION	Energy	DVN US Equity	0.01%	446,800,000	31,494,932,000	4,094,013	0.92%	30.7%
SCHLUMBERGER LTD	Energy	SLB US Equity	0.03%	1,195,634,000	77,214,043,720	14,510,407	1.21%	31.0%
BROWN-FORMAN CORP-CLASS B	Consumer, Non-cyclical	BF/B US Equity	0.05%	90,274,800	5,003,932,164	274,979	0.30%	18.3%
AT&T INC	Communications	T US Equity	0.04%	5,902,074,000	151,152,115,140	29,494,558	0.50%	15.8%
OCCIDENTAL PETROLEUM CORP	Energy	OXY US Equity	0.04%	811,956,000	66,401,761,680	5,524,251	0.68%	26.7%
YAHOO! INC	Communications	YHOO US Equity	0.06%	1,400,202,000	22,851,296,640	22,158,914	1.58%	25.6%
CHIPOTLE MEXICAN GRILL INC	Consumer, Cyclical	CMG US Equity	0.04%	31,559,070	3,628,030,687	507,083	1.61%	32.6%
CBS CORP-CLASS B NON VOTING	Communications	CBS US Equity	0.07%	625,501,600	9,132,323,360	10,756,028	1.72%	44.3%
GANNETT CO	Communications	GCI US Equity	0.06%	237,356,600	3,773,969,940	5,634,384	2.37%	62.6%
OMNICOM GROUP	Communications	OMC US Equity	0.03%	310,448,000	12,213,024,320	2,663,270	0.86%	23.3%
NEWS CORP-CLASS B	Communications	NWS US Equity	0.12%	798,521,000	13,199,552,130	3,396,161	0.43%	30.2%
CHINA ARCHITECTURAL ENGINEER	Industrial	CAEI US Equity	1.74%	55,156,870	64,533,538	213,438	0.39%	81.2%
EFUTURE INFORMATION TECHNOLO	Technology	EFUT US Equity	4.00%	2,633,500	17,117,750	9,000	0.34%	61.6%
CHINA NATURAL RESOURCES INC	Basic Materials	CHNR US Equity	0.67%	19,623,420	237,050,914	12,040	0.06%	54.3%
CHINA TECHNOLOGY DEVELOPMENT	Energy	CTDC US Equity	0.72%	19,280,060	53,984,168	23,954	0.12%	78.6%
CHINA AUTOMOTIVE SYSTEMS INC	Consumer, Cyclical	CAAS US Equity	0.49%	26,984,740	613,902,835	1,109,209	4.11%	84.5%

Marginal Supply-Demand Curves (MSDC)

- The information on a given asset liquidity is condensed in its MSDC, namely its “order book” in the considered time horizon
- The shape of MSDCs and their calibration is strongly asset-class specific



A Model for Equity MSDCs

- For the MSDCs of stocks, in this example, the model used is proposed by R. Almgren et al. for equity “market impact”
- The functional form allows for a straightforward calibration on public observable data (the indicators mentioned above).
- It displays **power-law behavior** with respect to the trade size

Power-Law MSDC (Almgren et al.)

- A stock MSDC can be expressed as

$$m(x) = \begin{cases} S_{bid} \left(1 - \gamma \sigma \frac{x}{V} \left(\frac{\Theta}{V} \right)^{1/4} - \frac{8}{5} \eta \sigma x \left| \frac{x}{VT} \right|^{3/5} \right), & x > 0 \\ S_{ask} \left(1 - \gamma \sigma \frac{x}{V} \left(\frac{\Theta}{V} \right)^{1/4} - \frac{8}{5} \eta \sigma x \left| \frac{x}{VT} \right|^{3/5} \right), & x < 0 \end{cases}$$

general

- $m(x)$: last price hit in a trade of x stocks
- x : number of stocks traded (bid if $x>0$, ask if $x<0$)
- T : trade time horizon

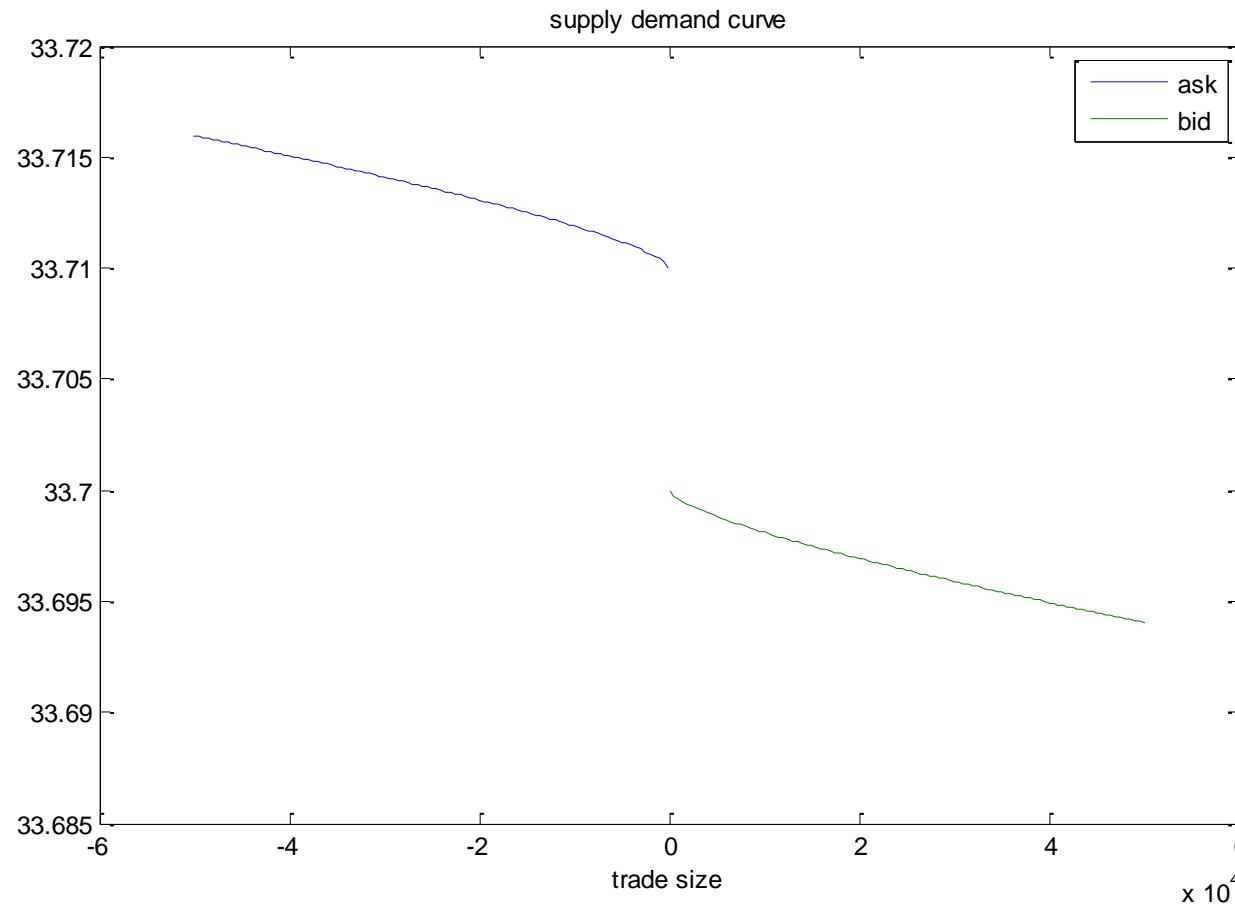
asset specific

- Θ : outstanding issued stocks
- V : average daily volume
- σ : 1-day volatility

universal

- $\eta = 0.142, \gamma = 0.314$: empirically estimated coefficients
- $1/4, 3/5$: empirically estimated exponents

Power-law MSDC (ex: DIS.US Equity)



Different Notions of Mark-to-Market

- For each stock the following notions are defined
 - $U = \text{MtM @ bid or ask}$ (for long or short positions resp.)
 - $L = \text{total liquidation proceeds}$
- and
 - $C = U - L$ interpreted as a “**Cost of Liquidation**”
- The liquidation is meant within an assigned time horizon. Here it is fixed at $T=1$ day
- “**Size effects**” are studied comparing portfolios of \$1M, \$10M, \$100M and \$1B

\$1M Portfolio (liq cost = 20 bp)

stock id	weight	M (= mid MtM)	U (= bid/ask MtM)	L (=Liquidation Value)	C=U-L (Liquidation Cost)
dollar	0.00%	-	-	-	-
COMCAST CORP-CLASS A	7.53%	75,300	75,278	75,277	1
EXXON MOBIL CORP	4.69%	46,900	46,896	46,896	0
GOLDMAN SACHS GROUP INC	4.04%	40,400	40,399	40,399	0
HEWLETT-PACKARD CO	3.75%	37,500	37,496	37,496	0
INTEL CORP	3.48%	34,800	34,792	34,792	0
PROCTER & GAMBLE CO/THE	3.34%	33,400	33,397	33,397	0
CHEVRON CORP	3.32%	33,200	33,198	33,198	0
MICROSOFT CORP	3.22%	32,200	32,194	32,194	0
WALT DISNEY CO/THE	4.82%	48,200	48,193	48,192	0
INTL BUSINESS MACHINES CORP	3.09%	30,900	30,896	30,896	0
NEWS CORP-CL A	3.09%	30,900	30,889	30,889	0
ABBOTT LABORATORIES	2.86%	28,600	28,597	28,597	0
CONOCOPHILLIPS	2.09%	20,900	20,898	20,898	0
DISCOVERY COMMUNICATIONS-C	2.00%	20,000	19,990	19,989	1
JOHNSON & JOHNSON	1.81%	18,100	18,099	18,099	0
TEXAS INSTRUMENTS INC	1.59%	15,900	15,897	15,897	0
LIBERTY GLOBAL INC-A	1.56%	15,600	15,597	15,597	0
DIRECTV-CLASS A	1.40%	14,000	13,998	13,998	0
TELEPHONE AND DATA SYSTEMS	1.25%	12,500	12,495	12,494	1
BROADCOM CORP-CL A	1.22%	12,200	12,196	12,196	0
DEVON ENERGY CORPORATION	1.24%	12,400	12,399	12,399	0
SCHLUMBERGER LTD	1.22%	12,200	12,198	12,198	0
BROWN-FORMAN CORP-CLASS B	1.20%	12,000	11,997	11,996	0
AT&T INC	1.15%	11,500	11,498	11,498	0
OCCIDENTAL PETROLEUM CORP	1.15%	11,500	11,498	11,498	0
YAHOO! INC	1.12%	11,200	11,197	11,197	0
CHIPOTLE MEXICAN GRILL INC	1.10%	11,000	10,998	10,997	0
CBS CORP-CLASS B NON VOTING	3.33%	33,300	33,289	33,288	1
GANNETT CO	6.67%	66,700	66,679	66,673	6
OMNICOM GROUP	3.33%	33,300	33,296	33,295	1
NEWS CORP-CLASS B	1.67%	16,700	16,690	16,689	0
CHINA ARCHITECTURAL ENGINEER	5.00%	50,000	49,569	49,109	460
EFUTURE INFORMATION TECHNOLO	3.33%	33,300	32,647	32,039	608
CHINA NATURAL RESOURCES INC	5.00%	50,000	49,834	49,120	714
CHINA TECHNOLOGY DEVELOPMENT	1.67%	16,700	16,640	16,417	223
CHINA AUTOMOTIVE SYSTEMS INC	1.67%	16,700	16,660	16,658	2
Portfolio		1,000,000	998,483	996,462	2,021

\$10M Portfolio (liq cost = 1.74%)

stock id	weight	M (= mid MtM)	U (= bid/ask MtM)	L (=Liquidation Value)	C=U-L (Liquidation Cost)
dollar	0.00%	-	-	-	-
COMCAST CORP-CLASS A	7.53%	753,000	752,784	752,720	64
EXXON MOBIL CORP	4.69%	469,000	468,965	468,959	6
GOLDMAN SACHS GROUP INC	4.04%	404,000	403,988	403,982	7
HEWLETT-PACKARD CO	3.75%	375,000	374,964	374,956	8
INTEL CORP	3.48%	348,000	347,918	347,912	6
PROCTER & GAMBLE CO/THE	3.34%	334,000	333,974	333,969	5
CHEVRON CORP	3.32%	332,000	331,977	331,971	6
MICROSOFT CORP	3.22%	322,000	321,945	321,941	4
WALT DISNEY CO/THE	4.82%	482,000	481,928	481,908	21
INTL BUSINESS MACHINES CORP	3.09%	309,000	308,964	308,959	5
NEWS CORP-CL A	3.09%	309,000	308,890	308,872	18
ABBOTT LABORATORIES	2.86%	286,000	285,974	285,968	6
CONOCOPHILLIPS	2.09%	209,000	208,980	208,975	4
DISCOVERY COMMUNICATIONS-C	2.00%	200,000	199,896	199,854	42
JOHNSON & JOHNSON	1.81%	181,000	180,986	180,984	1
TEXAS INSTRUMENTS INC	1.59%	159,000	158,967	158,963	4
LIBERTY GLOBAL INC-A	1.56%	156,000	155,972	155,954	18
DIRECTV-CLASS A	1.40%	140,000	139,980	139,977	3
TELEPHONE AND DATA SYSTEMS	1.25%	125,000	124,945	124,917	29
BROADCOM CORP-CL A	1.22%	122,000	121,963	121,959	4
DEVON ENERGY CORPORATION	1.24%	124,000	123,991	123,987	4
SCHLUMBERGER LTD	1.22%	122,000	121,981	121,979	2
BROWN-FORMAN CORP-CLASS B	1.20%	120,000	119,968	119,949	18
AT&T INC	1.15%	115,000	114,978	114,977	1
OCCIDENTAL PETROLEUM CORP	1.15%	115,000	114,979	114,977	2
YAHOO! INC	1.12%	112,000	111,966	111,963	2
CHIPOTLE MEXICAN GRILL INC	1.10%	110,000	109,976	109,967	9
CBS CORP-CLASS B NON VOTING	3.33%	333,000	332,886	332,845	41
GANNETT CO	6.67%	667,000	666,790	666,514	276
OMNICOM GROUP	3.33%	333,000	332,958	332,928	30
NEWS CORP-CLASS B	1.67%	167,000	166,899	166,879	20
CHINA ARCHITECTURAL ENGINEER	5.00%	500,000	495,690	457,988	37,701
EFUTURE INFORMATION TECHNOLO	3.33%	333,000	326,471	273,515	52,955
CHINA NATURAL RESOURCES INC	5.00%	500,000	498,339	434,629	63,710
CHINA TECHNOLOGY DEVELOPMENT	1.67%	167,000	166,401	147,149	19,253
CHINA AUTOMOTIVE SYSTEMS INC	1.67%	167,000	166,595	166,513	83
Portfolio		10,000,000	9,984,827	9,810,456	174,370

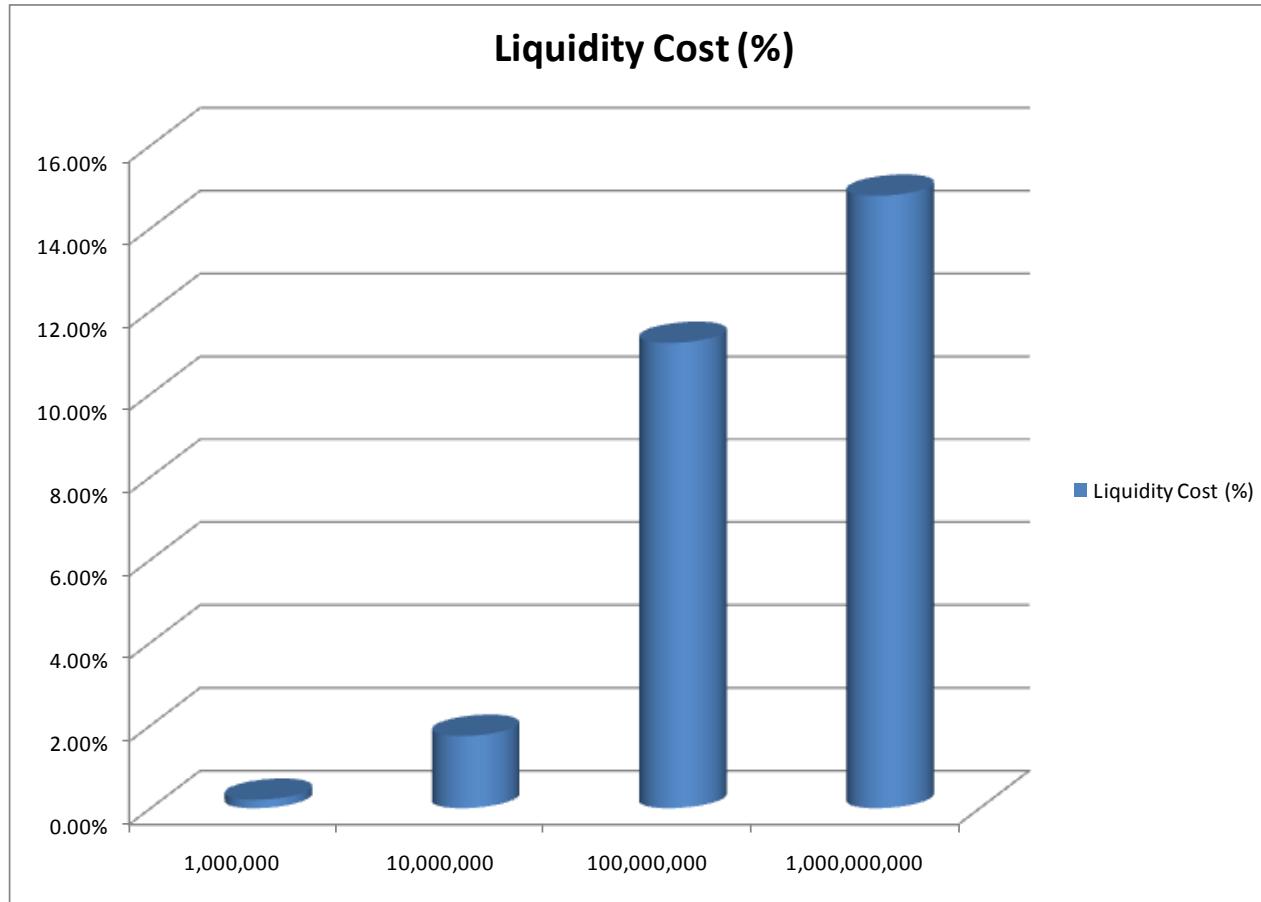
\$100M Portfolio (liq cost = 11.23%)

stock id	weight	M (= mid MtM)	U (= bid/ask MtM)	L (=Liquidation Value)	C=U-L (Liquidation Cost)
dollar	0.00%	-	-	-	-
COMCAST CORP-CLASS A	7.53%	7,530,000	7,527,839	7,524,391	3,448
EXXON MOBIL CORP	4.69%	4,690,000	4,689,649	4,689,356	293
GOLDMAN SACHS GROUP INC	4.04%	4,040,000	4,039,885	4,039,579	306
HEWLETT-PACKARD CO	3.75%	3,750,000	3,749,642	3,749,230	412
INTEL CORP	3.48%	3,480,000	3,479,182	3,478,878	304
PROCTER & GAMBLE CO/THE	3.34%	3,340,000	3,339,736	3,339,483	253
CHEVRON CORP	3.32%	3,320,000	3,319,775	3,319,478	297
MICROSOFT CORP	3.22%	3,220,000	3,219,450	3,219,265	185
WALT DISNEY CO/THE	4.82%	4,820,000	4,819,285	4,818,209	1,076
INTL BUSINESS MACHINES CORP	3.09%	3,090,000	3,089,638	3,089,383	255
NEWS CORP-CL A	3.09%	3,090,000	3,088,898	3,087,972	927
ABBOTT LABORATORIES	2.86%	2,860,000	2,859,738	2,859,423	315
CONOCOPHILLIPS	2.09%	2,090,000	2,089,798	2,089,582	216
DISCOVERY COMMUNICATIONS-C	2.00%	2,000,000	1,998,956	1,996,388	2,568
JOHNSON & JOHNSON	1.81%	1,810,000	1,809,859	1,809,788	71
TEXAS INSTRUMENTS INC	1.59%	1,590,000	1,589,669	1,589,478	191
LIBERTY GLOBAL INC-A	1.56%	1,560,000	1,559,725	1,558,757	967
DIRECTV-CLASS A	1.40%	1,400,000	1,399,799	1,399,654	145
TELEPHONE AND DATA SYSTEMS	1.25%	1,250,000	1,249,453	1,247,639	1,814
BROADCOM CORP-CL A	1.22%	1,220,000	1,219,626	1,219,449	178
DEVON ENERGY CORPORATION	1.24%	1,240,000	1,239,912	1,239,730	182
SCHLUMBERGER LTD	1.22%	1,220,000	1,219,811	1,219,734	77
BROWN-FORMAN CORP-CLASS B	1.20%	1,200,000	1,199,675	1,198,518	1,157
AT&T INC	1.15%	1,150,000	1,149,775	1,149,732	43
OCCIDENTAL PETROLEUM CORP	1.15%	1,150,000	1,149,789	1,149,686	103
YAHOO! INC	1.12%	1,120,000	1,119,657	1,119,552	105
CHIPOTLE MEXICAN GRILL INC	1.10%	1,100,000	1,099,761	1,099,276	485
CBS CORP-CLASS B NON VOTING	3.33%	3,330,000	3,328,859	3,326,698	2,161
GANNETT CO	6.67%	6,670,000	6,667,902	6,652,205	15,697
OMNICOM GROUP	3.33%	3,330,000	3,329,577	3,327,896	1,680
NEWS CORP-CLASS B	1.67%	1,670,000	1,668,989	1,667,859	1,130
CHINA ARCHITECTURAL ENGINEER	5.00%	5,000,000	4,956,897	1,769,882	3,187,015
EFINITE INFORMATION TECHNOLO	3.33%	3,330,000	3,264,706	522,225	2,742,480
CHINA NATURAL RESOURCES INC	5.00%	5,000,000	4,983,389	1,009,104	3,974,284
CHINA TECHNOLOGY DEVELOPMENT	1.67%	1,670,000	1,664,014	377,663	1,286,351
CHINA AUTOMOTIVE SYSTEMS INC	1.67%	1,670,000	1,665,953	1,661,427	4,526
Portfolio		100,000,000	99,848,267	88,616,568	11,231,698

\$1B Portfolio (liq cost = 14.78 %)

stock id	weight	M (= mid MtM)	U (= bid/ask MtM)	L (=Liquidation Value)	C=U-L (Liquidation Cost)
dollar	0.00%	-	-	-	-
COMCAST CORP-CLASS A	7.53%	75,300,000	75,278,393	75,051,951	226,442
EXXON MOBIL CORP	4.69%	46,900,000	46,896,488	46,880,034	16,454
GOLDMAN SACHS GROUP INC	4.04%	40,400,000	40,398,846	40,383,210	15,636
HEWLETT-PACKARD CO	3.75%	37,500,000	37,496,421	37,472,165	24,256
INTEL CORP	3.48%	34,800,000	34,791,821	34,775,216	16,605
PROCTER & GAMBLE CO/THE	3.34%	33,400,000	33,397,363	33,382,146	15,218
CHEVRON CORP	3.32%	33,200,000	33,197,749	33,180,416	17,334
MICROSOFT CORP	3.22%	32,200,000	32,194,499	32,184,453	10,045
WALT DISNEY CO/THE	4.82%	48,200,000	48,192,850	48,124,457	68,392
INTL BUSINESS MACHINES CORP	3.09%	30,900,000	30,896,378	30,881,454	14,923
NEWS CORP-CL A	3.09%	30,900,000	30,888,984	30,832,308	56,676
ABBOTT LABORATORIES	2.86%	28,600,000	28,597,379	28,577,896	19,483
CONOCOPHILLIPS	2.09%	20,900,000	20,897,979	20,885,573	12,406
DISCOVERY COMMUNICATIONS-C	2.00%	20,000,000	19,989,556	19,797,130	192,426
JOHNSON & JOHNSON	1.81%	18,100,000	18,098,590	18,094,558	4,032
TEXAS INSTRUMENTS INC	1.59%	15,900,000	15,896,687	15,886,048	10,639
LIBERTY GLOBAL INC-A	1.56%	15,600,000	15,597,246	15,534,722	62,524
DIRECTV-CLASS A	1.40%	14,000,000	13,997,992	13,989,830	8,162
TELEPHONE AND DATA SYSTEMS	1.25%	12,500,000	12,494,531	12,355,480	139,051
BROADCOM CORP-CL A	1.22%	12,200,000	12,196,262	12,186,675	9,587
DEVON ENERGY CORPORATION	1.24%	12,400,000	12,399,120	12,388,729	10,391
SCHLUMBERGER LTD	1.22%	12,200,000	12,198,111	12,194,146	3,964
BROWN-FORMAN CORP-CLASS B	1.20%	12,000,000	11,996,752	11,906,824	89,928
AT&T INC	1.15%	11,500,000	11,497,754	11,495,404	2,350
OCCIDENTAL PETROLEUM CORP	1.15%	11,500,000	11,497,890	11,492,164	5,726
YAHOO! INC	1.12%	11,200,000	11,196,568	11,190,894	5,673
CHIPOTLE MEXICAN GRILL INC	1.10%	11,000,000	10,997,607	10,966,977	30,630
CBS CORP-CLASS B NON VOTING	3.33%	33,300,000	33,288,592	33,151,131	137,461
GANNETT CO	6.67%	66,700,000	66,679,019	65,582,531	1,096,488
OMNICOM GROUP	3.33%	33,300,000	33,295,767	33,180,555	115,212
NEWS CORP-CLASS B	1.67%	16,700,000	16,689,891	16,609,897	79,994
CHINA ARCHITECTURAL ENGINEER	5.00%	50,000,000	49,568,966	1,769,882	47,799,084
EFINAL INFORMATION TECHNOLO	3.33%	33,300,000	32,647,059	522,225	32,124,833
CHINA NATURAL RESOURCES INC	5.00%	50,000,000	49,833,887	1,009,104	48,824,783
CHINA TECHNOLOGY DEVELOPMENT	1.67%	16,700,000	16,640,143	377,663	16,262,480
CHINA AUTOMOTIVE SYSTEMS INC	1.67%	16,700,000	16,659,529	16,355,808	303,720
Portfolio		1,000,000,000	998,482,668	850,649,658	147,833,010

Scale Effects



Outline

- Introduction to Mark-to-Liquidity (MtL)
- Liquidity Risk of an equity portfolio
 - Exogenous risk
 - Portfolio Value as a function of its Liquidity Policy
 - examples
- Properties of MtL in illiquid markets
 - Non-additivity
 - Concavity
 - Granularity effect
 - The added value of Liquidity

What is the Value of the Portfolio ?

- With MtL the **value of a portfolio** depends intrinsically on the liquidity constraints it is subject to, in short on its Liquidity Policy (LP)
- **An LP is the set of constraints the portfolio should be prepared to face.** These are of two kinds
 - Minimal limits of cash available
 - Maximal limits on risk (measured by any risk measure)
- The **value of a portfolio p given an LP** is the result of an optimization: **maximize the U-value of possible portfolios which are attainable from p and satisfy the LP**

... it Depends on the Constraints Used!

- One can show that defining in this way the value of a portfolio, **U and L are nothing but the two extreme cases**
 - “*you don’t need to be prepared to liquidate anything*” (U)
 - “*you need to be prepared to liquidate everything*” (L)
- A general LP formalizes any realistic case in between these two extremes
- The **convexity** of the optimization problem is fundamental for implementations on large and complex portfolios

Example: ‘Cash’ LP

- In the following slides the portfolio size is fixed at \$100M
- The portfolio value is studied imposing **cash constraints** of increasing severity
- ‘Long-only’ constraints are imposed by default, hereafter
- The example describes the case of a long only equity fund subject to possible future liquidations of different estimated amount

Optimal Portfolios (Cash LP)

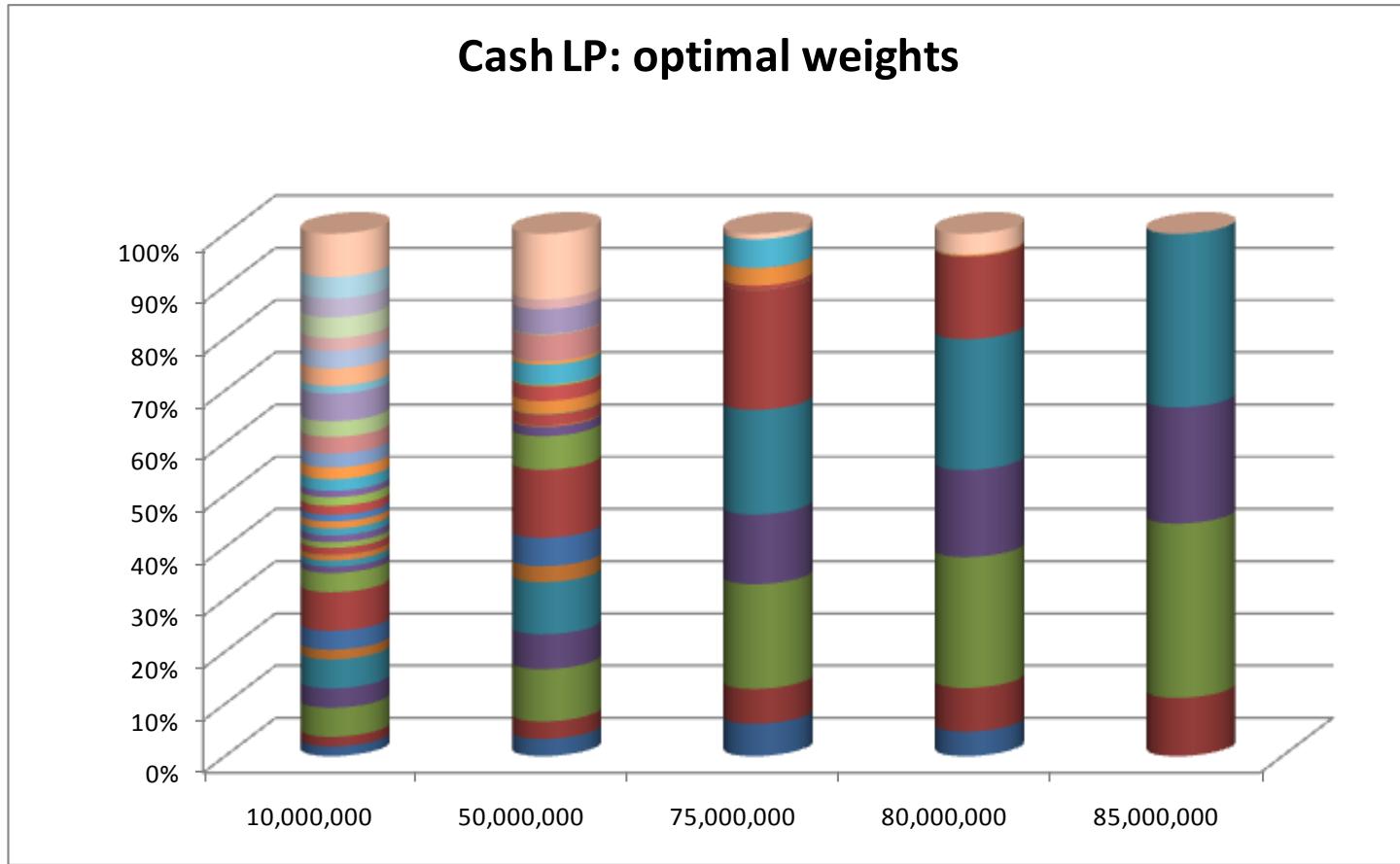
cash limit	10,000,000	50,000,000	75,000,000	80,000,000	85,000,000
	optimal portf				
dollar	10,000,000	50,032,615	75,015,083	80,000,005	85,000,000
COMCAST CORP-CLASS A	428,747	360,332	15,234	45,387	1
EXXON MOBIL CORP	55,214	16	19	12	1
GOLDMAN SACHS GROUP INC	18,633	1	1	0	0
HEWLETT-PACKARD CO	67,499	0	2	2	0
INTEL CORP	105,255	44,072	0	0	0
PROCTER & GAMBLE CO/THE	47,762	0	0	0	0
CHEVRON CORP	40,503	1	33	104	0
MICROSOFT CORP	46,868	1	0	0	0
WALT DISNEY CO/THE	140,266	70,633	0	121	0
INTL BUSINESS MACHINES CORP	21,009	565	19	24	0
NEWS CORP-CL A	205,592	176,050	11	0	0
ABBOTT LABORATORIES	43,922	1,056	44	1	1
CONOCOPHILLIPS	39,255	6,384	1	21	0
DISCOVERY COMMUNICATIONS-C	69,503	66,094	47,232	4	1
JOHNSON & JOHNSON	17,037	30	75	17	1
TEXAS INSTRUMENTS INC	61,943	6,008	71	9	0
LIBERTY GLOBAL INC-A	54,940	50,330	0	2	0
DIRECTV-CLASS A	31,963	4	1	1	0
TELEPHONE AND DATA SYSTEMS	36,250	34,612	24,526	1,440	1
BROADCOM CORP-CL A	36,484	10	16	2	0
DEVON ENERGY CORPORATION	16,560	1	9	1	0
SCHLUMBERGER LTD	15,099	1,479	0	8	2
BROWN-FORMAN CORP-CLASS B	21,551	19,241	3,725	34	0
AT&T INC	288	2	53	2	0
OCCIDENTAL PETROLEUM CORP	12,101	1,439	18	28	3
YAHOO! INC	65,665	1	0	12	1
CHIPOTLE MEXICAN GRILL INC	9,270	7,822	0	0	0
CBS CORP-CLASS B NON VOTING	226,186	219,496	1,100	543	10
GANNETT CO	419,485	409,844	359,051	198,306	1
OMNICOM GROUP	82,360	68,975	68	38	0
NEWS CORP-CLASS B	101,035	91,920	0	88	1
CHINA ARCHITECTURAL ENGINEER	4,310,282	4,309,977	4,308,721	4,310,116	4,280,524
EFUTURE INFORMATION TECHNOLO	522,353	522,314	522,227	522,146	521,075
CHINA NATURAL RESOURCES INC	415,281	415,254	415,282	415,044	413,958
CHINA TECHNOLOGY DEVELOPMENT	598,566	598,413	598,419	598,470	596,618
CHINA AUTOMOTIVE SYSTEMS INC	73,508	72,461	67,924	41,155	0

Portfolio Value (Cash LP)

CASH ONLY LP					
cash limit	10,000,000	50,000,000	75,000,000	80,000,000	85,000,000
U	99,848,267	99,848,267	99,848,267	99,848,267	99,848,267
Value	99,847,964	99,843,832	99,830,741	99,821,612	99,806,320
L	88,616,568	88,616,568	88,616,568	88,616,568	88,616,568
U-V	303	4,435	17,526	26,655	41,947
(U-V)/(U-L)	0.0027%	0.0395%	0.1560%	0.2373%	0.3735%
VaR %	7.39%	9.60%	12.50%	13.11%	14.23%

- Observations
 - Liquidity costs seem moderate
- However
 - The optimization liquidates the most liquid assets first
 - The remaining portfolio is concentrated in most illiquid and volatile stocks
 - The final portfolio risk is much higher (Value at Risk (VaR) jumps from 7.08% to 14.23%)

Optimal Weights (Cash LP)



Example: Cash Limits + VaR Limits

- As a second example, a further constraint is added to the LP, by imposing to the residual portfolio a **VaR not larger than 7.5%**
- This constraint rules out solutions concentrated in most volatile stocks
- Original VaR = 7.08%. VaR is varcov gaussian with confidence level 1% and time horizon 5 days

Optimal Portfolios (Cash + VaR LP)

cash limit	10,000,000	50,000,000	75,000,000	80,000,000	85,000,000
	optimal portf				
dollar	10,000,000	50,000,000	75,000,000	80,000,000	85,000,000
COMCAST CORP-CLASS A	426,237	219,511	1	0	-
EXXON MOBIL CORP	53,645	2,257	1	16,375	(0)
GOLDMAN SACHS GROUP INC	19,066	0	(0)	0	0
HEWLETT-PACKARD CO	63,354	0	0	(0)	(0)
INTEL CORP	137,989	1	1	(0)	(0)
PROCTER & GAMBLE CO/THE	42,876	52,735	52,735	14,034	(0)
CHEVRON CORP	38,185	1	0	0	(0)
MICROSOFT CORP	83,992	87,088	2	2	-
WALT DISNEY CO/THE	136,298	57,835	1	(0)	0
INTL BUSINESS MACHINES CORP	20,147	24,147	14,075	0	(0)
NEWS CORP-CL A	214,680	32	0	0	0
ABBOTT LABORATORIES	46,572	52,424	52,424	52,424	52,424
CONOCOPHILLIPS	36,362	159	0	(0)	(0)
DISCOVERY COMMUNICATIONS-C	69,302	64,327	0	0	0
JOHNSON & JOHNSON	14,068	28,209	28,209	28,209	8,500
TEXAS INSTRUMENTS INC	59,374	1,521	0	(0)	(0)
LIBERTY GLOBAL INC-A	54,788	16,267	0	0	0
DIRECTV-CLASS A	35,315	8,227	0	0	(0)
TELEPHONE AND DATA SYSTEMS	36,280	35,180	0	(0)	(0)
BROADCOM CORP-CL A	34,597	0	0	(0)	0
DEVON ENERGY CORPORATION	15,661	10	0	0	(0)
SCHLUMBERGER LTD	15,017	1	(0)	(0)	(0)
BROWN-FORMAN CORP-CLASS B	21,546	21,655	21,655	21,655	3,830
AT&T INC	19,961	44,913	44,913	19,342	0
OCCIDENTAL PETROLEUM CORP	11,926	2	0	(0)	0
YAHOO! INC	59,072	12,580	0	-	0
CHIPOTLE MEXICAN GRILL INC	284	5,108	(0)	(0)	0
CBS CORP-CLASS B NON VOTING	227,054	41,565	0	(0)	(0)
GANNETT CO	419,105	257,265	0	0	(0)
OMNICOM GROUP	83,501	63,562	0	(0)	0
NEWS CORP-CLASS B	99,995	0	0	0	0
CHINA ARCHITECTURAL ENGINEER	4,310,345	4,301,836	2,726,727	1,499,571	313,447
EFUTURE INFORMATION TECHNOLO	522,352	522,305	485,046	421,073	239,264
CHINA NATURAL RESOURCES INC	415,282	415,151	366,747	298,117	152,814
CHINA TECHNOLOGY DEVELOPMENT	598,565	598,320	524,733	445,589	292,639
CHINA AUTOMOTIVE SYSTEMS INC	73,505	54,195	(0)	0	0

Portfolio Value (Cash + VaR LP)

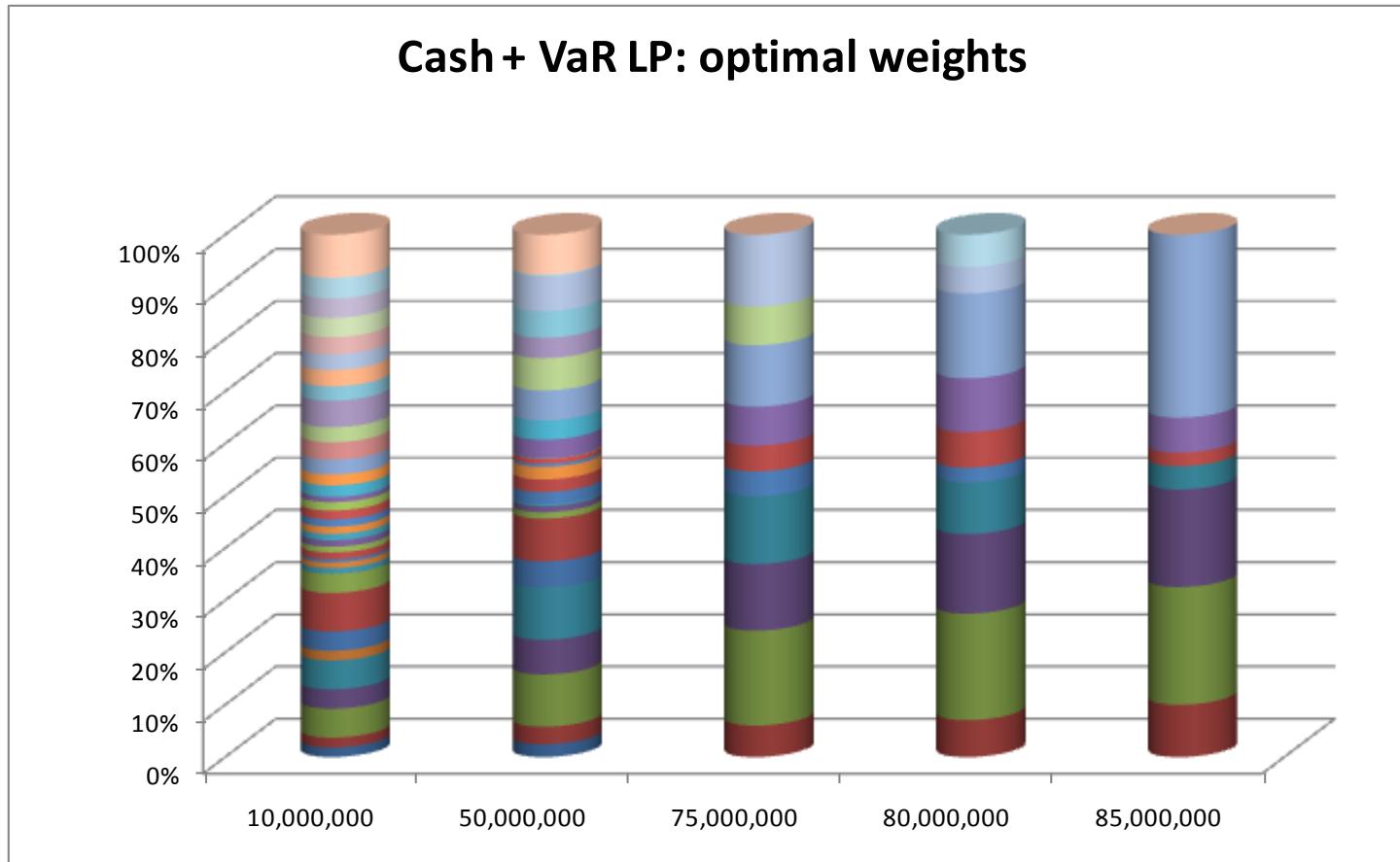
CASH + VaR LP					
cash limit	10,000,000	50,000,000	75,000,000	80,000,000	85,000,000
U	99,848,267	99,848,267	99,848,267	99,848,267	99,848,267
Value	99,847,593	99,836,366	99,186,844	97,518,837	93,120,431
L	88,616,568	88,616,568	88,616,568	88,616,568	88,616,568
U-V	674	11,901	661,423	2,329,430	6,727,836
(U-V)/(U-L)	0.0060%	0.1060%	5.8889%	20.7398%	59.9004%
VaR %	7.37%	7.50%	7.50%	7.50%	7.50%

- To be compared with

CASH ONLY LP					
cash limit	10,000,000	50,000,000	75,000,000	80,000,000	85,000,000
U	99,848,267	99,848,267	99,848,267	99,848,267	99,848,267
Value	99,847,964	99,843,832	99,830,741	99,821,612	99,806,320
L	88,616,568	88,616,568	88,616,568	88,616,568	88,616,568
U-V	303	4,435	17,526	26,655	41,947
(U-V)/(U-L)	0.0027%	0.0395%	0.1560%	0.2373%	0.3735%
VaR %	7.39%	9.60%	12.50%	13.11%	14.23%

- Imposing VaR constraints, determines a considerable impact on portfolio value

Optimal weights (Cash + VaR LP)



Example: Cash Limits + VaR Limits + Linear Limits

- In the following slides, a **concentration constraint is added that the most illiquid stocks** (i.e. “the last 5”) **should not exceed 20%** of the portfolio size
- This constraint forces further liquidation of illiquid assets
- The residual portfolio will have better liquidity and diversification properties, at the price of a larger impact on the portfolio value

Optimal Portfolios (Cash + VaR + Linear LP)

cash limit	10,000,000	50,000,000	80,000,000	85,000,000	85,000,000
	optimal portf				
dollar	10,000,000	50,000,000	75,000,000	80,000,000	85,000,000
COMCAST CORP-CLASS A	426,300	320,336	1,414	39	0
EXXON MOBIL CORP	56,246	369	1	1	379
GOLDMAN SACHS GROUP INC	19,556	75	0	0	0
HEWLETT-PACKARD CO	65,813	1	1	5	28
INTEL CORP	142,307	7	4	5	0
PROCTER & GAMBLE CO/THE	42,632	44,116	21,299	3	1,888
CHEVRON CORP	37,626	18	1,601	0	20
MICROSOFT CORP	77,467	451	3,963	402	1,681
WALT DISNEY CO/THE	138,224	82,296	1	0	140
INTL BUSINESS MACHINES CORP	20,513	19,138	1,269	0	4,957
NEWS CORP-CL A	215,358	55,387	170	7	343
ABBOTT LABORATORIES	46,899	52,424	27,514	49,406	2
CONOCOPHILLIPS	35,055	297	83	1	4
DISCOVERY COMMUNICATIONS-C	69,466	67,739	57,968	2,350	30,866
JOHNSON & JOHNSON	3,998	27,179	4,002	5,047	2
TEXAS INSTRUMENTS INC	61,018	9	0	4	126
LIBERTY GLOBAL INC-A	54,621	38,424	1,285	1	177
DIRECTV-CLASS A	37,244	26,617	94	4	705
TELEPHONE AND DATA SYSTEMS	36,167	35,524	33,248	30,227	472
BROADCOM CORP-CL A	35,097	58	23,819	1	315
DEVON ENERGY CORPORATION	16,520	82	1	8	(0)
SCHLUMBERGER LTD	15,663	2	915	0	503
BROWN-FORMAN CORP-CLASS B	21,492	21,636	21,250	19,796	16,290
AT&T INC	22,742	828	1,535	2	654
OCCIDENTAL PETROLEUM CORP	12,515	1	0	2	38
YAHOO! INC	59,493	35	0	71	143
CHIPOTLE MEXICAN GRILL INC	497	7,899	2,051	889	1,034
CBS CORP-CLASS B NON VOTING	226,681	144,447	25,782	5,234	4,105
GANNETT CO	418,880	362,538	150,875	139,450	40,500
OMNICOM GROUP	82,962	71,786	41,861	12,732	1,434
NEWS CORP-CLASS B	100,138	79,393	33,149	30,265	5
CHINA ARCHITECTURAL ENGINEER	4,310,333	2,063,864	373,397	41	164,216
EFUTURE INFORMATION TECHNOLO	522,352	399,434	8	1	1,415
CHINA NATURAL RESOURCES INC	415,280	293,385	227,320	145,994	58,666
CHINA TECHNOLOGY DEVELOPMENT	598,563	401,345	85,741	143,371	0
CHINA AUTOMOTIVE SYSTEMS INC	73,513	(0)	(0)	(0)	0

Portfolio Values (Cash + VaR + linear LP)

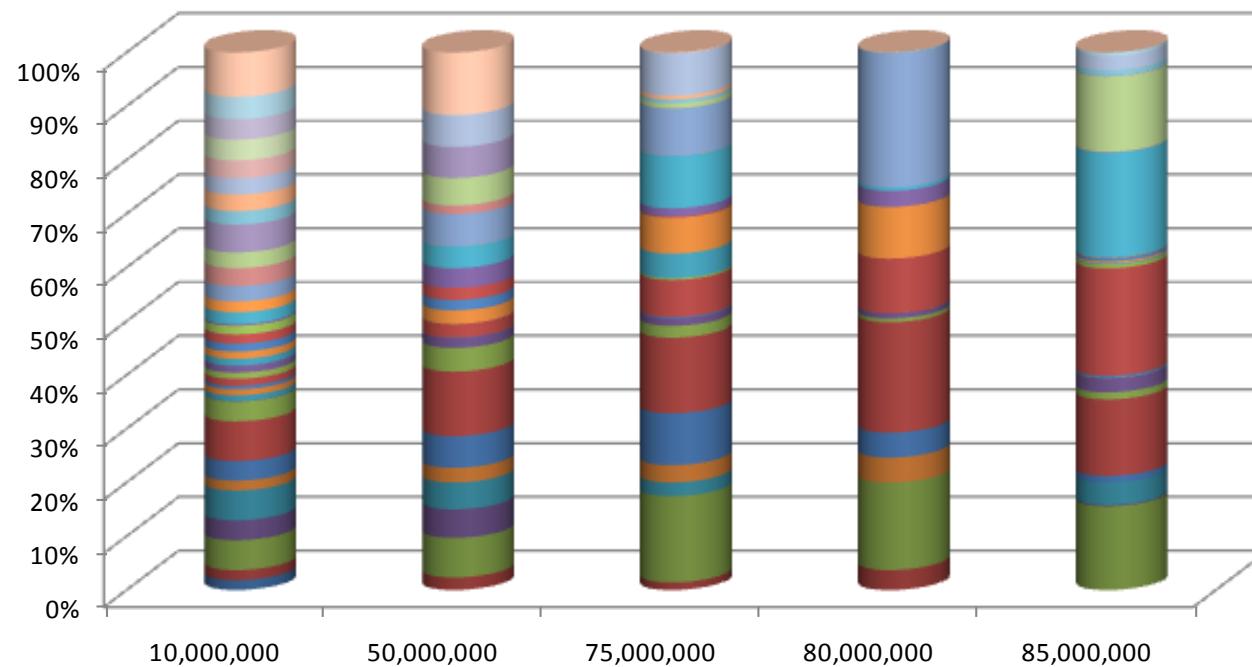
CASH + VaR + linear LP					
cash limit	10,000,000	50,000,000	75,000,000	80,000,000	85,000,000
U	99,848,267	99,848,267	99,848,267	99,848,267	99,848,267
Value	99,847,602	97,867,301	92,029,258	90,779,706	89,524,001
L	88,616,568	88,616,568	88,616,568	88,616,568	88,616,568
U-V	665	1,980,966	7,819,009	9,068,561	10,324,266
(U-V)/(U-L)	0.0059%	17.6373%	69.6155%	80.7408%	91.9208%
VaR %	7.40%	7.50%	7.50%	7.50%	7.50%

to be compared with

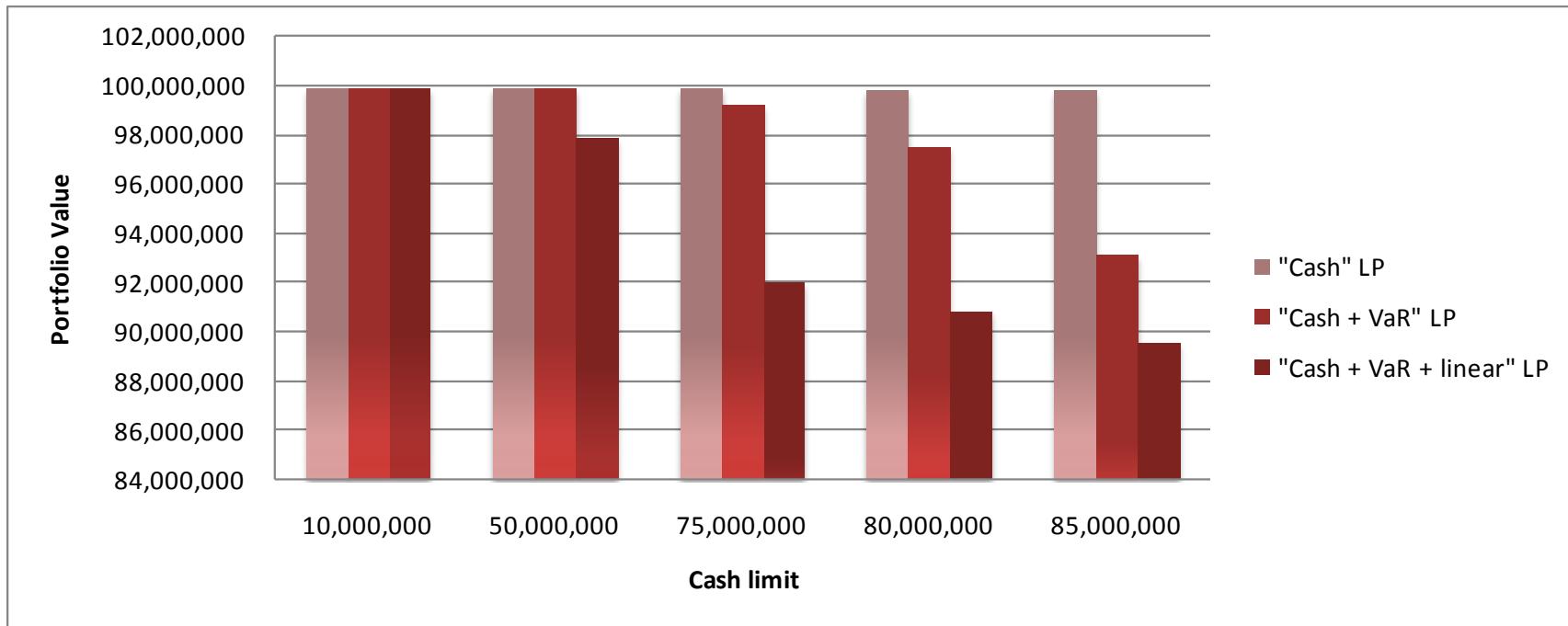
CASH + VaR LP					
cash limit	10,000,000	50,000,000	75,000,000	80,000,000	85,000,000
U	99,848,267	99,848,267	99,848,267	99,848,267	99,848,267
Value	99,847,593	99,836,366	99,186,844	97,518,837	93,120,431
L	88,616,568	88,616,568	88,616,568	88,616,568	88,616,568
U-V	674	11,901	661,423	2,329,430	6,727,836
(U-V)/(U-L)	0.0060%	0.1060%	5.8889%	20.7398%	59.9004%
VaR %	7.37%	7.50%	7.50%	7.50%	7.50%

Optimal Weights (Cash + VaR + Linear LP)

Cash + VaR + linear LP: optimal weights



Comparison Among Different LPs



Outline

- Introduction to Mark-to-Liquidity (MtL)
- Liquidity Risk of an equity portfolio
 - Exogenous risk
 - Portfolio Value as a function of its Liquidity Policy
 - examples
- Properties of MtL in illiquid markets
 - Non-additivity
 - Concavity
 - Granularity effect
 - The added value of Liquidity

Non-linearity of MtL

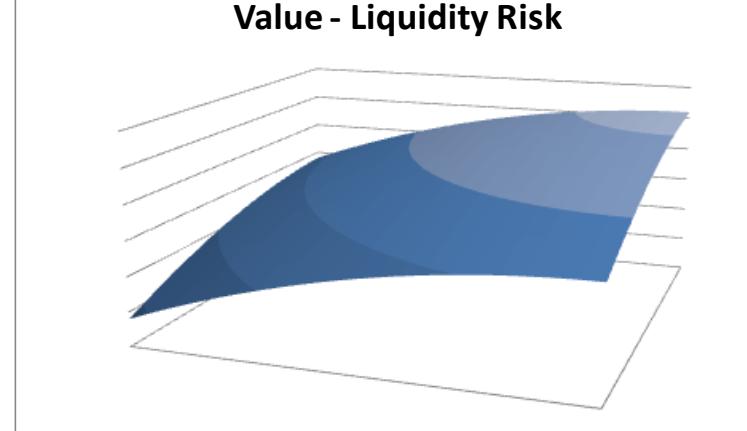
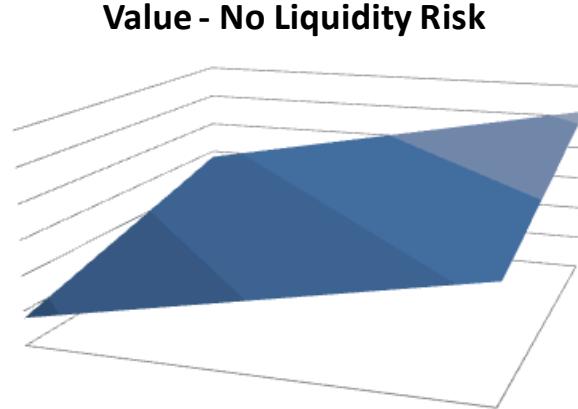
- The function $V^L(p)$ is no longer linear in p
- In general, fixing L

$$V^L(\alpha p + \beta q) \neq \alpha V^L(p) + \beta V^L(q)$$

- Many properties taken for granted no longer hold
 - The value of sum of two portfolios is not the sum of the two values
 - A two times larger portfolio is not worth twice
 - The value of a portfolio is no more simply the sum of its assets' values

Non-linearity of the Value Function

- Actually, it's exactly the non-linearity of the value function that detects the presence of liquidity risk
- In the limit of vanishing liquidity risk (ex: flat MSDCs, tiny portfolios, ...) the function $V^L(p)$ reduces to a linear function in p



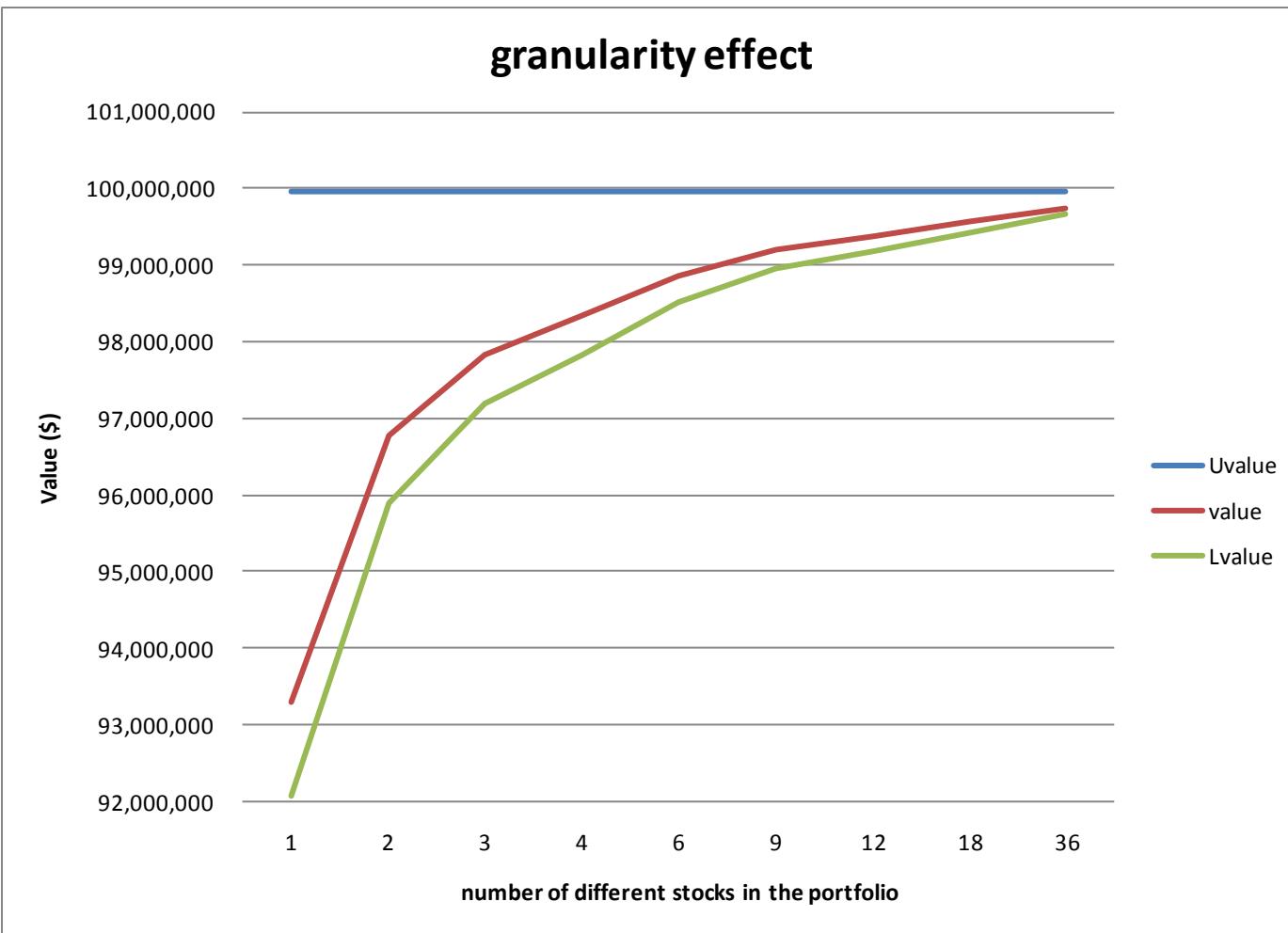
Granularity Effect

- In all generality it's clear that **the more granular a portfolio** (namely the more fragmented into many different assets) **the less its liquidity risk is**
- MtL describes correctly this effect, which is not captured by standard accounting at all
- Correct formalization of a well known fact, never formalized so far
- Do not confuse **granularity effect** with **diversification principle** associated to assets correlations. The former is a purely liquidity effect on current portfolio value, which has nothing to do with future asset distributions

Example: Granularity Effect

- Consider a portfolio equally weighted in N stocks with identical exogenous liquidity
- Assigning an LP, let's study the portfolio value as a function of N , namely its granularity
- The following example shows a \$100M portfolio investing in hypothetical stocks with msdc identical to the one of TDS.US and a “cash” LP with limit \$85M

Granularity effect



Concavity of the Value Function

- Blending two portfolios always improves granularity. In an illiquid market **the value of a “blended portfolio” should display a liquidity benefit**
- MtL captures this phenomenon: if $\alpha \in (0, 1)$

$$V^L(\alpha \mathbf{p} + (1 - \alpha) \mathbf{q}) \geq \alpha V^L(\mathbf{p}) + (1 - \alpha) V^L(\mathbf{q})$$

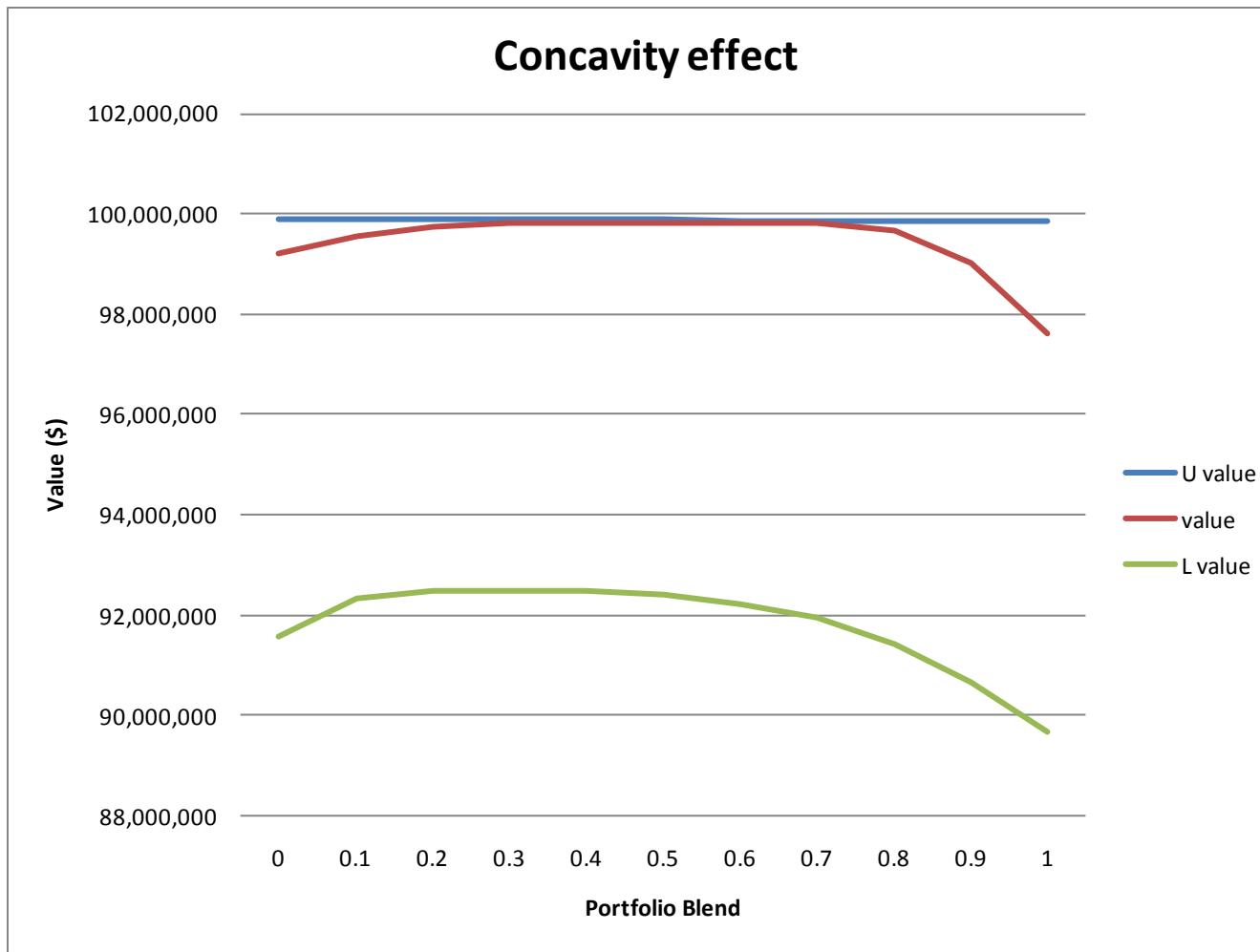
namely $V^L(\mathbf{p})$ is **concave** in \mathbf{p} whatever its LP

- In other words: **the value of the blend is higher than the blend of the values**
- Again: well known fact, never formalized before

Example: Concavity of Value

- In the portfolio, consider two subportfolios: “even” stocks and “odd” stocks, in the list
- Observe the portfolio value obtained when blending the even with the odd
- Size: \$100M. LP: \$85M minimal cash and $\text{VaR} < 7\%$

Concavity of Value



The Added Value of Liquidity

- Injecting cash improves a portfolio liquidity. Also in this case a liquidity benefit should be detected
- In general, given p and a cash amount $a > 0$ it's possible to show that

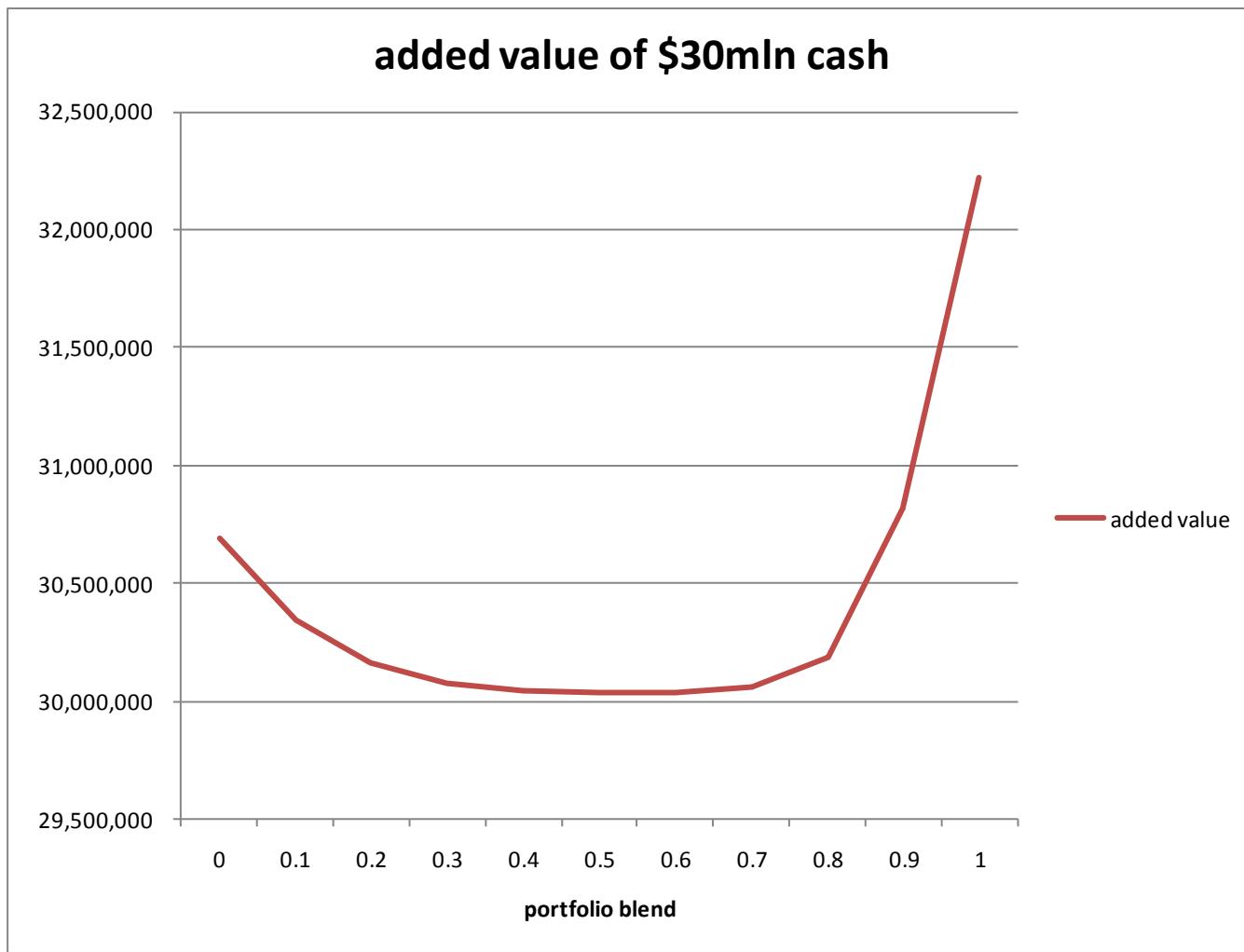
$$V^L(p + a) \geq V^L(p) + a$$

- Namely **an injection of quantity a of cash raises the portfolio value of a quantity generally larger than a**
- Once again an intuitive fact, never formalized before

Example: The Added Value of Liquidity

- In the blended portfolios of the previous example, measure the value impact produced by a \$30M cash injection
- The value increase is always larger than \$30M and is larger for more illiquid portfolios

The Added Value of Liquidity



An *Endogenous* Liquidity Risk ‘Heat Map’

- People don't really care about “how liquid a stock is in general”. They rather care about “how liquid it is for them”, namely given their portfolio/constraints
- To compare how liquid are the constituents of a portfolio, one can probe **what is the additional value provided by adding \$1 in each different stock**
- The resulting map, will yield a number
 - >1 for most liquid assets
 - <1 for most illiquid assets
- The resulting indicator will provide a natural **liquidity ranking** among all positions

Added Value of \$1 of a Chosen Stock

	lambda	lambda-1
dollar	1.021	2.06%
COMCAST CORP-CLASS A	1.021	2.06%
EXXON MOBIL CORP	1.021	2.06%
GOLDMAN SACHS GROUP INC	1.021	2.06%
HEWLETT-PACKARD CO	1.021	2.06%
INTEL CORP	1.021	2.06%
PROCTER & GAMBLE CO/THE	1.021	2.06%
CHEVRON CORP	1.021	2.06%
MICROSOFT CORP	1.021	2.06%
WALT DISNEY CO/THE	1.021	2.06%
INTL BUSINESS MACHINES CORP	1.021	2.06%
NEWS CORP-CL A	1.021	2.06%
ABBOTT LABORATORIES	1.021	2.06%
CONOCOPHILLIPS	1.021	2.06%
DISCOVERY COMMUNICATIONS-C	1.021	2.06%
JOHNSON & JOHNSON	1.021	2.06%
TEXAS INSTRUMENTS INC	1.021	2.06%
LIBERTY GLOBAL INC-A	1.021	2.05%
DIRECTV-CLASS A	1.021	2.06%
TELEPHONE AND DATA SYSTEMS	1.021	2.06%
BROADCOM CORP-CL A	1.021	2.06%
DEVON ENERGY CORPORATION	1.021	2.06%
SCHLUMBERGER LTD	1.021	2.06%
BROWN-FORMAN CORP-CLASS B	1.021	2.06%
AT&T INC	1.021	2.06%
OCCIDENTAL PETROLEUM CORP	1.021	2.06%
YAHOO! INC	1.021	2.06%
CHIPOTLE MEXICAN GRILL INC	1.020	2.05%
CBS CORP-CLASS B NON VOTING	1.021	2.05%
GANNETT CO	1.020	2.04%
OMNICOM GROUP	1.021	2.06%
NEWS CORP-CLASS B	1.021	2.05%
CHINA ARCHITECTURAL ENGINEER	0.945	-5.47%
EFUTURE INFORMATION TECHNOLO	0.945	-5.55%
CHINA NATURAL RESOURCES INC	0.946	-5.45%
CHINA TECHNOLOGY DEVELOPMENT	0.946	-5.44%
CHINA AUTOMOTIVE SYSTEMS INC	1.020	1.97%

Some Possible Applications

- Quantify the implicit cost of committing to redemptions liquidity, countering rush-to-the-exit behavior
- Quantify the implicit cost of meeting ongoing margin requirements
- Quantify the implicit cost of meeting Basel liquidity constraints
- Quantify liquidity stress tests rather than simply bucketing assets
- Describe and quantify market-liquidity interaction
- Find most efficient liquidation strategy while maintaining portfolio risk profile
- Map liquidity risk within a portfolio / institution
- Set a quantitative standard language for setting liquidity limits
- ...

Key Messages

- A new portfolio evaluation method is proposed that captures liquidity risk effects
- Liquidity risk arises from the joint presence of portfolio constraints and market (exogenous) illiquidity. Hence the need to express the dependence of the value on the portfolio LP
- The model is applicable to any portfolio. However the exogenous liquidity data for many asset classes may be difficult to find. Hypotheses are needed as well as additional empirical research
- The method is able to quantify correctly several well known phenomena that had never been formalized before.

References

- C. Acerbi, C. Finger, “The Value of Liquidity: can it be measured?”, RBC Dexia white paper, available on www.riskmetrics.com

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