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Liquidity-Adjusted VaR

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การประชุมวิชาการ “ศาสตราจารย์สังเวียน อินทรวิชัย
ด้านตลาดการเงินไทย”

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Outlines

-
-  **1 Standard VaR Model**.....●
 -  **2 Issues of Standard VaR Model**.....●
 -  **3 Adjustments of liquidity to VaR Model**.....●
 -  **4 Results of LVaR implementation**.....●
 -  **5 Summary**.....●
-



Re-visit standard VaR model/calculation – Analytical VaR

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- One among 3 approaches (Analytical VaR, Historical VaR and Monte Carlo simulation VaR), derived from closed form solutions
- The possible values of the market variables can be captured by Variance-Covariance Matrix (VCM) of the market returns, which can be computed by several approaches, such as simple, GARCH, EWMA volatility models.
- Historical market data (i.e. security prices) are required to calculate volatility of security or portfolio.



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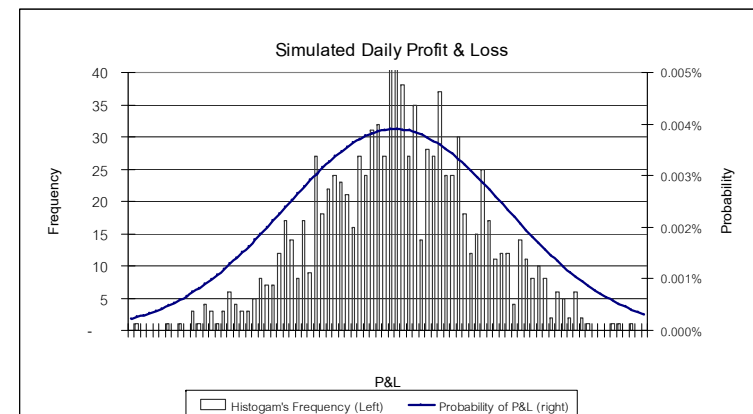
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Re-visit standard VaR model/calculation – Analytical VaR

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- Analytical VaR (Variance-Covariance)

$$VaR_{1-\alpha} = -Z_{\alpha} \sigma_p$$



$$\sigma_p = \sqrt{[W_1 \quad \dots \quad W_n] \begin{bmatrix} \sigma_{11} & \dots & \sigma_{1n} \\ \vdots & \ddots & \vdots \\ \sigma_{n1} & \dots & \sigma_{nn} \end{bmatrix} \begin{bmatrix} W_1 \\ \vdots \\ W_n \end{bmatrix}}$$



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Re-visit standard VaR model/calculation – Analytical VaR

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Confidential level of VaR is based on Z score

$$\text{VaR}_{1-\alpha} = -Z_{\alpha} \sigma$$

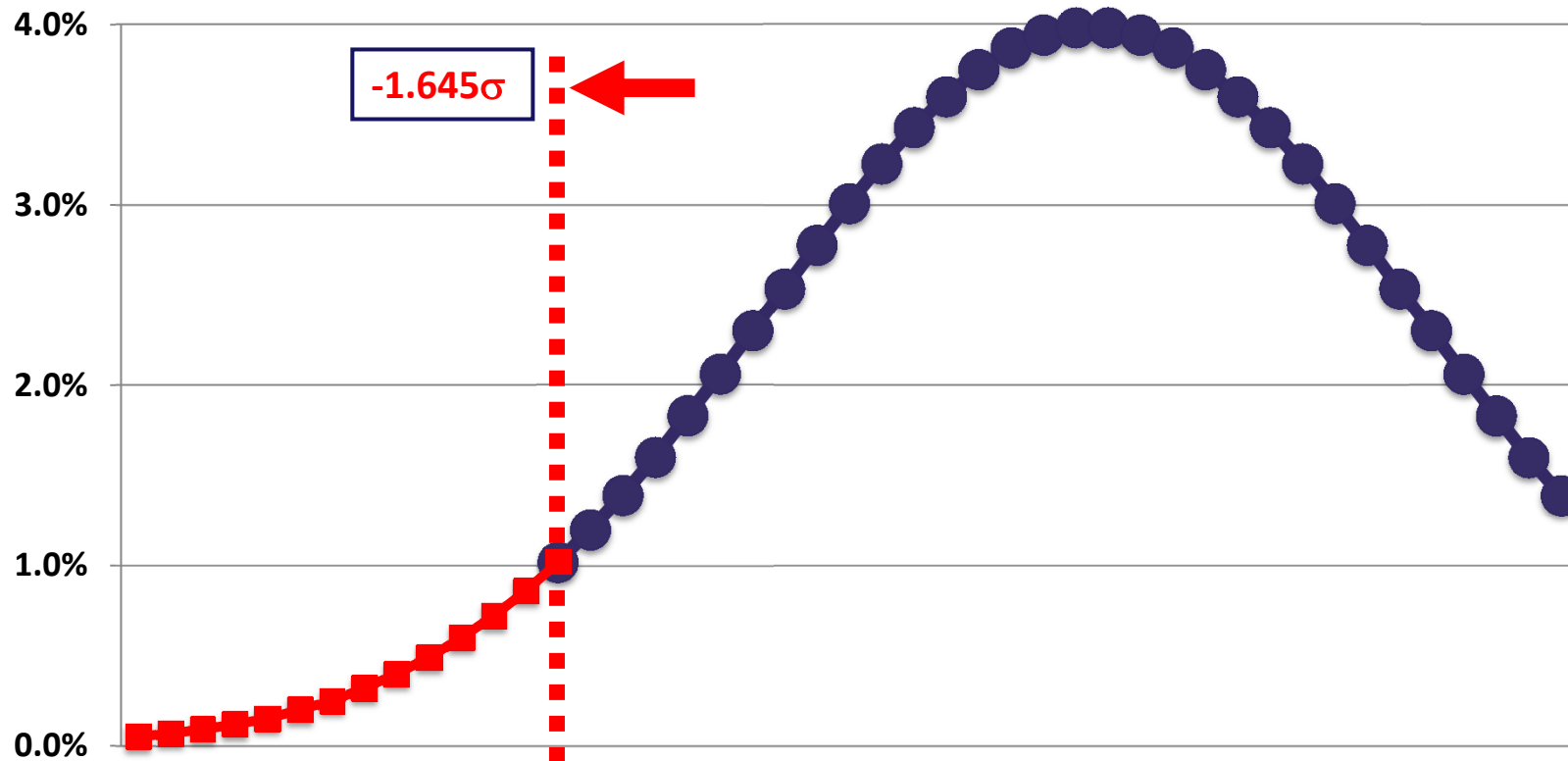
$$\text{VaR}_{95\%} = -(-1.645)\sigma$$

$$\text{VaR}_{99\%} = -(-2.33) \sigma$$

Re-visit standard VaR model/calculation – Analytical VaR

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One-Period VaR with 95% confidence (5% significance)



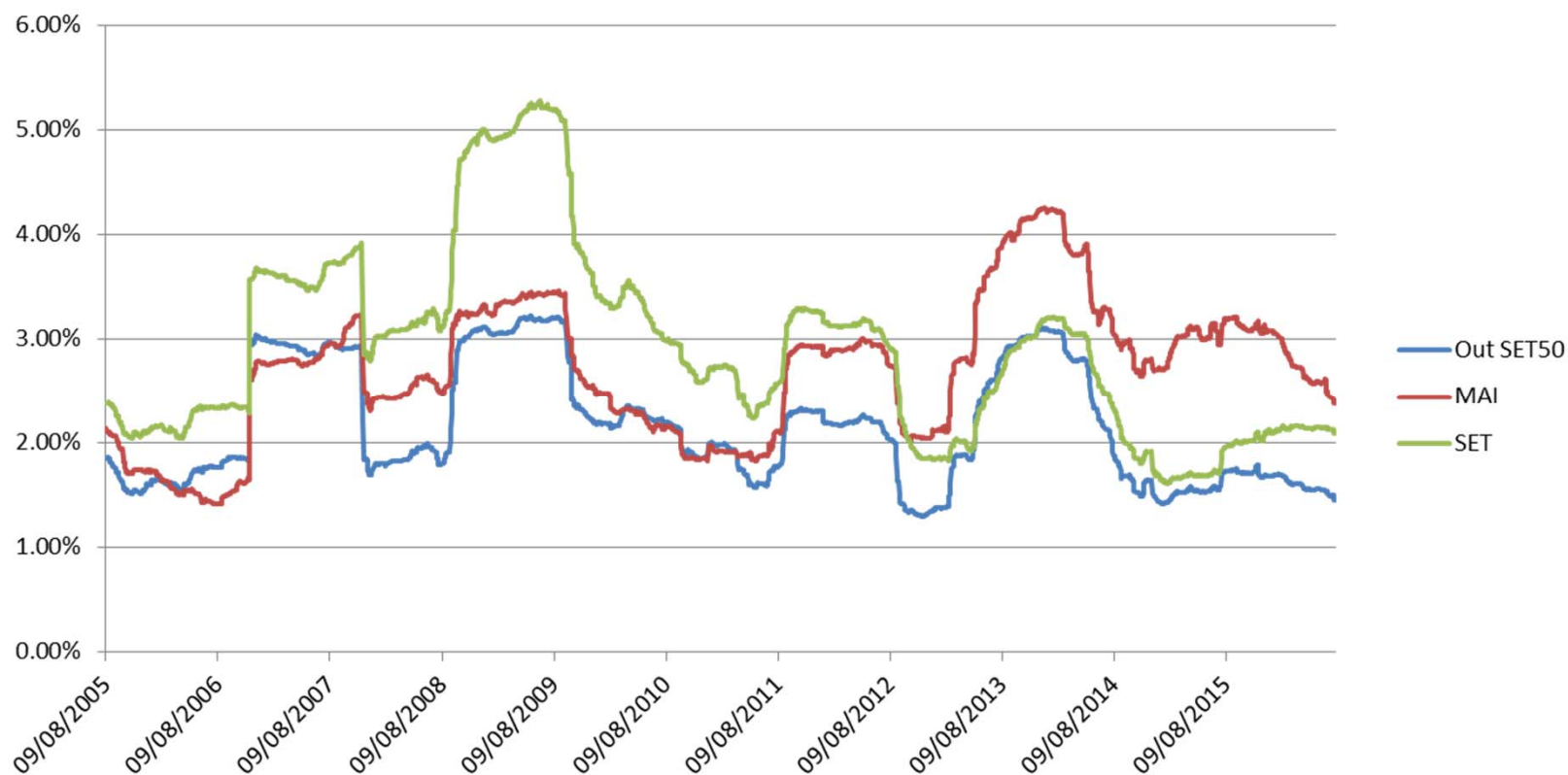
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Analytical VaR – SET VS MAI

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Historical 1-Day VaR

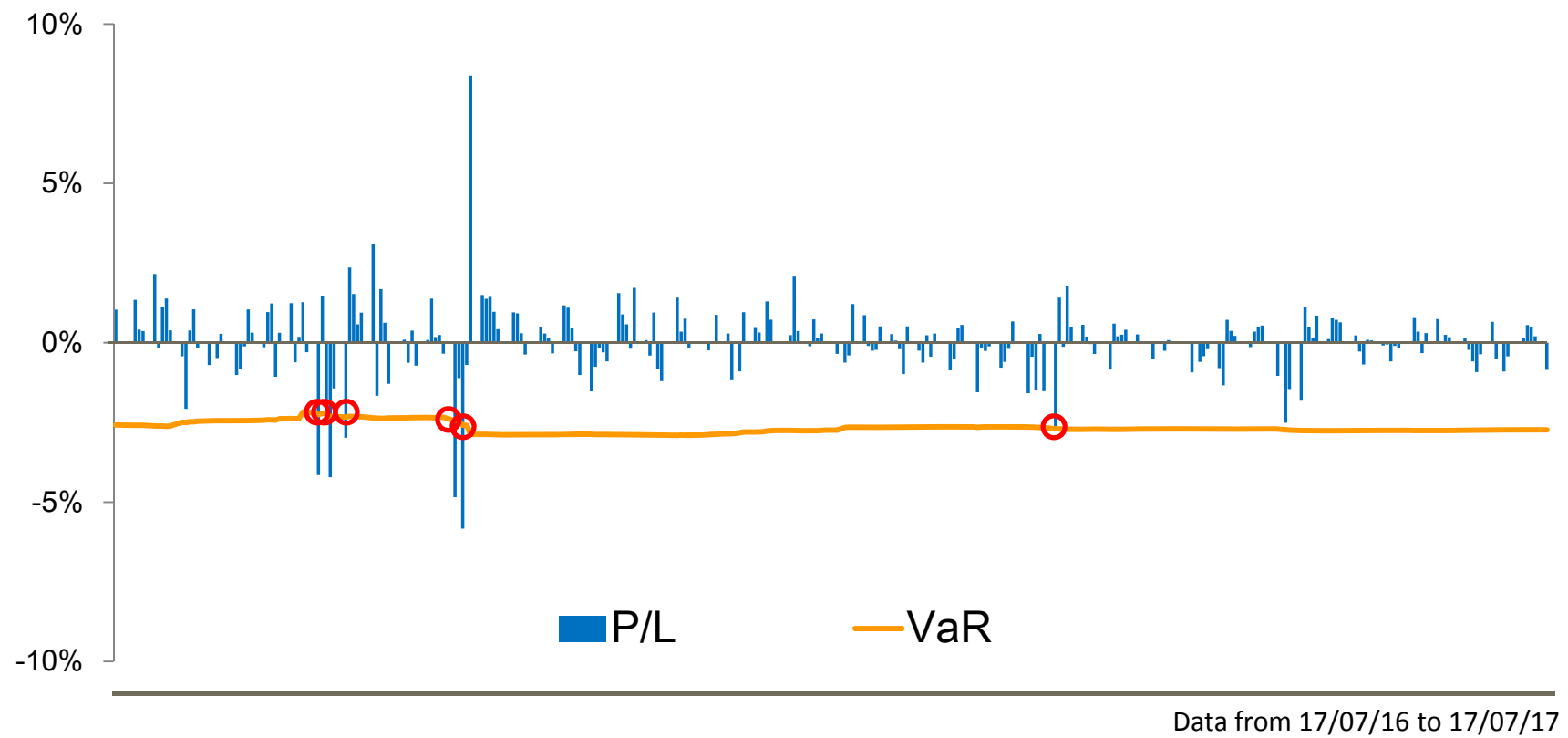


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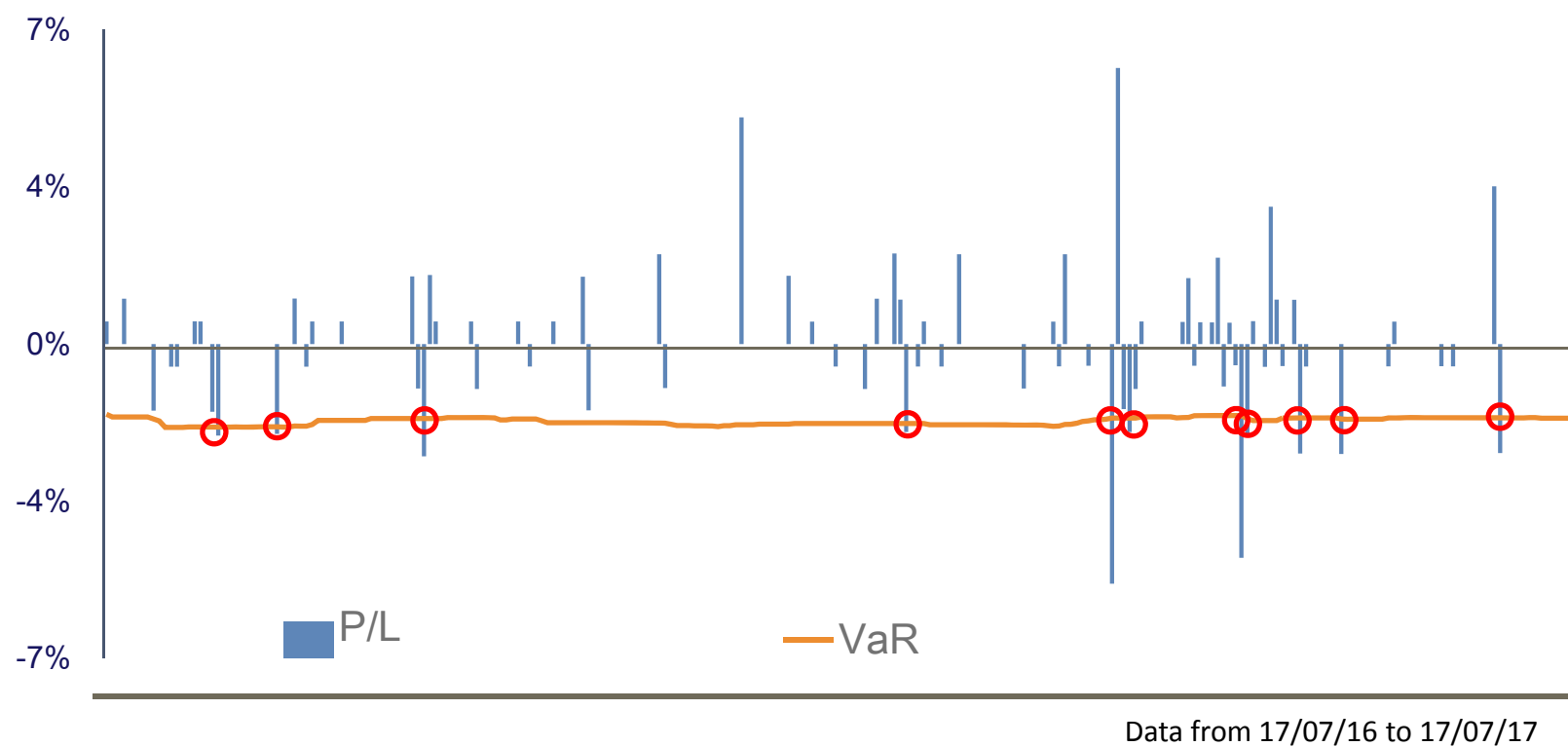
VaR backtesting results - MAI

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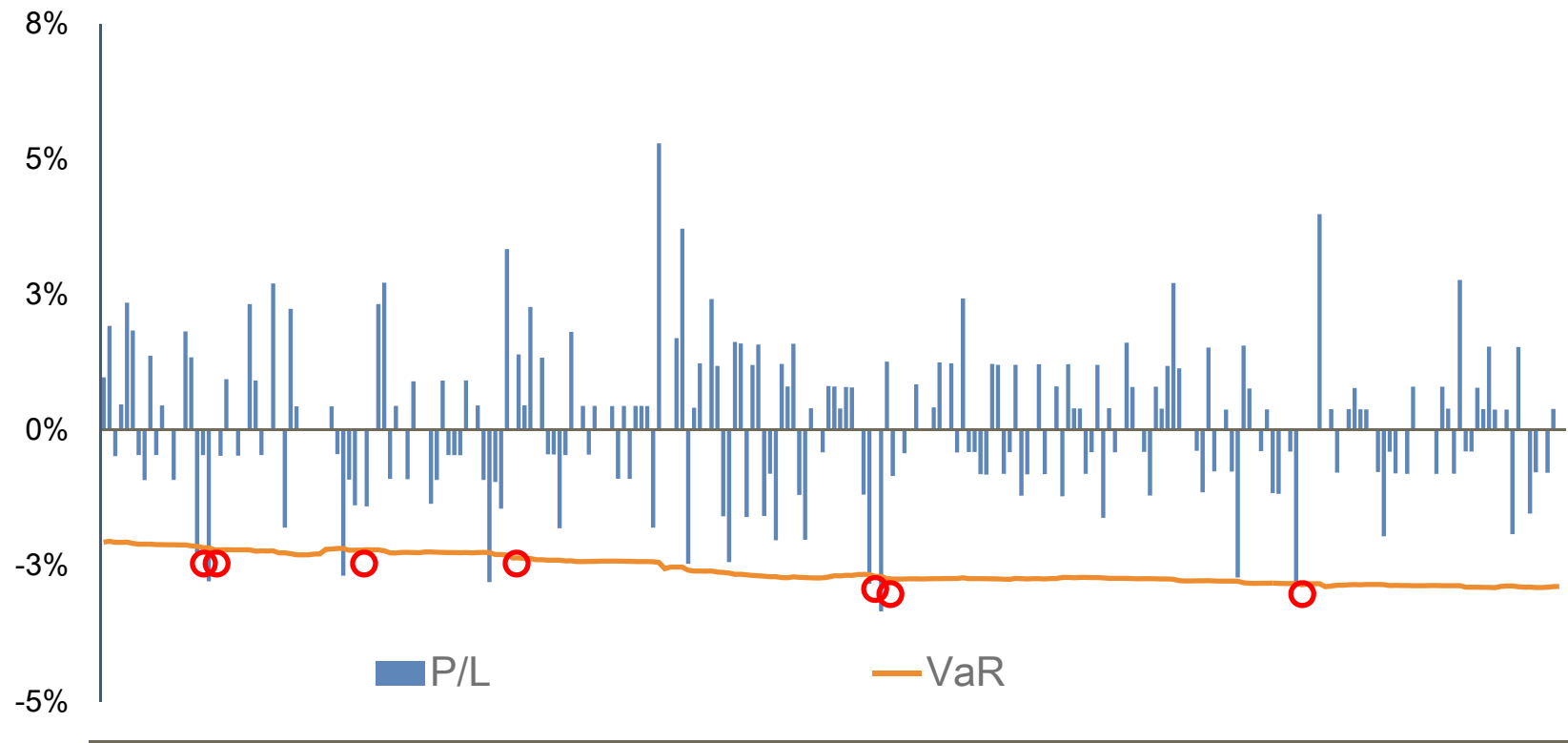
VaR backtesting results - WACOAL

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VaR backtesting results - APCO

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Data from 17/07/16 to 17/07/17

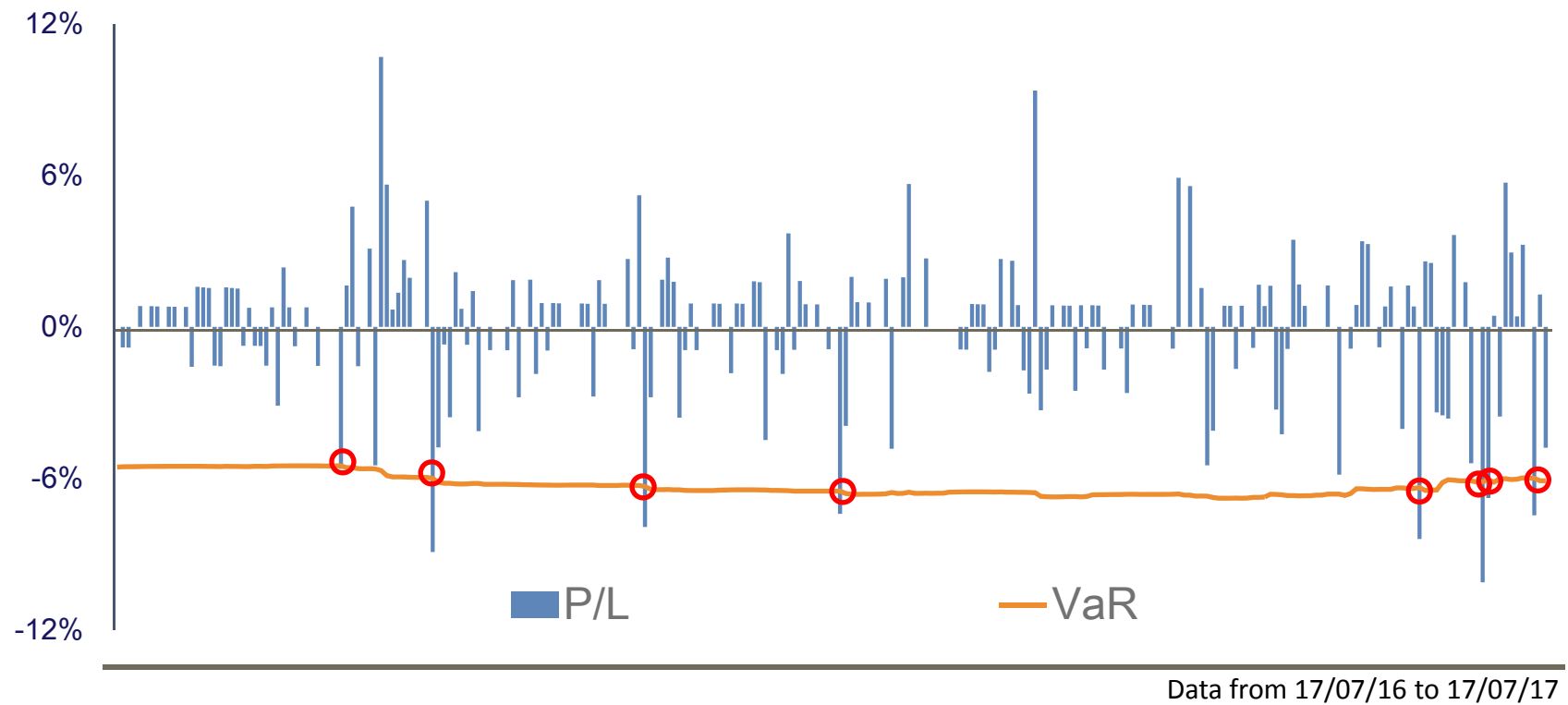


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VaR backtesting results - M

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Issues of Analytical VaR model/calculation

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-
- Market data/prices of low liquid stock(s) are used to calculate VaR .
 - Market risk of low liquidity security/portfolio is likely underestimated.
 - If the backtesting of VaR model fails, it is required to apply scaling factor or re-visit VaR model according to BIS framework

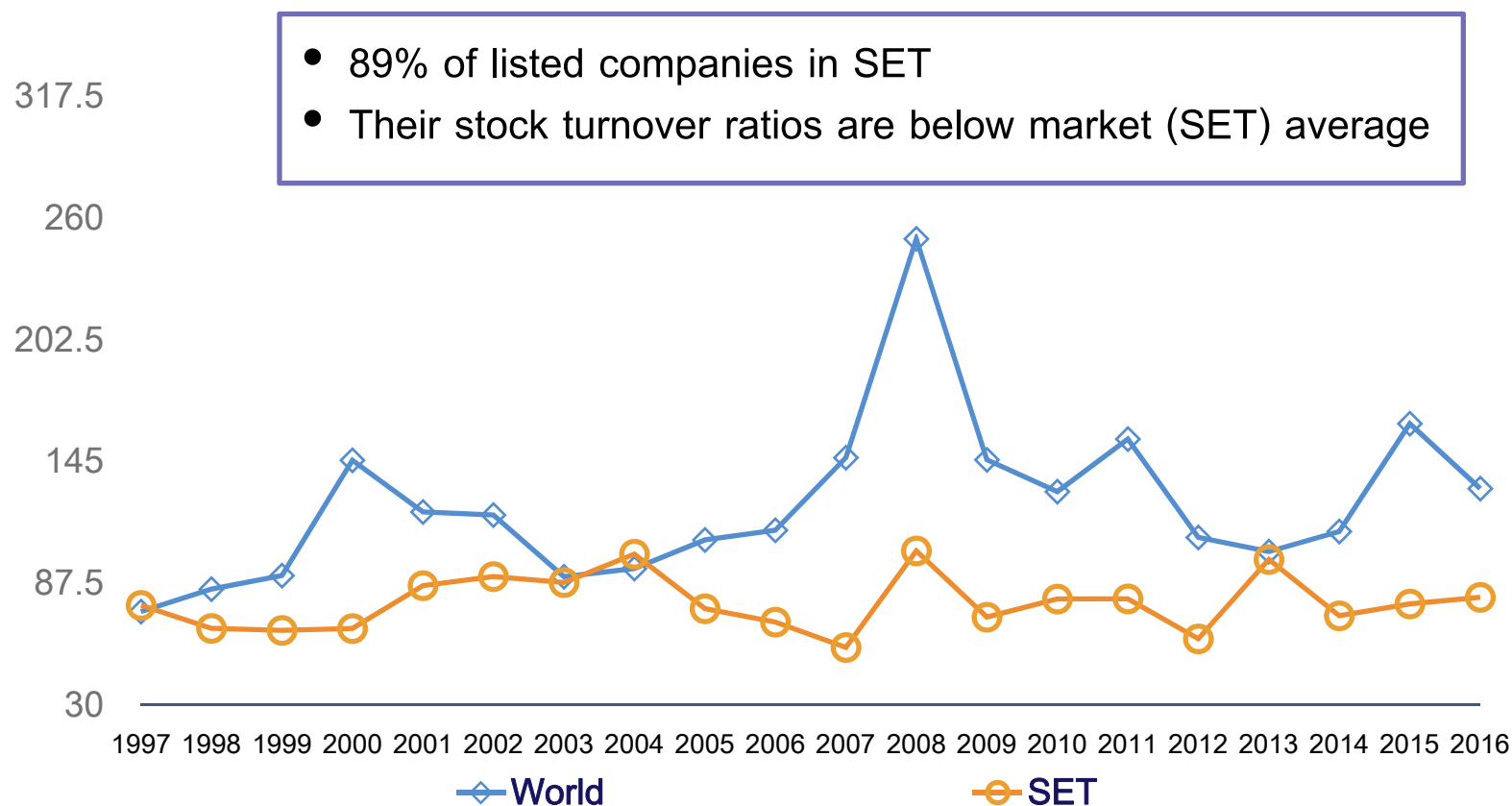


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Comparison of Stock market turnover ratios

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Source : Worldbank



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- Standard measures to gauge illiquidity of security

Liquidity Proxy for Stock

Bid-Ask
spread

Stock
Turnover

Trading
Volume

Trading
Value

Incorporating (i)liquidity to VaR Model - Market liquidity risk ¹⁵

Endogenous liquidity risk

The result of market characteristic; it is common to all market players and unaffected by the actions of any one participant

Exogenous liquidity risk

Specific to the position in the market and varies across market participants. The exposure of anyone participant is affected by the actions of that participant

Bangia et al. (1998)



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Incorporating (i)liquidity to VaR Model

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Bangia et al (1999)

- used Bid-Ask spread as a cost of liquidity to incorporate into VaR

Francios-Heude
and Van Wynendaele
(2001)

- enhanced Bangia et al. (1999) model by relaxing the Bid-Ask spread distribution and random behavior assumptions

Jarrow and
Subramanian (1997)

- proposed the model that incorporate time to liquidation and the liquidity discount into VaR



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-
- Used liquidity discount as a proxy for liquidity risk
 - The model includes both Endogenous and Exogenous liquidity risks
 - Optimal liquidate time
 - Liquidity Discount

$$LVaR_{JS} = \rho.S. \left[\mu. \left\{ E(\Delta S) + E(\ln[c(S)]) \right\} - CI \left(\sigma_E \cdot \sqrt{E(\Delta S)} + |\mu|. \sigma_{\Delta S} + \sigma_{\ln[c(S)]} \right) \right]$$

$$LVaR_{JS} = \rho.S. \left[\mu. \{E(\Delta S) + E(\ln[c(S)])\} - CI \left(\sigma_E \cdot \sqrt{E(\Delta S)} + |\mu|. \sigma_{\Delta S} + \sigma_{\ln[c(S)]} \right) \right]$$

Where

- ρ is the quantity of equity purchased (or short-sold)
- S is the equity price (hence $\rho \times S$ is essentially the nominal amount invested: ie quantity $\times$ price)
- μ is the average portfolio return
- $E(\Delta S)$ is the expected value of the time horizon to liquidation
- $c(S)$ is the liquidity discount – ie the difference between the market value of a trader's position and its value when it is ultimately liquidated
- CI is the confidence interval
- $\sigma_{\Delta S}$ is the volatility of the time horizon to the position's liquidation
- σ_E is the equity return volatility and
- $\sigma_{\ln[c(S)]}$ is the volatility of the natural logarithm of the liquidity discount.

Jarrow and Subramanian (1997) and Botha (2008)

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- Modify LVaR model of Jarrow and Subramanian (1997)
- Apply Ad-hoc approach (JP Morgan/Reuters : 1996)
 - Assume average return = 0
- Utilize Price drop function parameter (Lau and Kwok : 2001) to determine liquidity discount
- Time to liquidation given by AIFMD (2015)

Jarrow and Subramanian (1997) and Botha (2008)

Liquidity adjusted VaR

$$LVaR_{\alpha}^i = (\rho \times S_i) \left| \left\{ \mu \{ E(\Delta S_i) + E(\ln[c(s_i)]) \} + Z_{\alpha} (\sigma_{e_i} \sqrt{E(\Delta S_i)} + |\mu| \sigma_{\Delta S_i} + \sigma_{\ln|c(s_i)|}) \right\} \right|$$

Assume $\mu = 0$ (JP. Morgan, 1996)

$$LVaR_{\alpha}^i = Z_{\alpha} (\sigma_{e_i} \sqrt{E(\Delta S_i)} + \sigma_{\ln|c(s_i)|})$$

$$\Delta S_i = \frac{|S_i|}{\theta \mu_{vol}}$$

Time to
Liquidate

$$c(s_i) = p \alpha(s_i) \exp(\mu \Delta S_i)$$

Liquidity
Discount

$$\alpha(s_i) = \frac{0.5}{1 - 0.5e^{-as_i}}$$

Lau and Kwok
(2001)



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Jarrow and Subramanian (1997) and Botha (2008)

Liquidity adjusted VaR

Price-drop function is a pre-deterministic function which decreasing to S, and when $S = 0$ then $\alpha(S) = 1$

$$\alpha(s_i) = \frac{0.5}{1 - 0.5e^{-as_i}}$$

where

s_i is number of shares liquidated

a is instantaneous price-drop parameters



$a = 0.02$

Lau and Kwok (2001) studied the optimal liquidating strategy under the Jarrow and Subramanian (1997) model and **assumptions**.

'Trader will always use liquidation strategy that gives the maximum cash'



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Jarrow and Subramanian (1997) and Botha (2008)

Liquidity adjusted VaR

AIFMD* (2015) proposed the time to liquidation given by

$E(\Delta S_i)$ is expected time to liquidate position

$$\Delta S_i = \frac{|S_i|}{\theta \mu_{vol}}$$

where

$|S_i|$ is absolute amount of position liquidated

θ is percentage of position liquidated

μ_{vol} is average 3-month trading volume

*AIFMD :Alternative Investment Fund Managers Directive



Jarrow and Subramanian (1997) and Botha (2008)

Portfolio LVaR

Portfolio parametric VaR (JP. Morgan/Reuters, 1996)

$$VaR_{\alpha}^{port} = Z_{\alpha} \sqrt{(w_1 \cdots w_n) \begin{pmatrix} \sigma_1^2 & \cdots & \sigma_1 \sigma_n \rho_{1n} \\ \vdots & \ddots & \vdots \\ \sigma_n \sigma_1 \rho_{n1} & \cdots & \sigma_n^2 \end{pmatrix} \begin{pmatrix} w_1 \\ \vdots \\ w_n \end{pmatrix}}$$

$$VaR_{\alpha}^{port} = Z_{\alpha} \sqrt{(w_1 \sigma_1, \cdots, w_n \sigma_n) \begin{pmatrix} 1 & \cdots & \rho_{1n} \\ \vdots & \ddots & \vdots \\ \rho_{n1} & \cdots & 1 \end{pmatrix} \begin{pmatrix} w_1 \sigma_1 \\ \vdots \\ w_n \sigma_n \end{pmatrix}}$$

$$VaR_{\alpha}^{port} = \sqrt{(w_1 Z_{\alpha} \sigma_1, \cdots, w_n Z_{\alpha} \sigma_n) \begin{pmatrix} 1 & \cdots & \rho_{1n} \\ \vdots & \ddots & \vdots \\ \rho_{n1} & \cdots & 1 \end{pmatrix} \begin{pmatrix} w_1 Z_{\alpha} \sigma_1 \\ \vdots \\ w_n Z_{\alpha} \sigma_n \end{pmatrix}}$$

Jarrow and Subramanian (1997) and Botha (2008)

Portfolio LVaR

$$VaR_{\alpha}^{port} = \sqrt{(VaR_1, \dots, VaR_n) \begin{pmatrix} 1 & \dots & \rho_{1n} \\ \vdots & \ddots & \vdots \\ \rho_{n1} & \dots & 1 \end{pmatrix} \begin{pmatrix} VaR_1 \\ \vdots \\ VaR_n \end{pmatrix}}$$

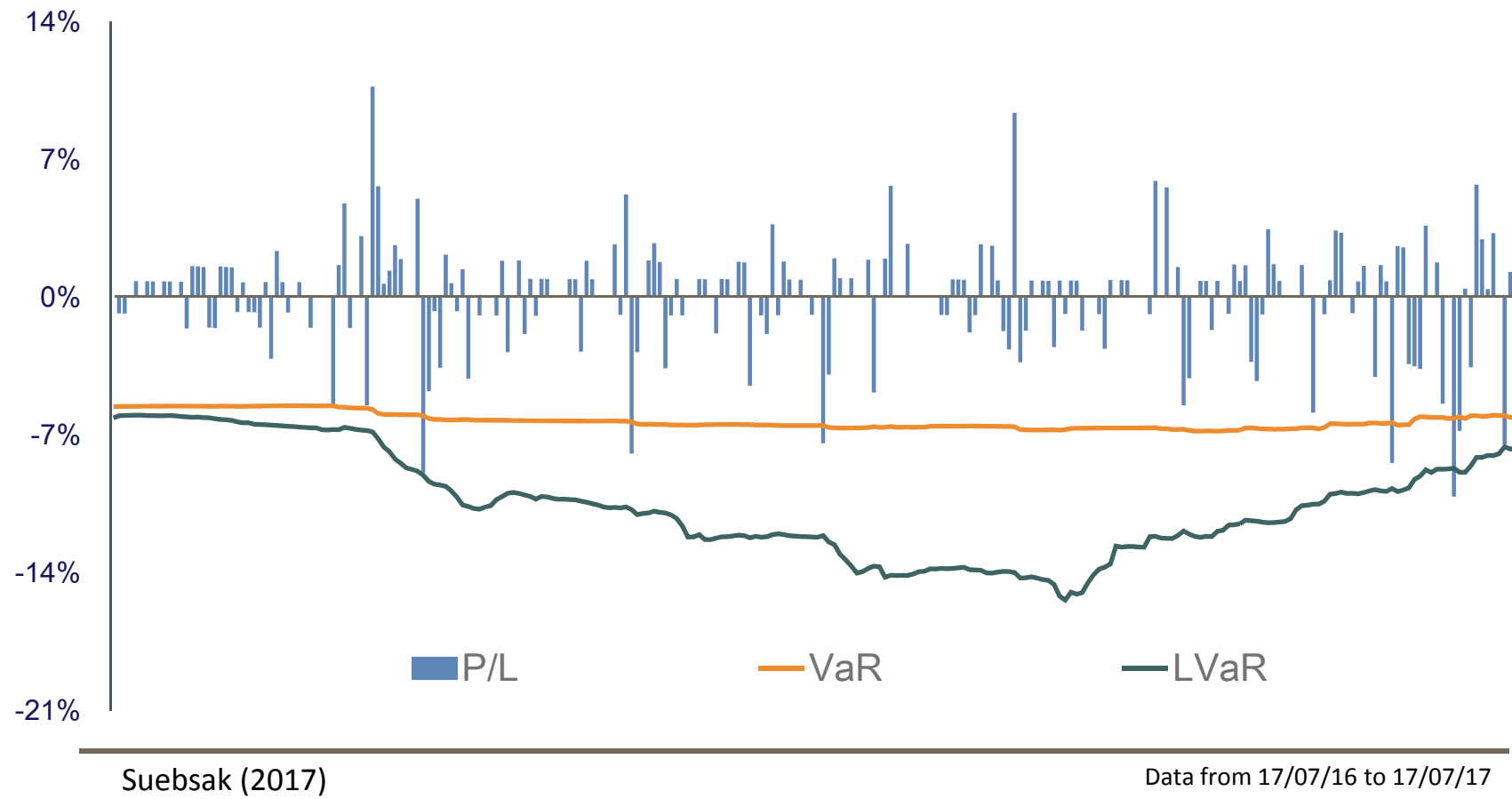
Botha (2008) concluded that Portfolio LVaR can be written as

$$LVaR_{\alpha}^{port} = \sqrt{(LVaR_1, \dots, LVaR_n) \begin{pmatrix} 1 & \dots & \rho_{1n} \\ \vdots & \ddots & \vdots \\ \rho_{n1} & \dots & 1 \end{pmatrix} \begin{pmatrix} LVaR_1 \\ \vdots \\ LVaR_n \end{pmatrix}}$$



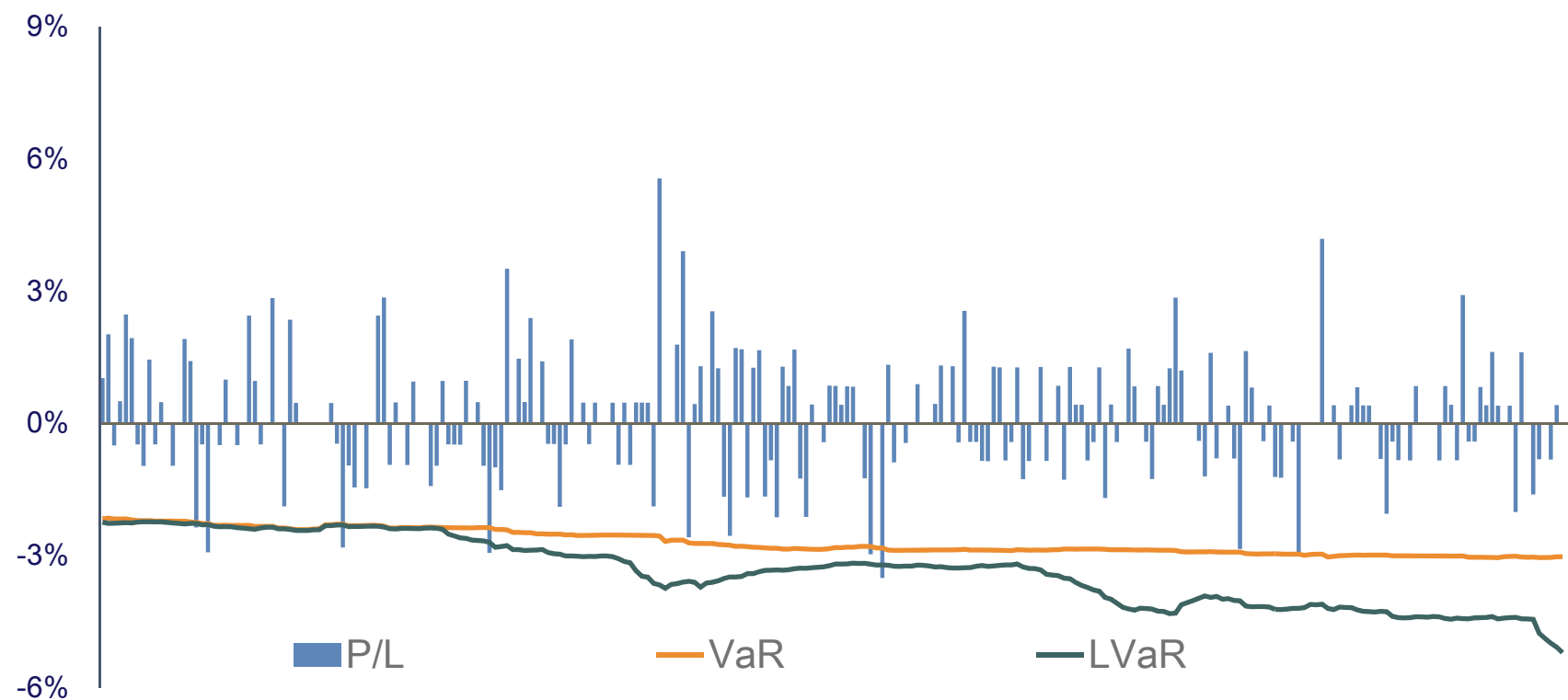
Backtesting LVaR - APCO

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Backtesting LVaR - M

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Suebsak (2017)

Data from 17/07/16 to 17/07/17

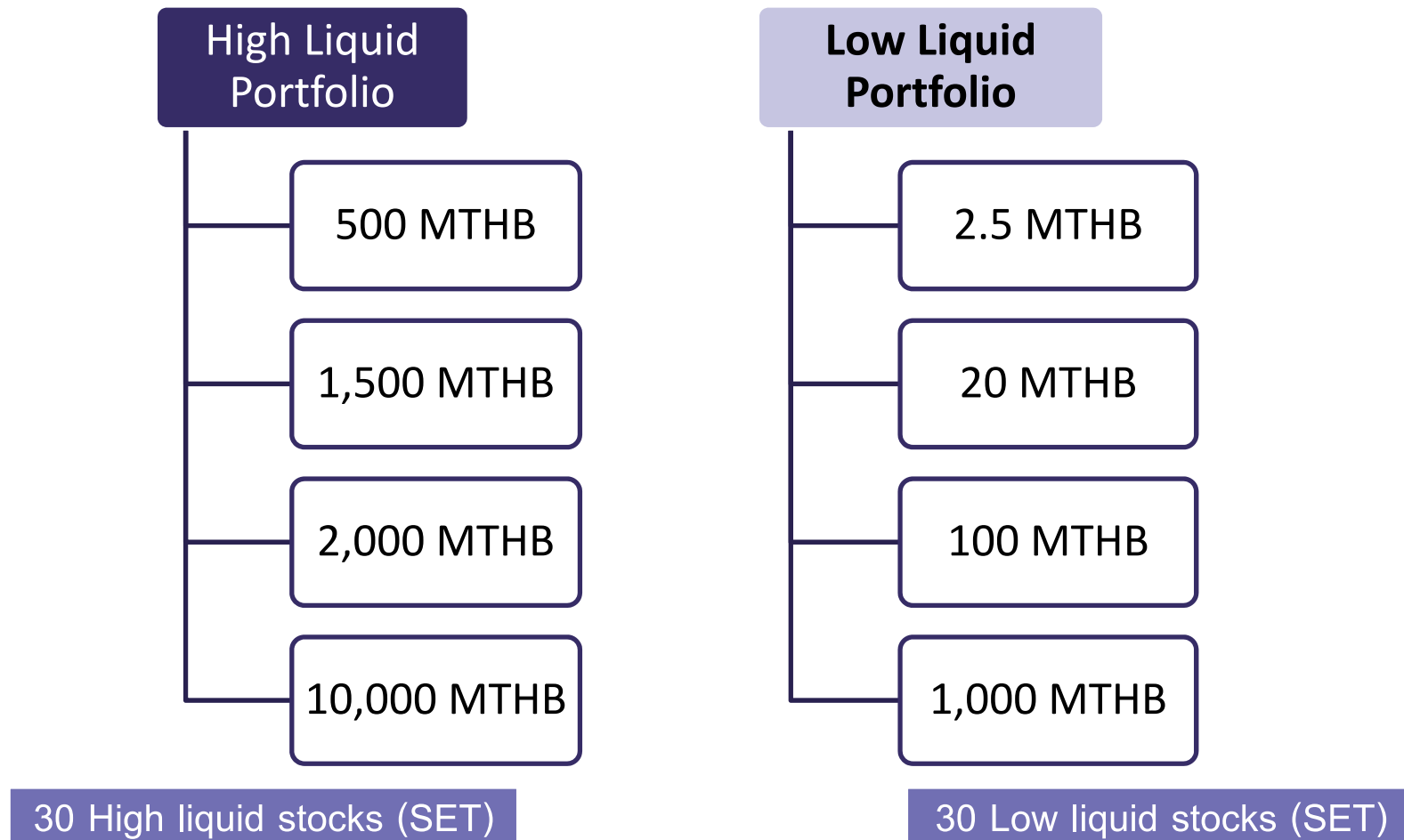


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Backtesting for different levels of liquidity portfolios

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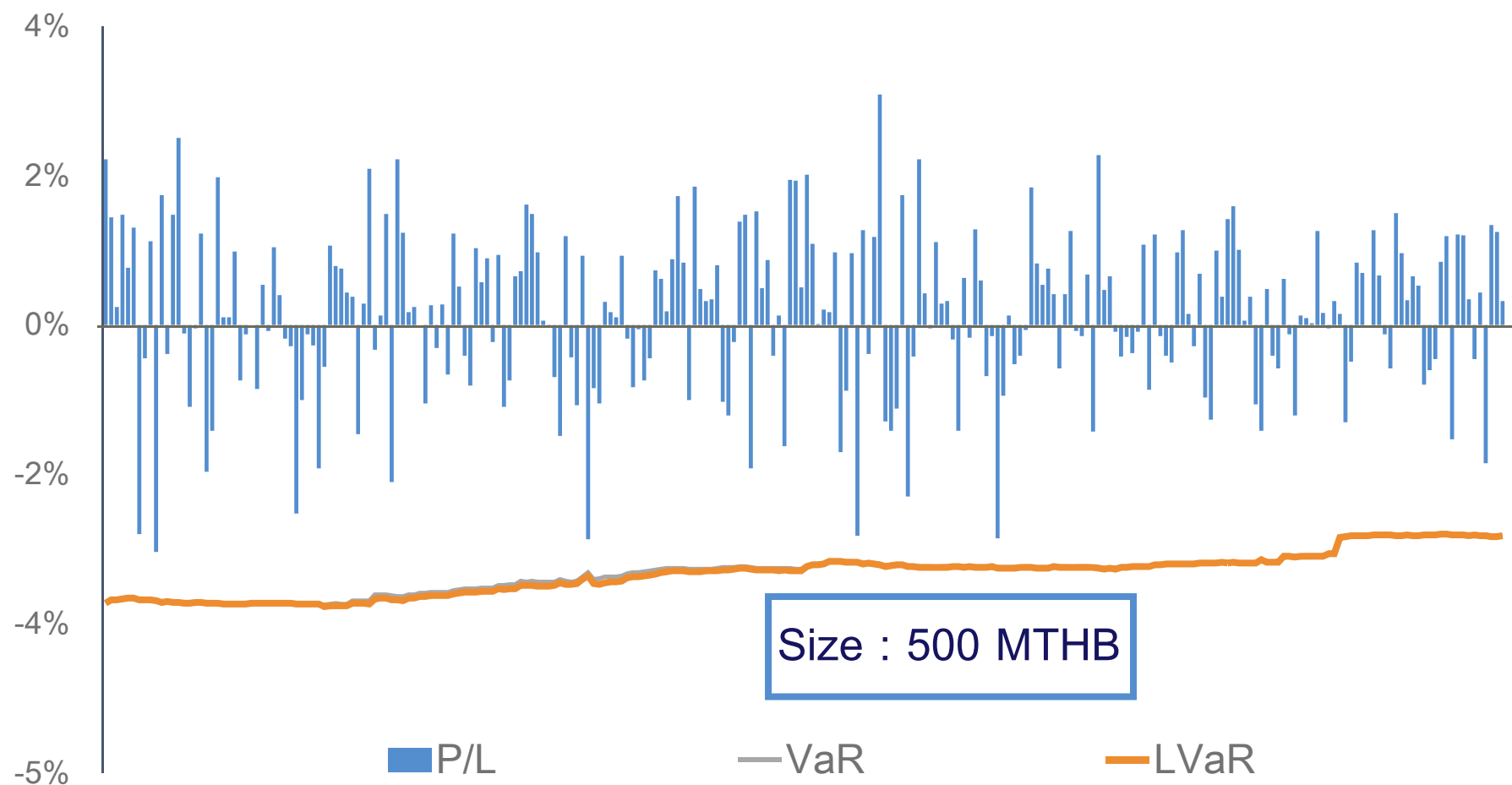


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Backtesting for different levels of liquidity portfolios

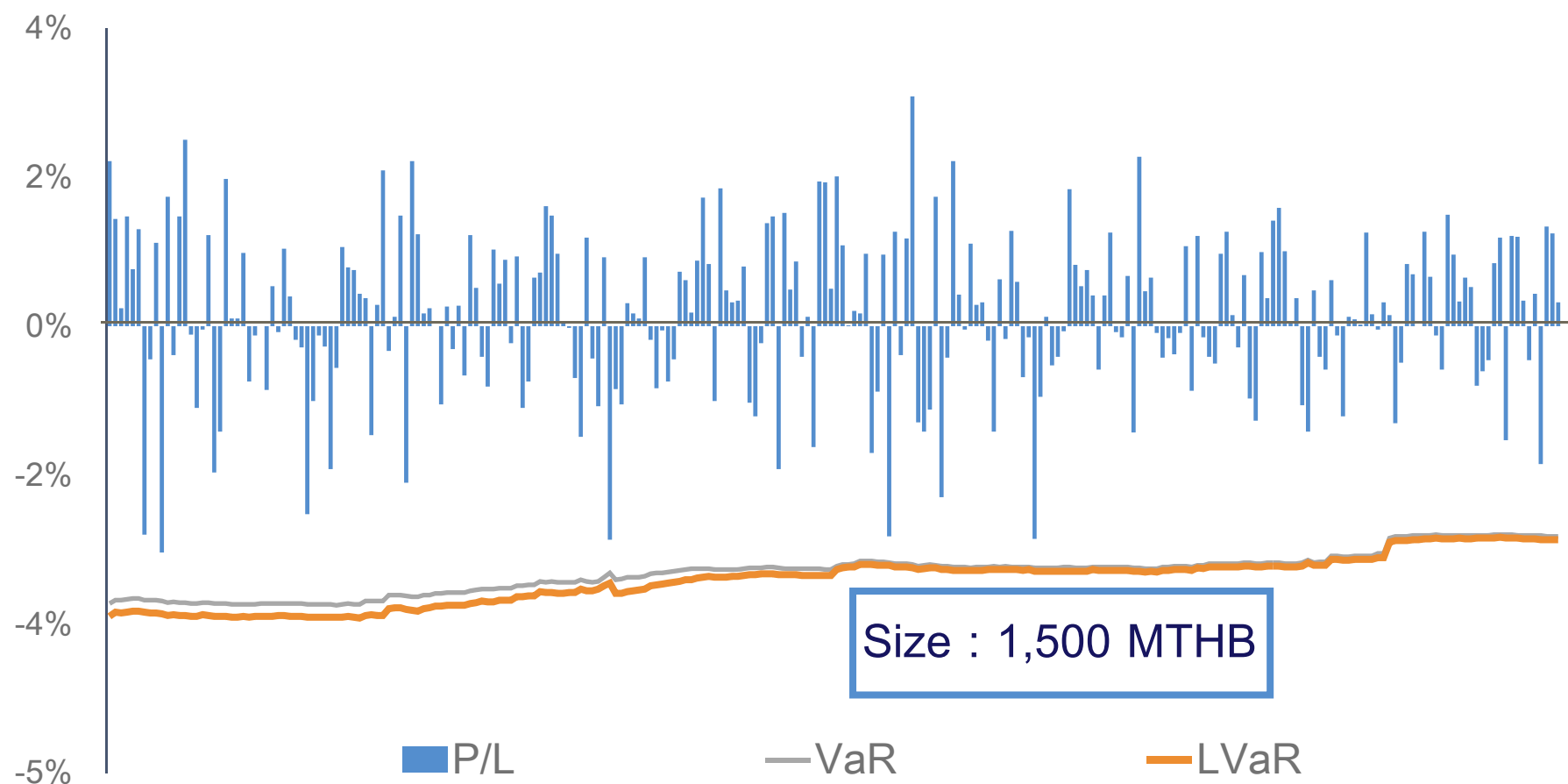
High Liquid Portfolio



Suebsak (2017)

Backtesting for different levels of liquidity portfolios

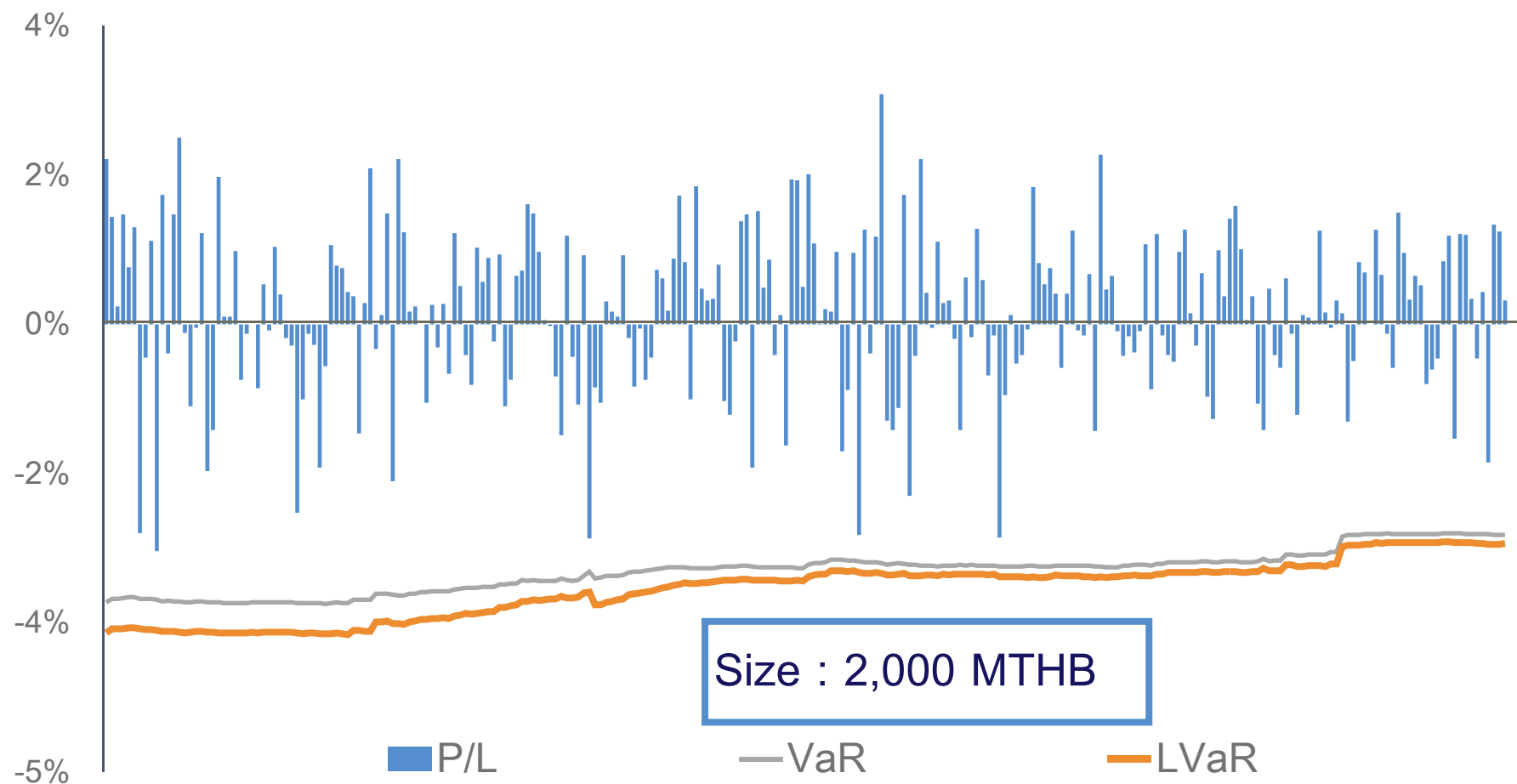
High Liquid Portfolio



Suebsak (2017)

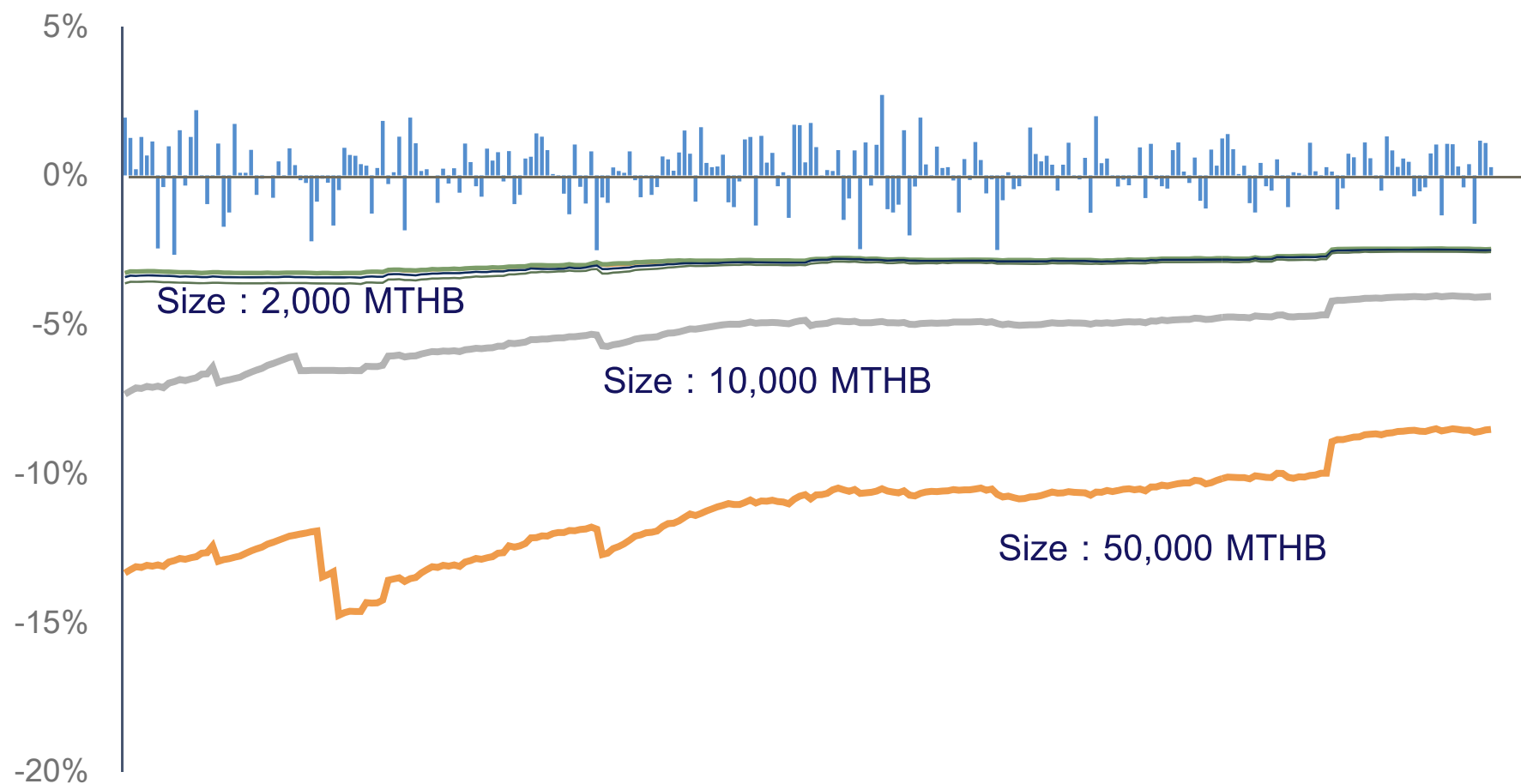
Backtesting for different levels of liquidity portfolios

High Liquid Portfolio



Backtesting for different levels of liquidity portfolios

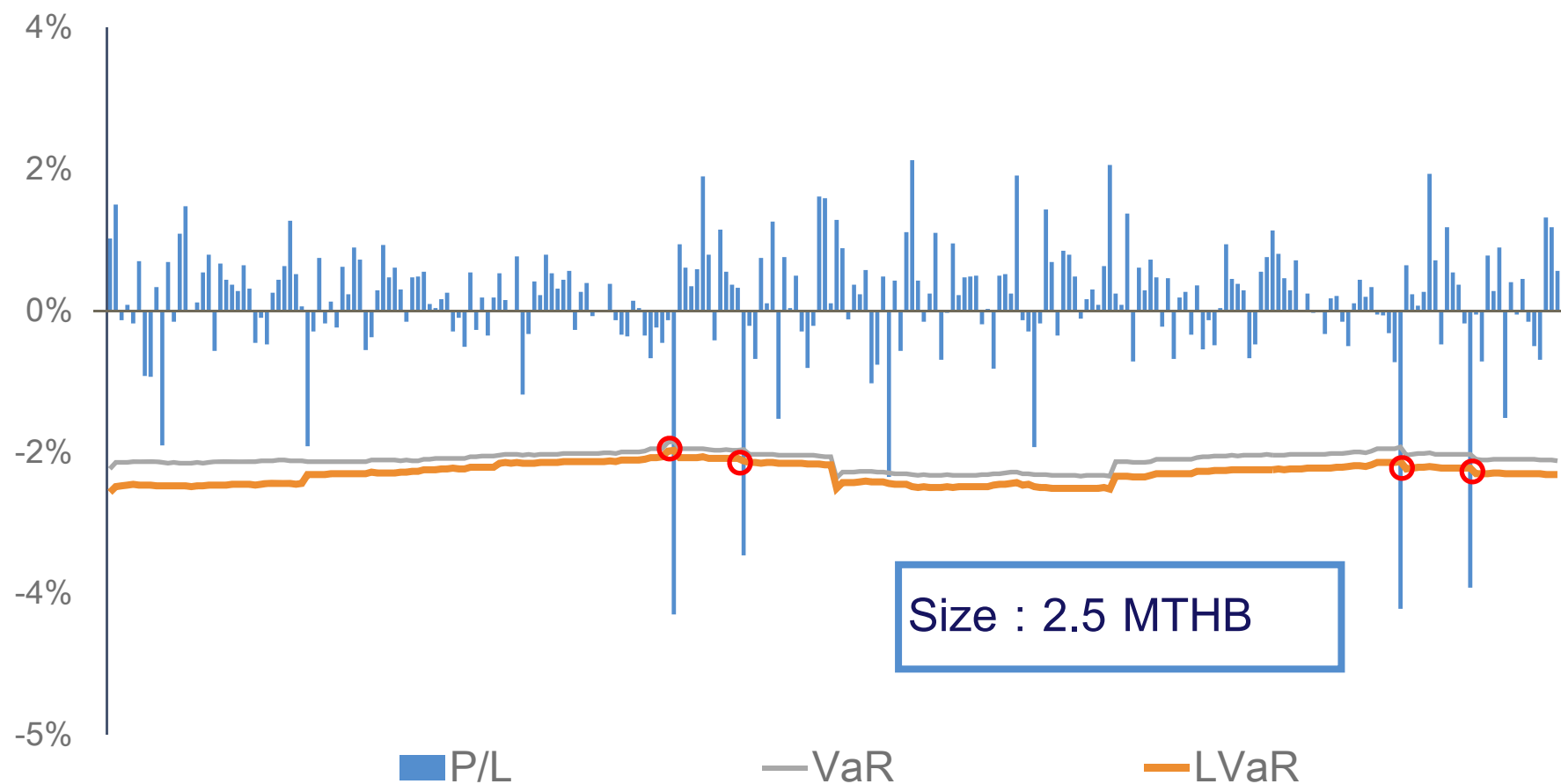
High Liquid Portfolio



Suebsak (2017)

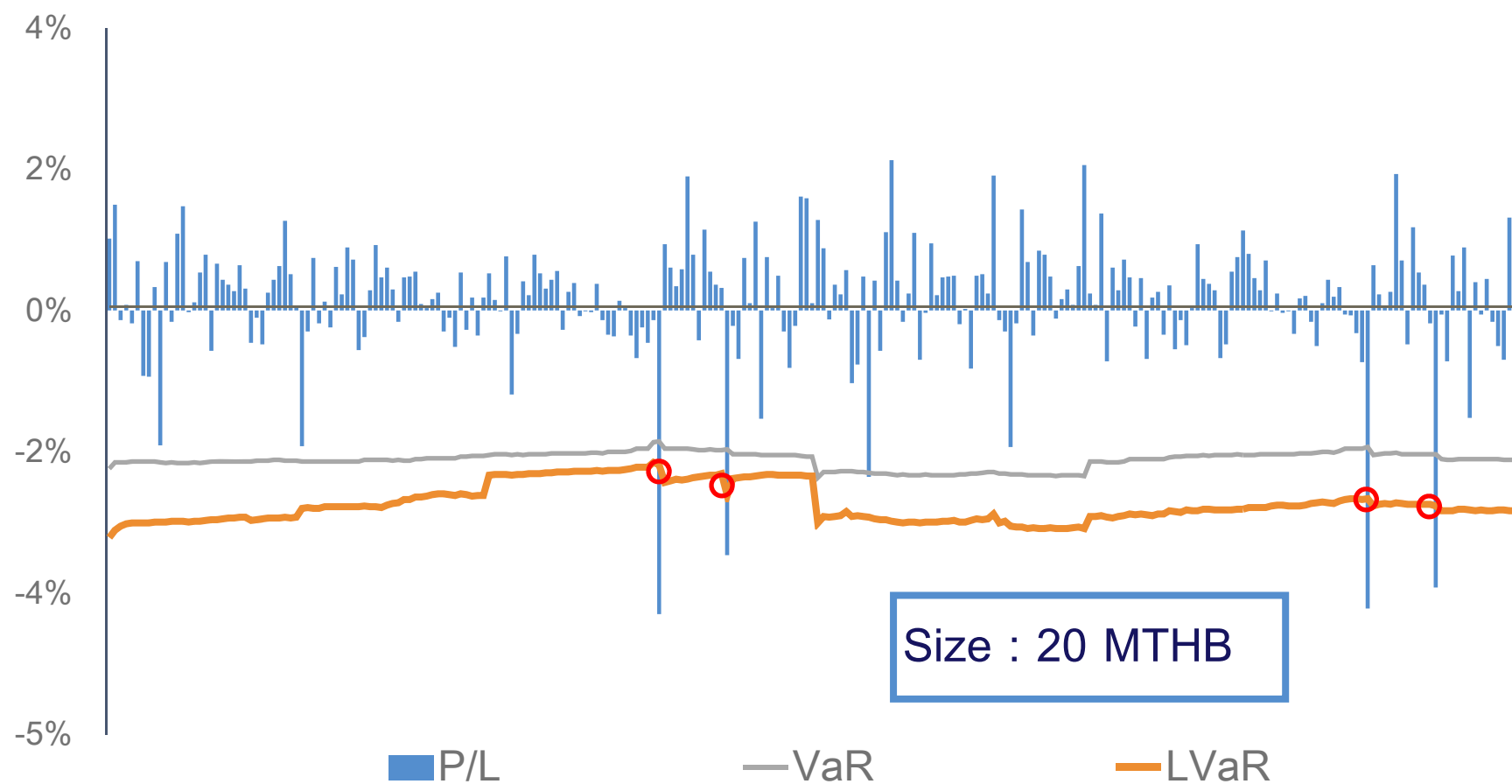
Backtesting for different levels of liquidity portfolios

Low Liquid Portfolio



Backtesting for different levels of liquidity portfolios

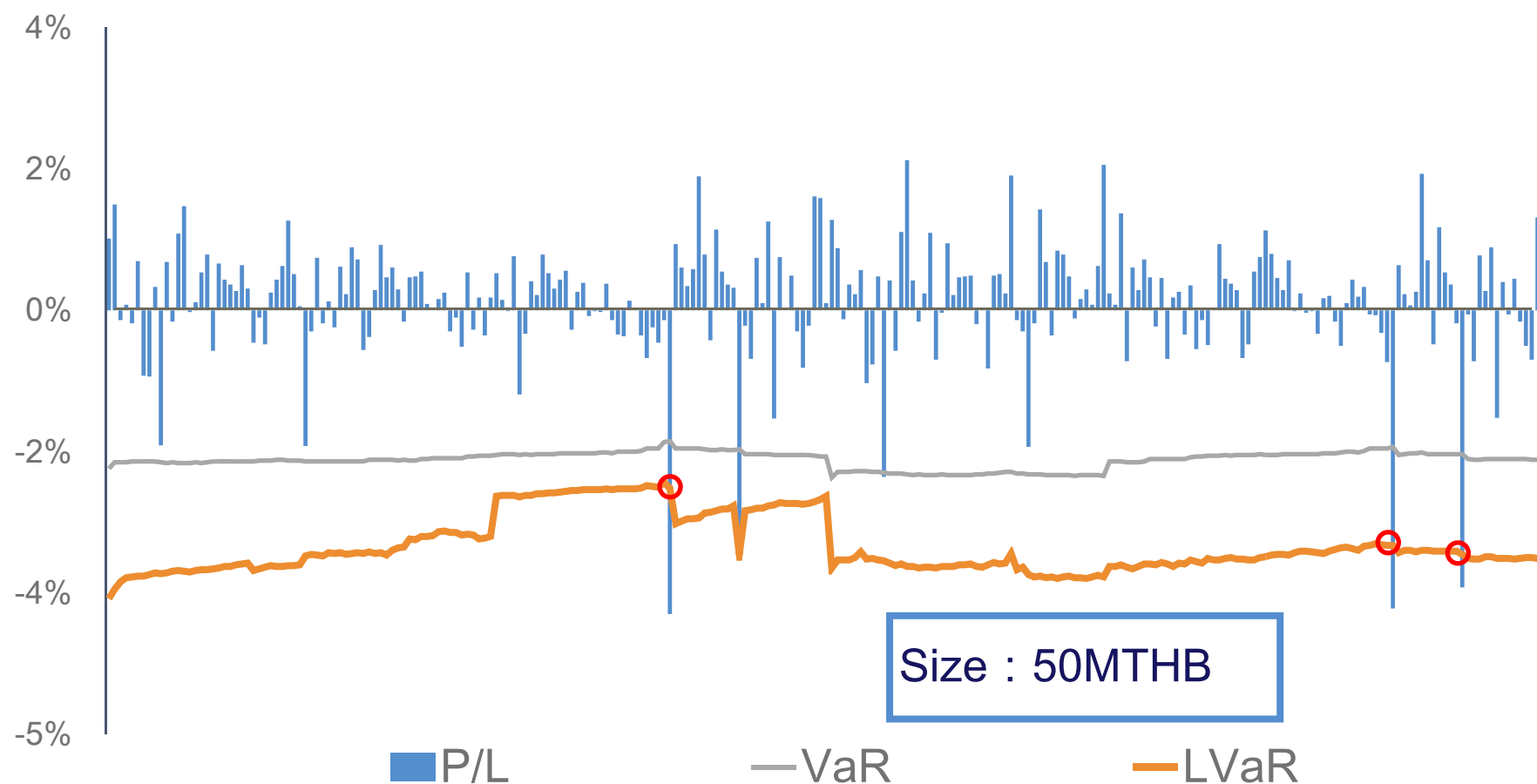
Low Liquid Portfolio



Suebsak (2017)

Backtesting for different levels of liquidity portfolios

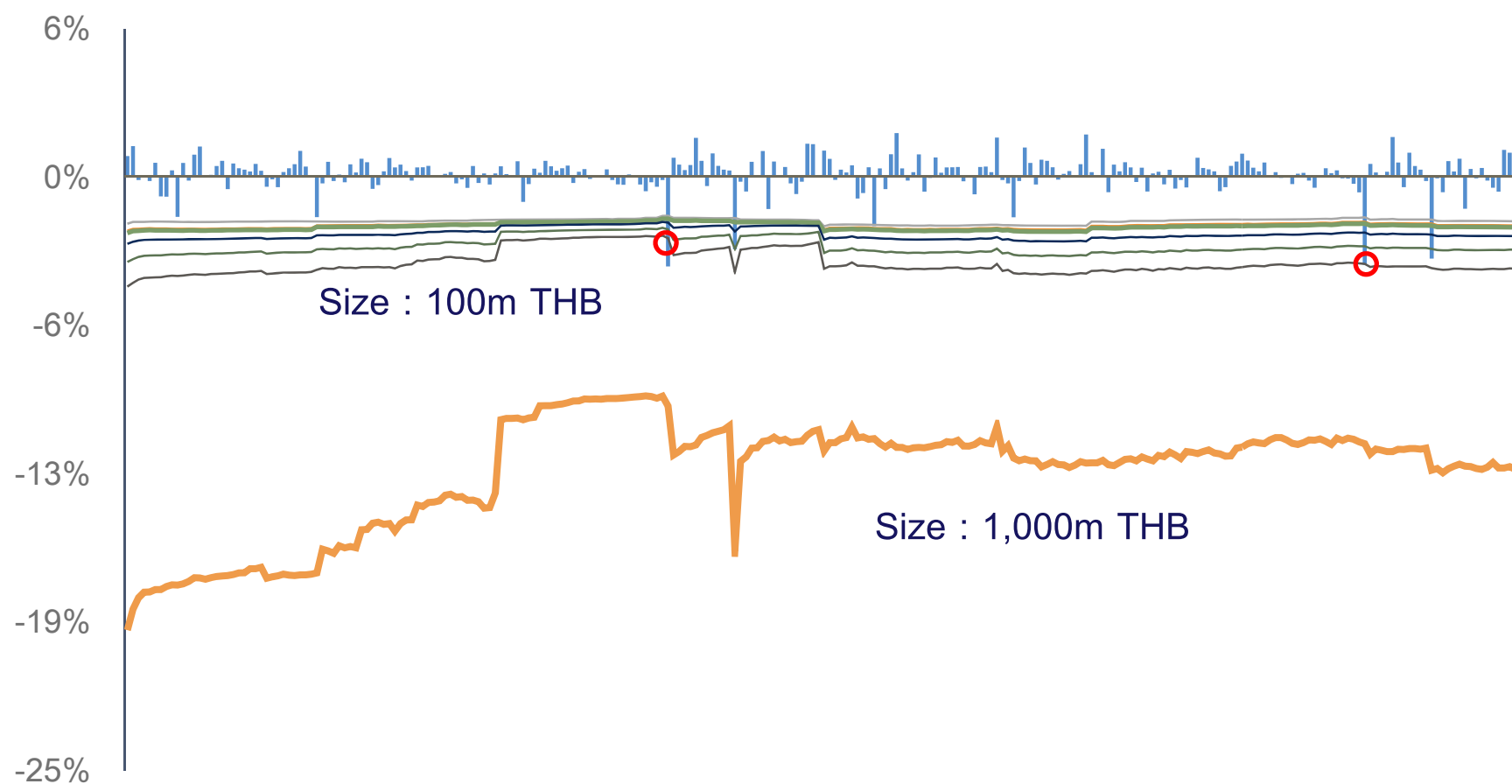
Low Liquid Portfolio



Suebsak (2017)

Backtesting for different levels of liquidity portfolios

Low Liquid Portfolio



Suebsak (2017)

Summary of backtesting results

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BIS Backtesting framework

	HIGH LIQUID PORTFOLIO						LOW LIQUID PORTFOLIO					
Observation	250						250					
Size (MTHB)	500	1,000	1,500	2,000	10,000	50,000	2.5	5	20	50	100	1,000
	Number of Exceptions						Number of Exceptions					
VaR	0	0	0	0	0	0	5	5	5	5	5	5
LVaR	0	0	0	0	0	0	4	4	4	3	2	0

Suebsak (2017)

-
- The approach used to calculate LVaR incorporates:
 - Exogenous liquidity risk
 - Endogenous liquidity risk – depending on position required to liquidate
 - LVaR is dependent with size of portfolio/position required to liquidate, while Analytical VaR is not.
 - The results of LVaR model shows improvement in forecasting over traditional Analytical VaR.
 - LVaR implementation should consider trade-off between benefit and required resources.



End of Presentation