Risk measures for large portfolios and their applications in energy trading

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Energie
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Agenda

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2. A short introduction of the electricity market
3. Does Value-at-Risk quantify portfolio risk adequately?
4. An alternative risk measure: Profit-at-Risk
5. Liquidity adjusted Value-at-Risk (LVaR)
6. Example for a LVaR calculation

Brief portrait: EnBW Energie Baden-Württemberg AG

- Third-largest energy company in Germany
- Business segments:
  electricity generation and trading, electricity grid and sales, gas, energy and environmental services
- Annual revenue 2010: in excess of € 17 billion
- Customers: some 6 million
- employees: more than 20,000

Brief portrait: EnBW

At a glance

EnBW group		2010	2009
External revenue	m €	17,509.0	15,564.2
Adjusted EBITDA	m €	2,837.8	2,615.3
Adjusted EBIT	m €	1,932.6	1,793.9
Operating cash flow	m €	2,560.9	2,443.4
Free cash flow	m €	1,060.1	1,292.1
Capital expenditure	m €	2,327.9	4,374.1
ROCE	%	14.5	15.5
Capital employed	m €	15,119.7	13,559.7
Value added	m €	831.6	840.7
Employees (annual average)		20,450	20,914

Brief portrait: EnBW
Shareholdings in Europe

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Wroclaw [Kogeneracja]
Rybnik [ERSA]

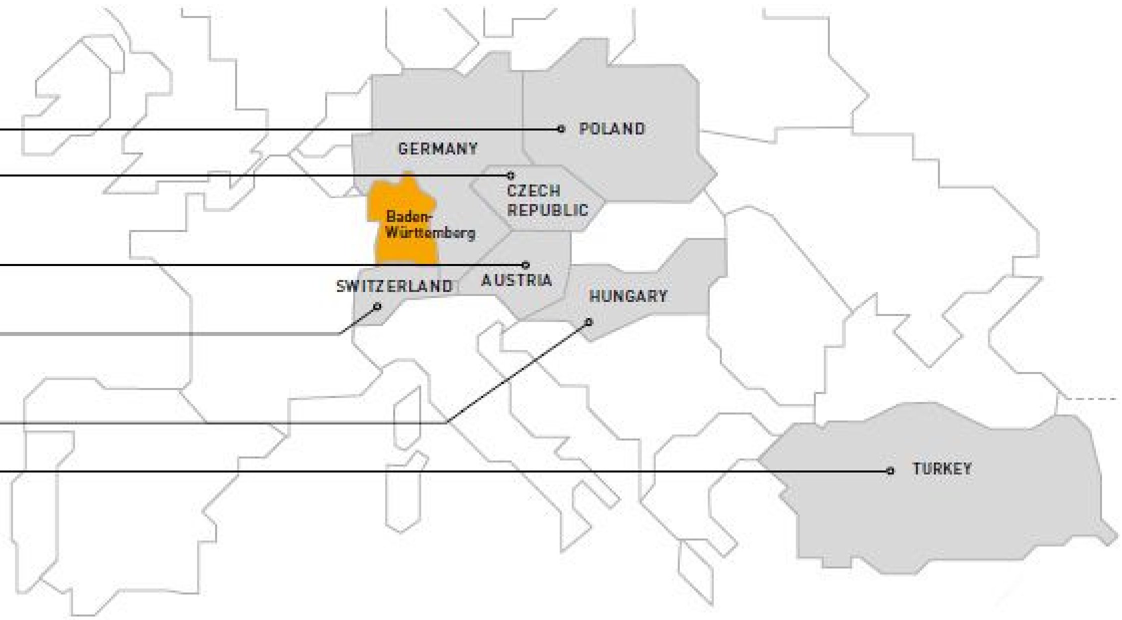
Prague [PRE]

Maria Enzersdorf [EVN]
Bregenz [VIW]
Sellrain-Silz [TIWAG]

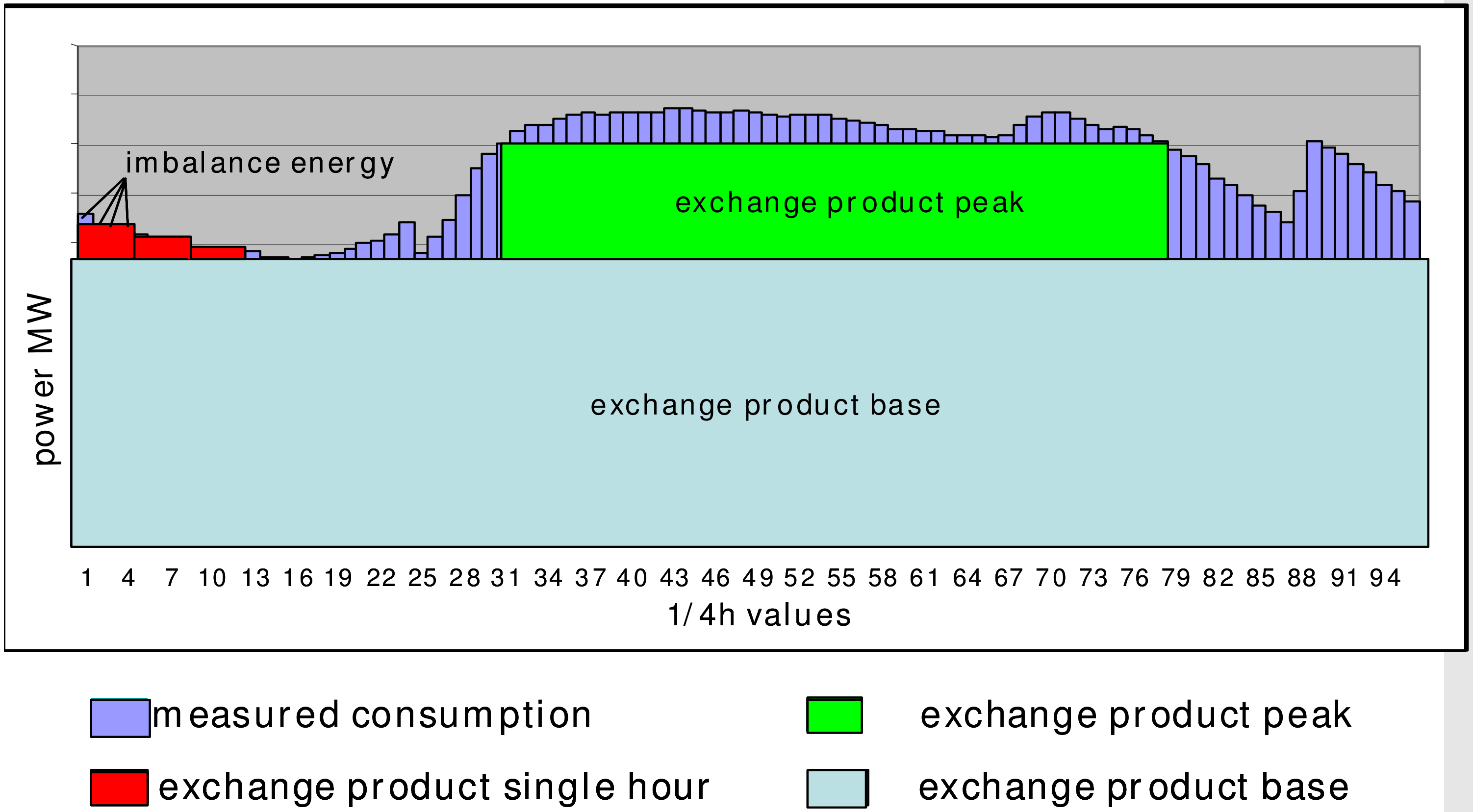
Laufenburg [ED]
Visp [EnAlpin]

Budapest [ELMÜ]
Miskolc [EMASZ]
Visonta [MATRA]

Istanbul [Borusan EnBW Enerji]



A short introduction of the electricity market
Trading products in electricity markets



A short introduction of the electricity market

Definition: Spot- and forward market for electricity

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Spot market:
- delivery time at or before the next trading day

OTC-traded

Exchange traded

Forward market:
- delivery time after the next trading day

Forward: OTC-traded

Futures: exchange traded

Special products:

Intraday market:
- delivery time is at the trading day
- OTC and exchange traded

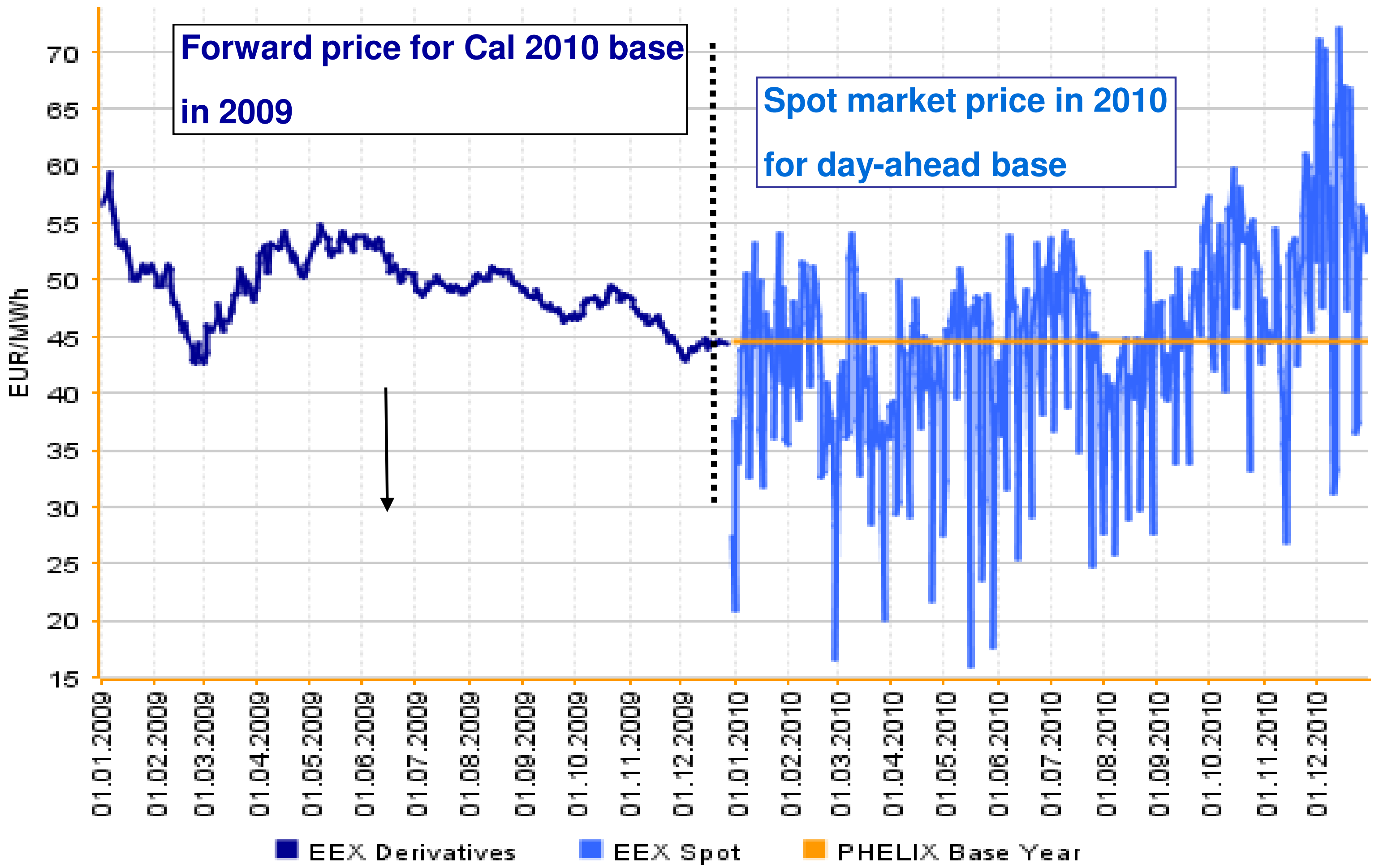
Tertiary (minutes) reserve
- tender procedure of TSO
- optional character

Special products:

Primary- , Secondary reserve
- tender procedure of TSO
- optional character

A short introduction of the electricity market

Forward market vs. spot market



A short introduction of the electricity market
One Year Ahead Forward Price

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Does Value-at-Risk quantify portfolio risk adequately?

Traditional Risk Measures

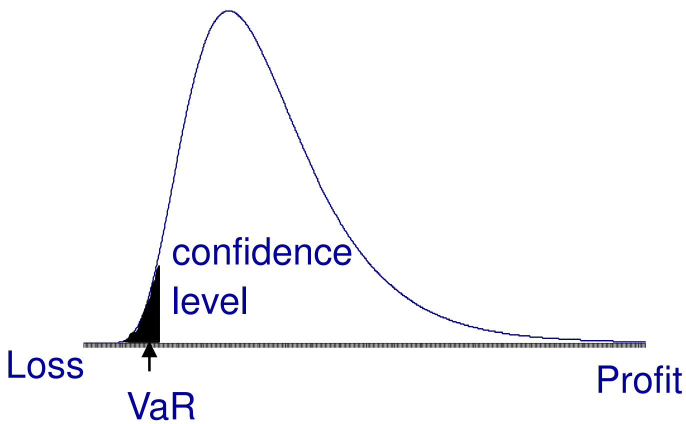
- In general:

  Risk measures are concepts that have to be adapted for specific usage
- There are often no standardized definitions for risk measures
  - Exception: Described definition and implementation for Value-at-Risk (VaR) in

    Guldimann Risk Metrics-Technical Document, Morgan Guaranty 1995
  - For many other risk measures like Profit-at-Risk (PaR), Earnings-at-Risk (EaR), Cashflow-at-Risk (CFaR) there are no widely accepted definitions and implementation rules

Does Value-at-Risk quantify portfolio risk adequately?

Review: Value-at-risk



- What is the management question, that is answered by a VaR number?
  - „How bad can things get?“ (John Hull)
  - More precisely: How bad can things get during the holding period and with the given confidence level?

Does Value-at-Risk quantify portfolio risk adequately?
Review: Value-at-risk Parameters

- Typical choice of parameters:
  - Holding period p between 1 and 10 days
    - Reason:
      - Portfolio position and sensitivities changes rapidely
      - Stopp Loss limits take effect
      - Daily Marked-to-market
  - Confidence level between 95% and 99%
    - Reason:
      - Banking supervision rules

Does Value-at-Risk quantify portfolio risk adequately?
Informative value of VaR

- Value-at-Risk quantifies the risk adequate if
  - Risk can removed after holding period
  - Portfolio position can be closed during the holding period
- Value-at-Risk is adequate e.g for
  - Proprietary Trading in liquid markets

Does Value-at-Risk quantify portfolio risk adequately?
Problems where VaR is not adequate

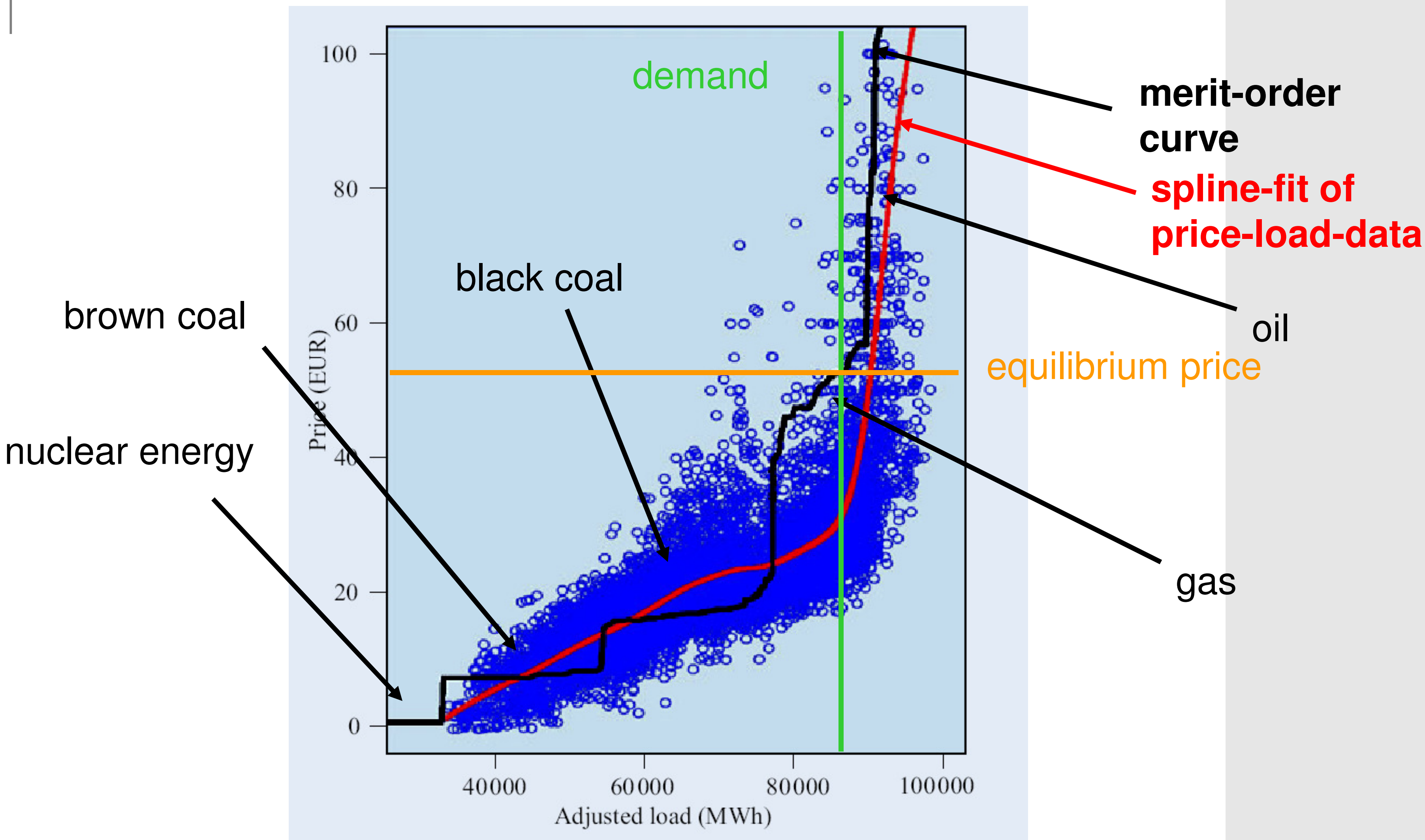
- Determining the absolute market price risk for:
  - Substantial generation portfolio of an energy supplier
    - Value of the generation portfolio is determined by volatile energy prices
    - Market share of these suppliers is high
  - Generation portfolio that will be hedged with an given strategy
  - Generation portfolio of an energy supplier that is used for retail customers

An alternative risk measure: Profit-at-Risk

- Definition: Profit-at-Risk with the confidence level a is the 1-a quantile of the change in the value of a given portfolio until delivery
  - No fixed holding period
  - Risk of the volatile spot market is included
- Market Price Risk of the spot markt is included
- Profit-at-Risk requires a spot market model
  - Calculation of PaR with Monte Carlo Simulation
- Example: Profit-at-Risk calculation für a power portfolio using the stochastic electricity market model SMaPS

An alternative risk measure: Profit-at-Risk

SMaPS-Modell: Marginal cost of electricity generation



A Stochastic model for electricity: SMaPS

$$\ln S_t = f(t, L_t/v_t) + X_t + Y_t$$

Where:

$f(t, L_t/v_t)$ empirical price-load-curve (PLC): cubic spline fit of the EEX-prices as a function of the adjusted load L_t/v_t (load normalised by power plant availability)

$L_t = l_t + \hat{L}_t$ deterministic load prognosis + SARIMA (1,0,1)x(1,0,1)$_{24}$-model with 24h-seasonality

$$(1 - \psi_1 B)(1 - \Psi_1 B^{24}) \cdot \hat{L}_t = (1 - \lambda_1 B)(1 - \Lambda_1 B^{24})\varepsilon_t^L$$

X_t short-term process: SARIMA (2,0,1)x(1,0,1)$_{24}$-model with 24 h-seasonality

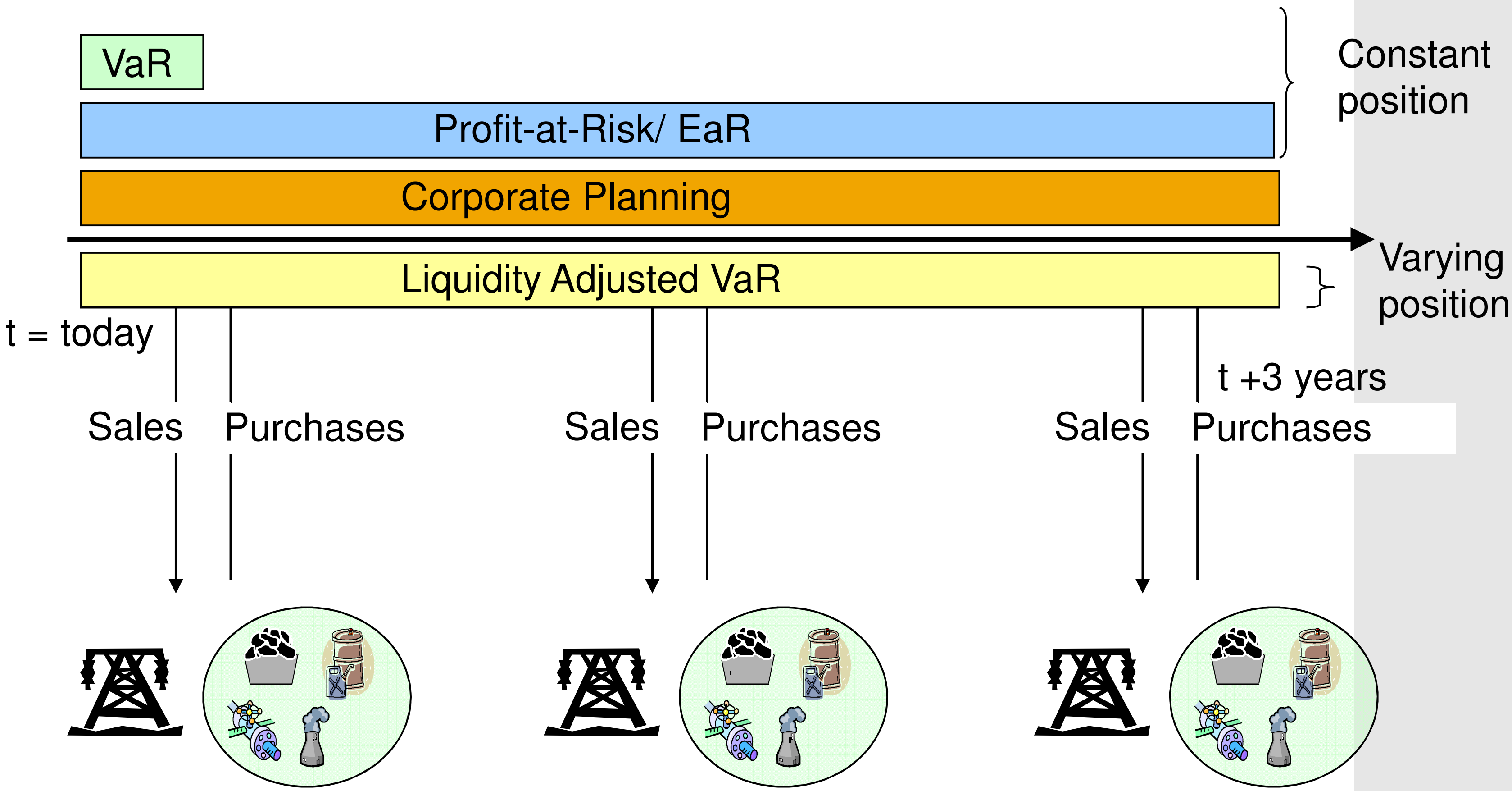
$$(1 - \phi_1 B - \phi_2 B^2)(1 - \Phi_1 B^{24}) \cdot X_t = (1 - \theta_1 B)(1 - \Theta_1 B^{24})\varepsilon_t^X$$

Y_t long-term process: Brownian motion

$$Y_{t+1} = Y_t + (\mu_t - \tfrac{1}{2}\sigma_Y^2) + \sigma_Y \varepsilon_t^Y$$

An alternative risk measure: Profit-at-Risk

Comparison of different risk measures



Liquidity adjusted Value-at-Risk
Concept

- Calculating the risk for a portfolio with a non-time-constant position
  - Time-dependent position is determenistic
    - Time dependent position is determined e.g. by market liquidity or portfolio strategy
- Calculating the risk until the risk driver is eliminated (similar to Profit-at-risk)

Risk factors

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- Determine the risk factors $q_i, i=1, \ldots, n$ of the portfolio value ΔV with respect to the traded standard contracts with price $F_i, i=1, \ldots, n$
- Determine the number β_i of standard contracts (belonging to F_i) tradable in holding period unit Δt (considering liquidity and/or our hedging strategy)
- We need p periods Δt, $p := max\{q_i / \beta_i : i = 1, \ldots, n\}$, to liquidate our position

Liquidity adjusted Value-at-Risk

VaR calculation for the first holding period Δt

Calculation of the standard deviation σ of the change of the portfolio value ΔV over the time period Δt:

- σ_i denotes the (daily) volatility of F_i
- (C_{ij}) denotes the correlation matrix of the returns r_i of F_i
- $v:=(q_1 F_1(t_0)\sigma_1, \ldots, q_n F_n(t_0)\sigma_n)$

$$\sigma^2 = \Delta t \, \mathbf{v}^{\mathbf{T}} (\mathbf{C}_{\mathbf{i},\mathbf{j}}) \mathbf{v}$$

Liquidity adjusted Value-at-Risk

VaR calculation for the holding period $k\Delta t$: notation

Calculation of the standard deviation $\sigma(k)$ of the change of the portfolio value ΔV_k:

- at period $k=[t_0+k\Delta t, t_0+(k+1)\Delta t]$, $k=0,1,\ldots,p-1$

portfolio consists of $a_{ik}(q_i-kb_i)$ units of F_i , $i=1, \ldots, n$ with

- the indicator

$$a_{ik} = \begin{cases} 1, \text{if } \; k\beta_i \le q_i \\ 0, \text{else} \end{cases}, i \in \{1,\ldots,n\}, k \in \{0,\ldots,p-1\}$$

if the total number of contracts have been reached

VaR calculation for the holding period $k\Delta t$

With

$$v_k = \left(a_{1k}\left(q_1 - k\beta_1\right)F_1\left(t_0\right)\sigma_1, \ldots, a_{nk}\left(q_n - k\beta_n\right)F_n\left(t_0\right)\sigma_n\right)$$

the standard deviation σ_k of the change of the portfolio value ΔV_k over the time period $k\Delta t$ is:

$$\sigma^2(k) = \Delta t \; v_k^T (C_{i,j}) v_k$$

Assumption:

- ΔV is approximately normally distributed with a mean of zero

Liquidity adjusted Value-at-Risk
Variance of the change of the total asset portfolio

Common assumption:

Changes of the prices of a futures contract are independent.

The change of the total asset portfolio is also $N(0,\sigma^2)$-distributed with variance:

$$\sigma^2 = \sum_{k=1}^{p} \sigma^2(k) = \sum_{k=1}^{p} \Delta t \, \boldsymbol{v}_k^T (\boldsymbol{C}_{i,j}) \boldsymbol{v}_k$$

Formula for the Liquidity adjusted VaR(LVaR)

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With the quantile $m_\alpha = N^{-1}(\alpha)$, the requested confidence level the $LVaR(\alpha)$ is

$$(1) \quad LVaR(\alpha) = m_\alpha \sqrt{\Delta t \sum_{k=1}^{p} \mathbf{v}_\mathbf{k}^\mathbf{T} (\mathbf{C}_{\mathbf{i,j}}) \mathbf{v}_\mathbf{k}}$$

Particular case: Proportional closing of the position

Particular case:

Closing the asset position for all commodities with the same degree i.e.:

Replacing β_i by $\overline{\beta}_i = q_i / p$ gives at period k the quantities

$$q_i - k\overline{\beta}_i = (p-k)\overline{\beta}_i$$

and implies $a_{ik}=1$ if and only if $k \leq p$

We have

$$v_k = (p-k)\left(\overline{\beta}_1 F_1(t_0)\sigma_1, \ldots, \overline{\beta}_n F_n(t_0)\sigma_n\right) =: (\mathrm{p-k})\mathrm{v}$$

and hence

$$(2) \quad \sigma^2 = \Delta t \mathbf{v}^{\mathbf{T}} (\mathbf{C}_{\mathbf{i,j}}) \mathbf{v} \sum_{k=1}^{p} (p-k)^2 = \Delta t \mathbf{v}^{\mathbf{T}} (\mathbf{C}_{\mathbf{i,j}}) \mathbf{v} \frac{(p-1)p(2p-1)}{6}$$

Liquidity adjusted Value-at-Risk
Proportional closing of the position

Formula for the LVaR(α) for the special case of a proportional closing of the position:

$$(3) \quad LVaR(\alpha) = m_\alpha \sqrt{\frac{(p-1)p(2p-1)}{6} \Delta t \mathbf{v}^{\mathbf{T}} \left(\mathbf{C}_{\mathbf{i,j}}\right) \mathbf{v}}$$

Liquidity adjusted Value-at-Risk

Example: Risk factors of the asset portfolio

Assumed multi-commodity portfolio:

Risk factor	Quantity	Price	Volatility 1d
Baseload 2012	10,000,000 MWh	57.86 EUR/MWh	1.0%
Peakload 2012	5,000,000 MWh	70.70 EUR/MWh	1.0%
Coal: API#2	-1,000,000 t	128.61 USD/t	1.0%
USD	-85,000,000 USD	0.71 EUR/USD	0.7%
Emission CO2	-1,000,000 t	17.61 EUR/t	1.5%

Assumed proportional closing of the position within 100 trading days (liquidity restricted or hedge concept restricted), i.e. $\Delta t = 1 day$ and $p = 100$.

Example: Correlations of the commodities

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Determination of the correlation matrix *(C_{ij}):*

	Baseload	Peakload	Coal	USD	CO2
Baseload	1.0	0.9	0.7	0.0	0.5
Peakload	0.9	1.0	0.7	0.1	0.5
Coal	0.7	0.7	1.0	0.2	0.3
USD	0.0	0.1	0.2	1.0	0.1
CO2	0.5	0.5	0.3	0.1	1.0

Liquidity adjusted Value-at-Risk
Example: LVaR for a multi-commodity portfolio

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Using equation (2) gives the variance of the value change of the asset portfolio:

$$\sigma^2 = \frac{99 \cdot 100 \cdot 199}{6} \begin{pmatrix} 58{,}608 \\ 36{,}068 \\ -12{,}940 \\ -6{,}613 \\ -2{,}650 \end{pmatrix}^T \begin{pmatrix} 1.0 & 0.9 & 0.7 & 0.0 & 0.5 \\ 0.9 & 1.0 & 0.7 & 0.1 & 0.5 \\ 0.7 & 0.7 & 1.0 & 0.2 & 0.3 \\ 0.0 & 0.1 & 0.2 & 1.0 & 0.1 \\ 0.5 & 0.5 & 0.3 & 0.1 & 1.0 \end{pmatrix} \begin{pmatrix} 58{,}608 \\ 36{,}068 \\ -12{,}940 \\ -6{,}613 \\ -2{,}650 \end{pmatrix} = 2.27E+15$$

The liquidity adjusted Value-at-Risk is therefore:

LVaR(98%)=2.05σ=97,714,151

EUR

Liquidity adjusted Value-at-Risk

Example: Interpretation of the result

The liquidity in 2012 is restricted. If the estimated time for the closing of a position of 15 TWh and the belonging coal, emission and USD Position is 100 trading days, the market risk of the generation portfolio considering market liquidity is 98 Mio. Euro

Liquidity adjusted Value-at-Risk
Monte Carlo Methods

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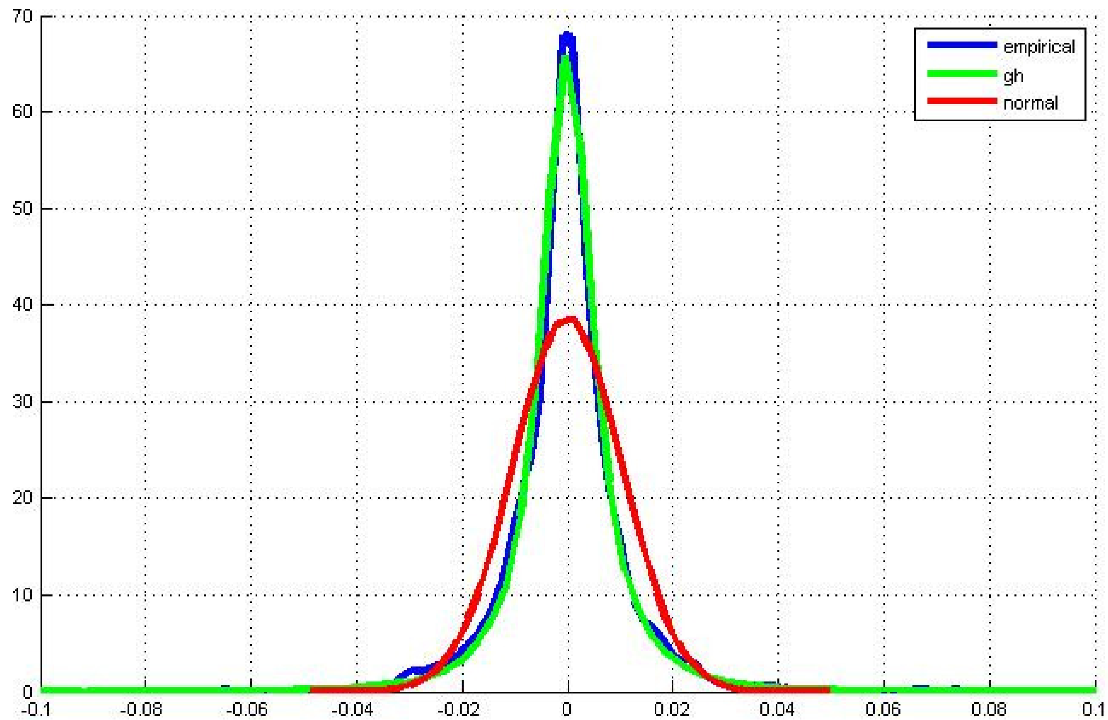
- Drawback of analytical method: Approximation of log-normal distribution by normal distribution is inaccurate.
- Draw Monte Carlo paths from multi-dimensional log-normal distribution to calculate dynamical value at risk path wise according to closing vector.
- Large amount of sample paths is needed for stable results (~100.000) because of quantile estimation.

- As Monte Carlo method does not make any assumptions on the underlying price processes, more complex stochastic processes could be used.

Liquidity adjusted Value-at-Risk
Logarithmic price returns are not normal

Generalized hyperbolic distribution fits better than normal distribution to logarithmic returns of prices.



Distribution of logarithmic price returns (EEX Baseload 2012)

Liquidity adjusted Value-at-Risk
Simulation results for dynamical VaR

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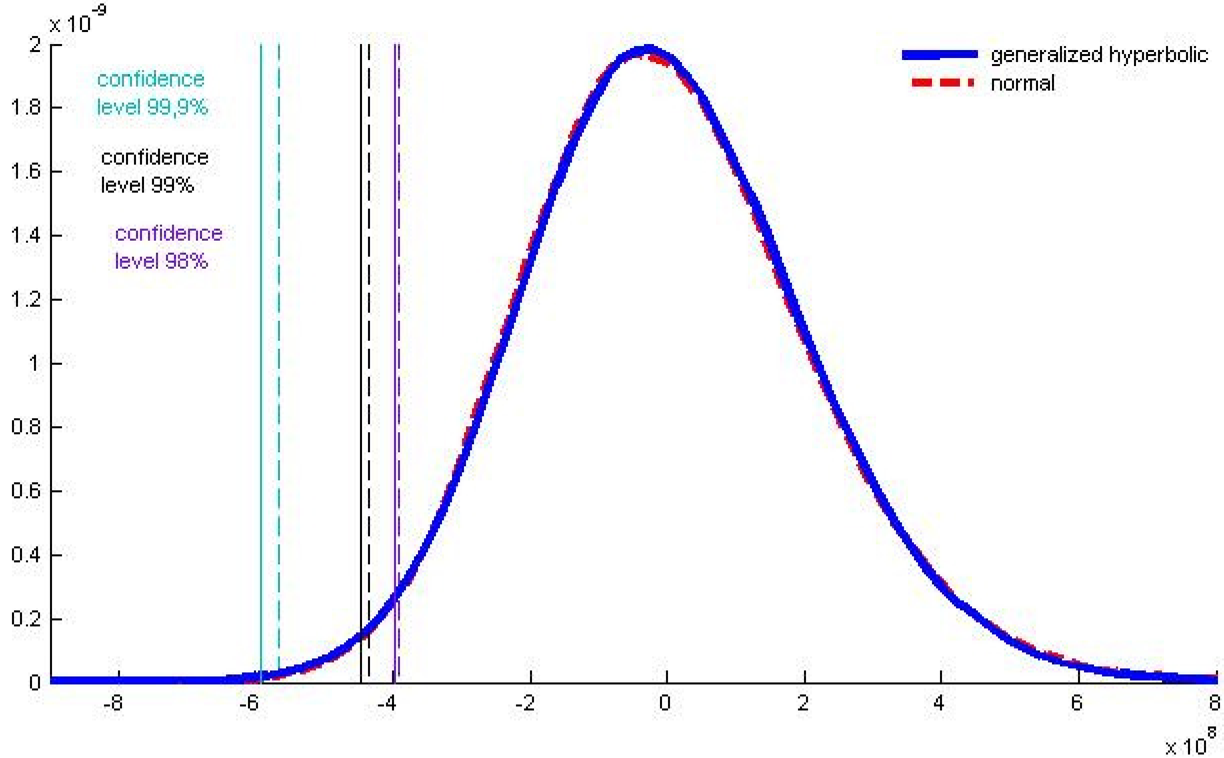
Simulation of dynamical VaR with 1.000.000 sample paths yields similar distribution for generalized hyperbolic and normal model. But difference increases in the tails.

Reason: averaging makes gh model converge to normal (central limit theorem)



Liquidity adjusted Value-at-Risk

LVaR: Further Reading

Burger M., Graeber B., Schindlmayr G. :

Managing energy risk:

An integrated View on Power and Other Energy Markets.

Wiley Finance 2007