The Actuarial Profession
making financial sense of the future

GIRO Conference and Exhibition 2012

Statistical Modelling of Operational Risk Severity Distributions with Insurance Applications

Jens Perch Nielsen

Four published papers on operational risk

A. Guillen, Gustafsson, Nielsen and Pritchard (2007). Using external data in operational risk. Geneva papers, 178-189.

B. Buch-Kromann, Englund, Gustafsson, Nielsen, Thuring (2007). Non-Parametric estimation of operational risk losses adjusted for under-reporting. Scandinavian Actuarial Journal, 293-304.

C. Gustafsson and Nielsen (2008). A mixing model for operational risk. Journal of operational risk, 3, 25-37.

D. Guillen, Gustafsson and Nielsen (2008). Combining under-reported internal and external data for operational risk measurement. Journal of operational risk, 4, 1-22.

Festina Lente

AGENDA

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AGENDA

- **Painting the picture**

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AGENDA

- Painting the picture

- **Collecting the materials**

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AGENDA

- Painting the picture

- Collecting the materials

- **Behind the scenes**

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AGENDA

- Painting the picture

- Collecting the materials

- Behind the scenes

- **Mixing the colours**

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AGENDA

- Painting the picture

- Collecting the materials

- Behind the scenes

- Mixing the colours

- **Painting by numbers**

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AGENDA

- Painting the picture

- Collecting the materials

- Behind the scenes

- Mixing the colours

- Painting by numbers

- **Framing the canvas**

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- **Painting the picture**

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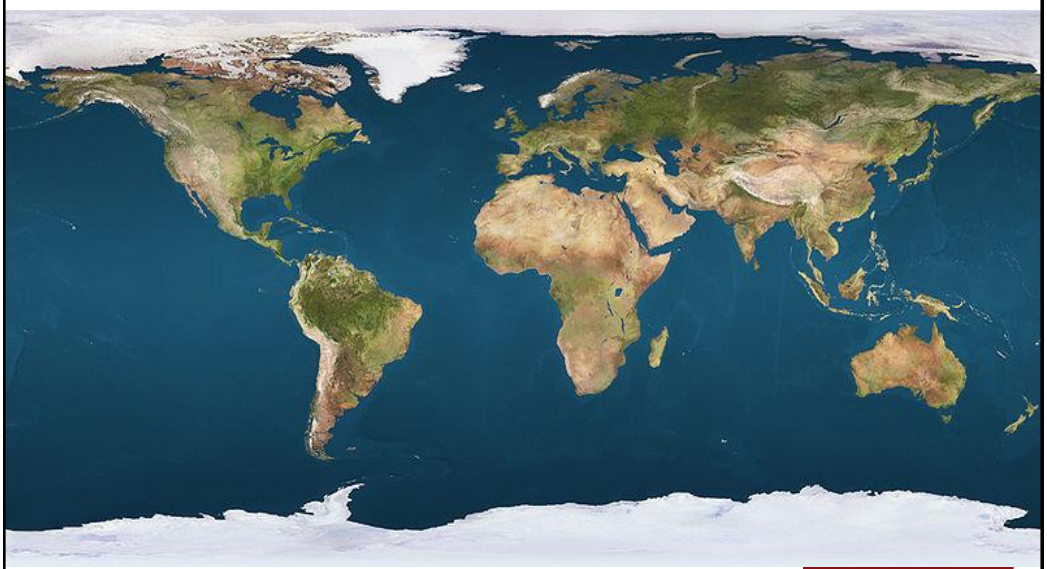
Painting the picture | Collecting the material | Behind the scenes | Mixing the colours | Painting by numbers | Framing the canvas



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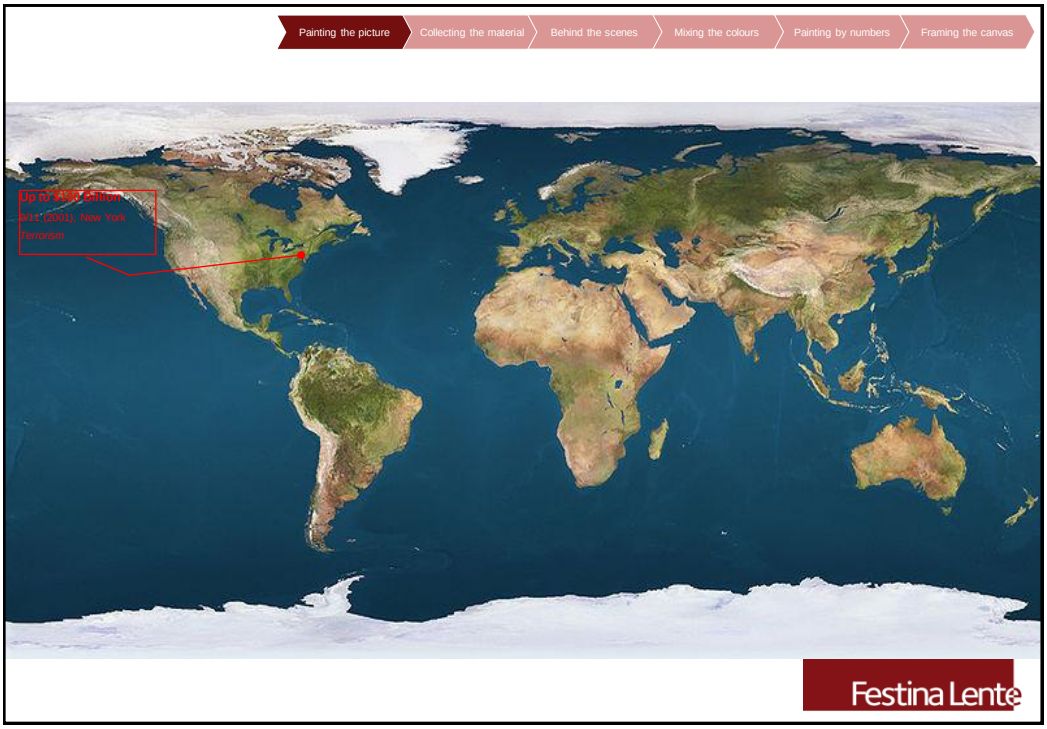
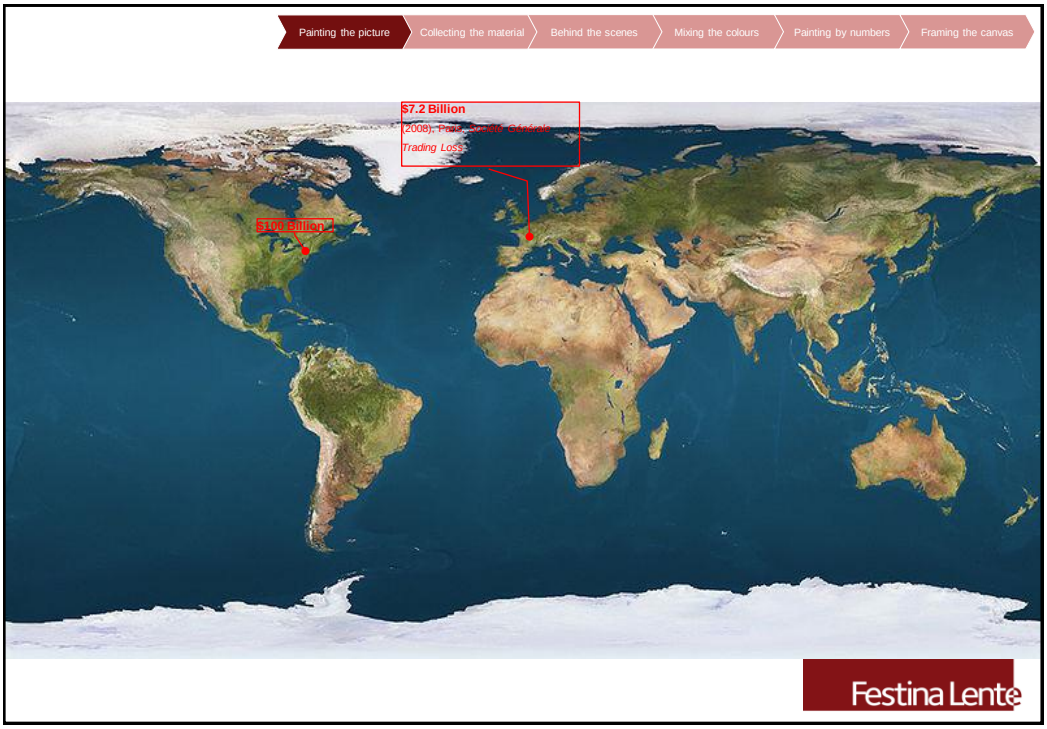

Painting the picture
Collecting the material
Behind the scenes
Mixing the colours
Painting by numbers
Framing the canvas
Up to $40 Billion
9/11 (2001), New York
Terrorism
Festina Lente


Painting the picture
Collecting the material
Behind the scenes
Mixing the colours
Painting by numbers
Framing the canvas
$7.2 Billion
Trading Loss
$100 Billion
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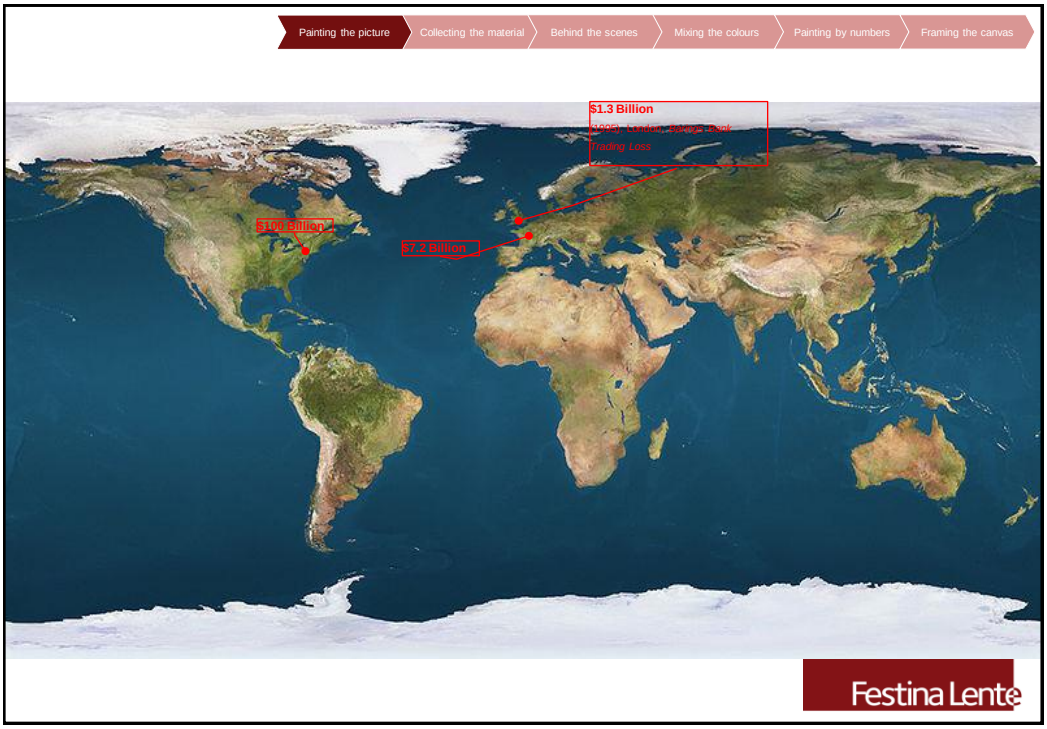
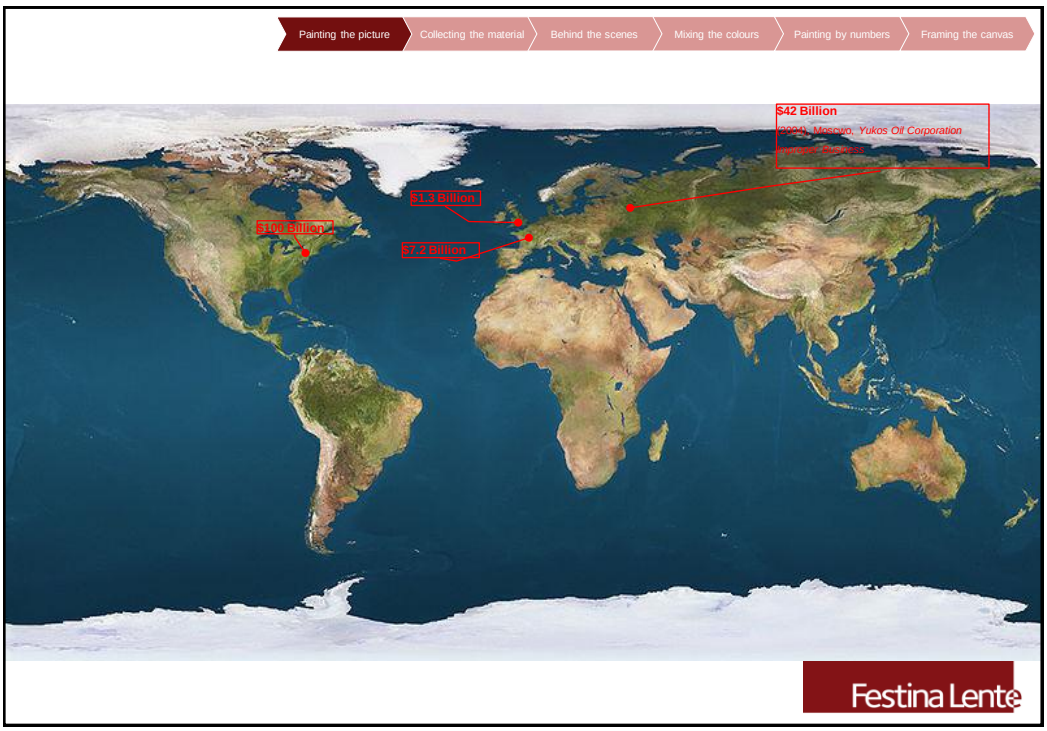
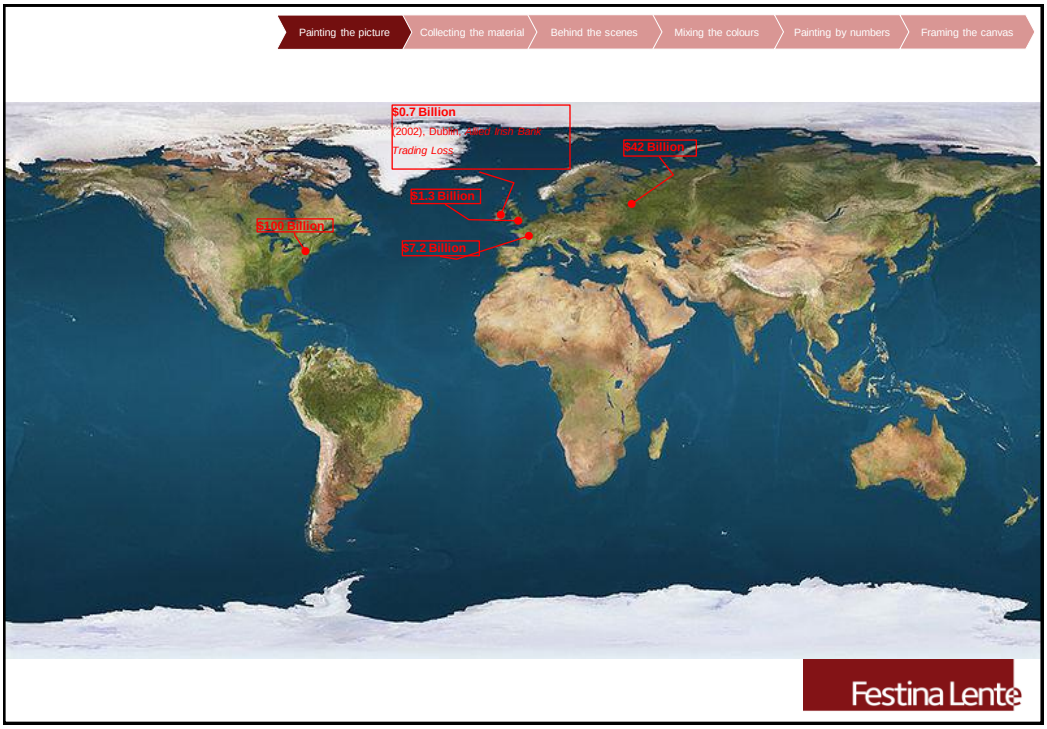

Painting the picture
Collecting the material
Behind the scenes
Mixing the colours
Painting by numbers
Framing the canvas
$1.3 Billion
Trading Loss
$100 Billion
$7.2 Billion
Festina Lente


Painting the picture
Collecting the material
Behind the scenes
Mixing the colours
Painting by numbers
Framing the canvas
$42 Billion
Yukos Oil Corporation
$1.3 Billion
$100 Billion
$7.2 Billion
Festina Lente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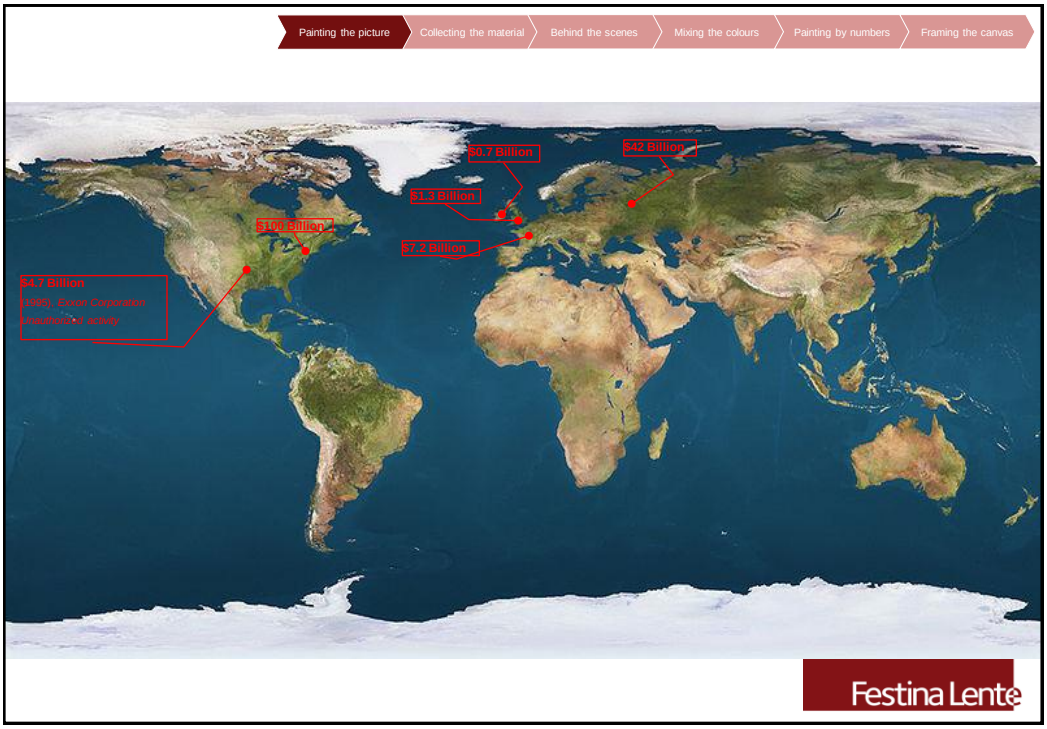
Collecting the material
Behind the scenes
Mixing the colours
Painting by numbers
Framing the canvas
$0.7 Billion
(2002), Dublin, Allied Irish Bank
Trading Loss
$42 Billion
$1.3 Billion
$100 Billion
$7.2 Billion
Festina Lente


Painting the picture
Collecting the material
Behind the scenes
Mixing the colours
Painting by numbers
Framing the canvas
$0.7 Billion
$42 Billion
$1.3 Billion
$100 Billion
$7.2 Billion
$4.7 Billion
(1985), Exxon Corporation
Unauthorized activity
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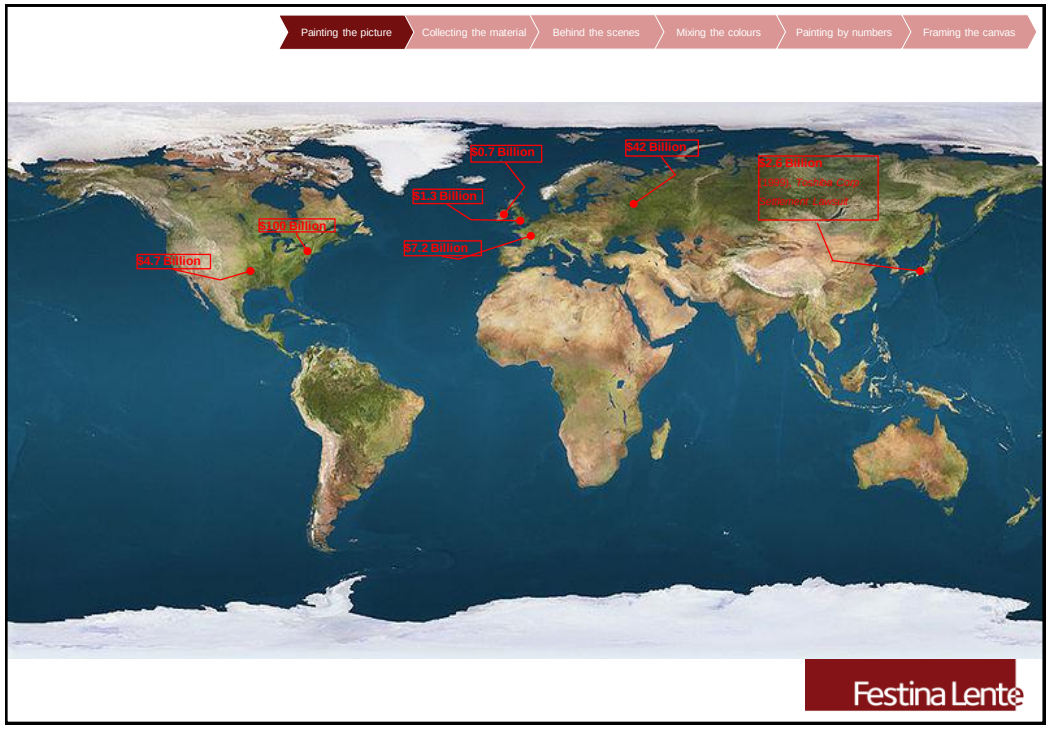
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Behind the scenes
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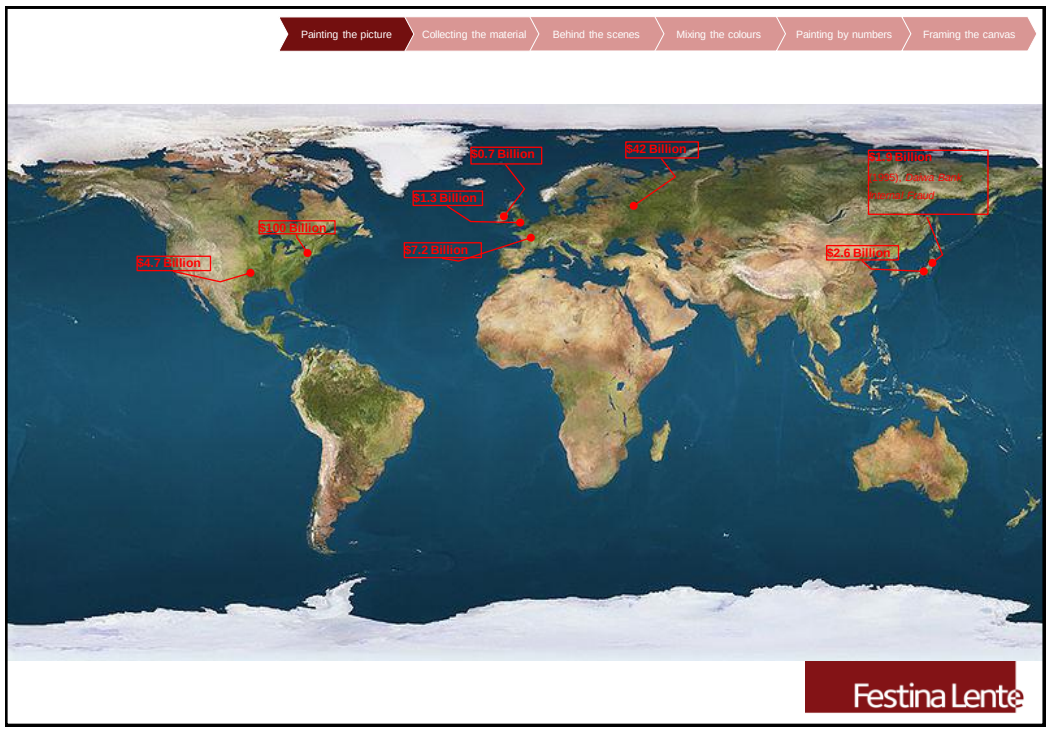
Painting by numbers
Framing the canvas
$0.7 Billion
$42 Billion
$1.3 Billion
$100 Billion
$7.2 Billion
$4.7 Billion
Festina Lente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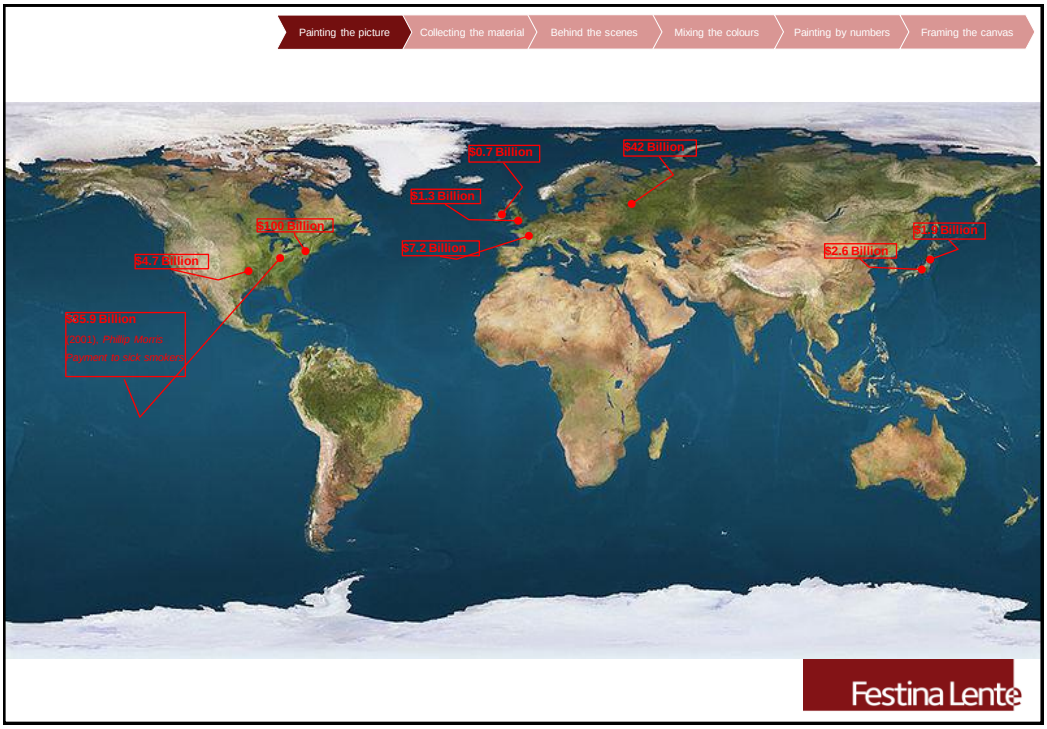
Behind the scenes
Mixing the colours
Painting by numbers
Framing the canvas
$0.7 Billion
$42 Billion
$1.3 Billion
$100 Billion
$7.2 Billion
$4.7 Billion
$2.6 Billion
Festina Lente


Painting the picture
Collecting the material
Behind the scenes
Mixing the colours
Painting by numbers
Framing the canvas
$0.7 Billion
$42 Billion
$1.3 Billion
$100 Billion
$7.2 Billion
$4.7 Billion
$2.6 Billion
$35.9 Billion
(2001), Philip Morris
Payment to sick smokers
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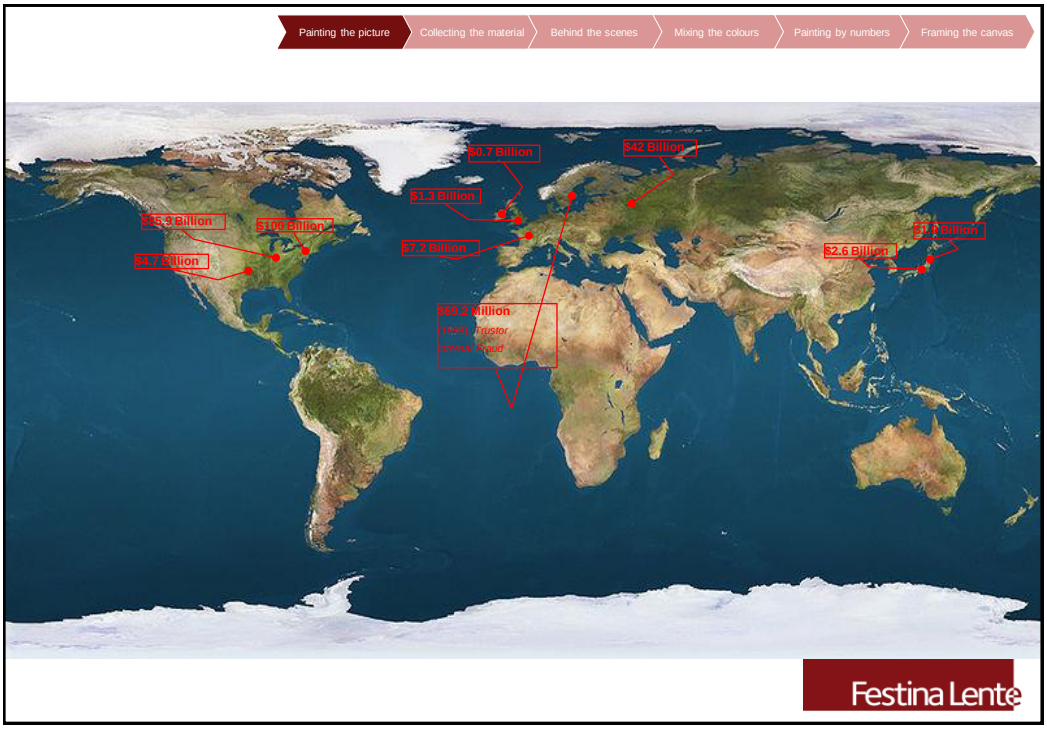
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Collecting the material
Behind the scenes
Mixing the colours
Painting by numbers
Framing the canvas
$0.7 Billion
$42 Billion
$1.3 Billion
$35.9 Billion
$100 Billion
$7.2 Billion
$4.7 Billion
$2.6 Billion
$63.2 Million
(1994), Trustor
Internal Fraud
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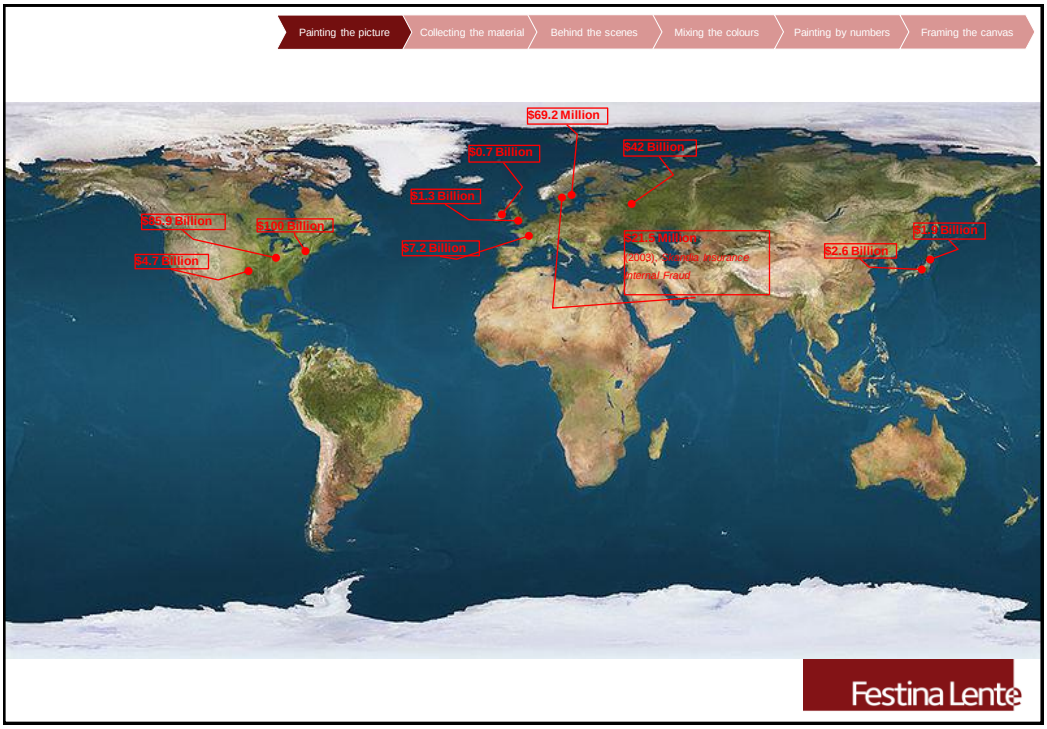
Painting the picture
Collecting the material
Behind the scenes
Mixing the colours
Painting by numbers
Framing the canvas
$69.2 Million
$0.7 Billion
$42 Billion
$1.3 Billion
$55.9 Billion
$100 Billion
$7.2 Billion
$4.7 Billion
$2.6 Billion
Internal Fraud
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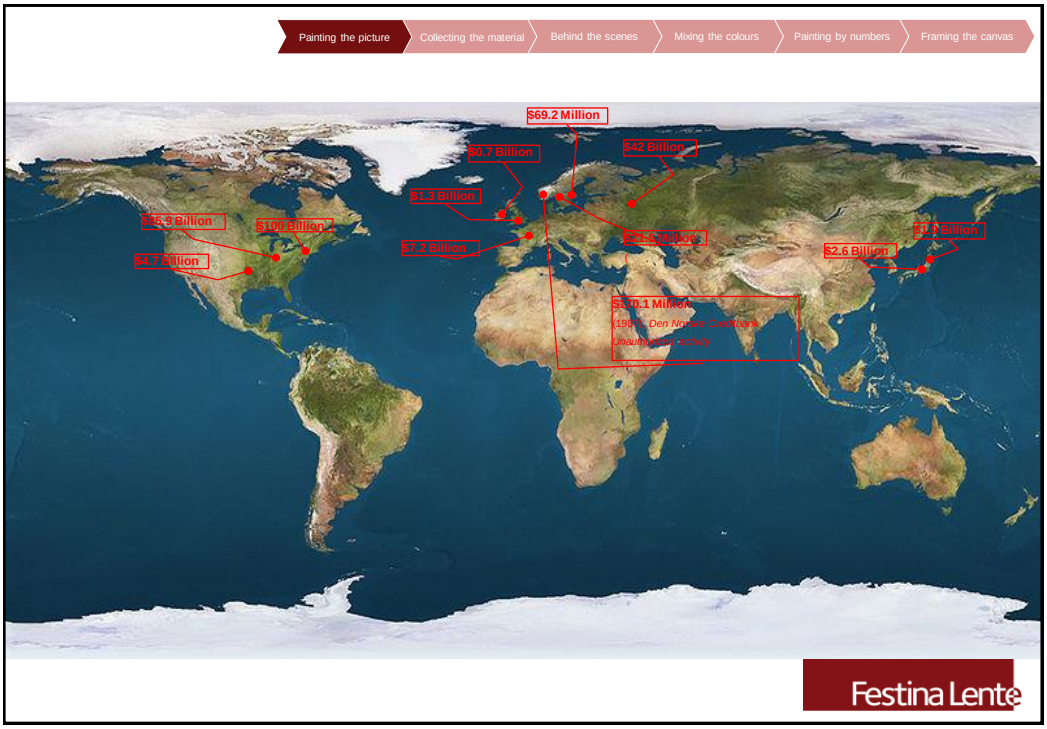
Painting the picture
Collecting the material
Behind the scenes
Mixing the colours
Painting by numbers
Framing the canvas
$69.2 Million
$0.7 Billion
$42 Billion
$1.3 Billion
$55.9 Billion
$100 Billion
$7.2 Billion
$4.7 Billion
$2.6 Billion
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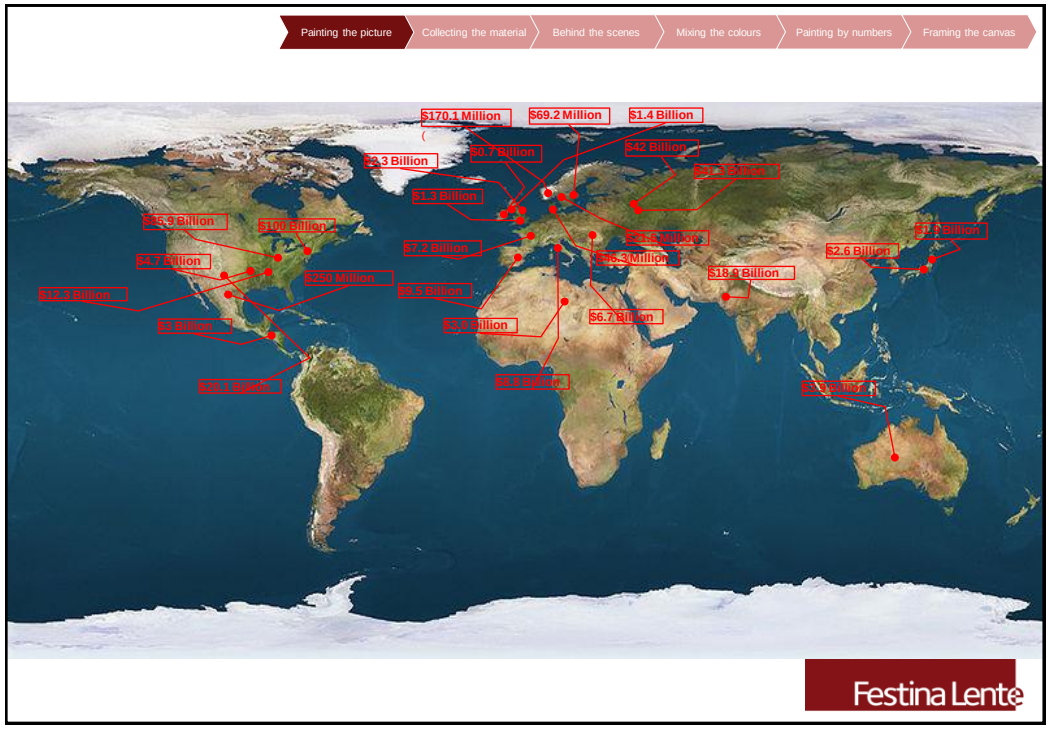
Painting the picture
Collecting the material
Behind the scenes
Mixing the colours
Painting by numbers
Framing the canvas
$170.1 Million
$69.2 Million
$1.4 Billion
$0.7 Billion
$42 Billion
$3.3 Billion
$1.3 Billion
$5.3 Billion
$100 Billion
$7.2 Billion
$4.7 Billion
$250 Billion
$12.3 Billion
$9.5 Billion
$3 Billion
$6.7 Billion
$2.6 Billion
$18.8 Billion
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Painting the picture
Collecting the material
Behind the scenes
Mixing the colours
Painting by numbers
Framing the canvas
$170.1 Million
$69.2 Million
$1.4 Billion
$0.7 Billion
$42 Billion
$3.3 Billion
$1.3 Billion
$5.3 Billion
$100 Billion
$7.2 Billion
$4.7 Billion
$250 Billion
$12.3 Billion
$9.5 Billion
$3 Billion
$6.7 Billion
$2.6 Billion
$18.8 Billion
More than 100 losses exceeding $100 Million over the last decade in the financial industry
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Definition

Operational risk is the risk of economic loss resulting from inadequate or failed internal process and methodologies, people, systems, or from external events.

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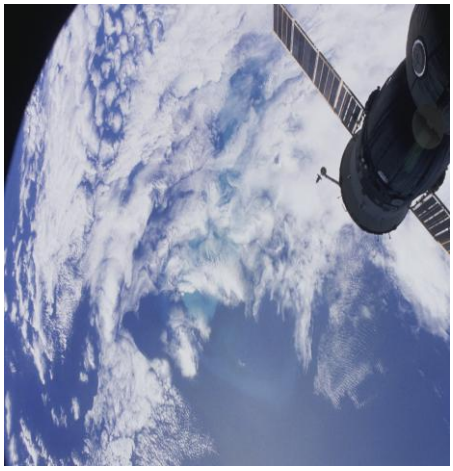
Operational Risk Universe

Level 1	Level 2	Level 3	
Crime		External Fraud	Internal Fraud
Employment Practices		Diversity and Discrimination	Employee Relations
External Requirements		Money Laundering	Market Misconduct
External Events		Natural Disasters	War and Terrorism
Internal Changes		Internal Change	Mergers, Acquisition and Disposals
Systems		Hardware Failures	Software Failure
Business Processing		Transaction Capture, Execution and Maintenance	Customer Management
Relationship with Counterparties		Outsourcing Contracts	Vendors and Suppliers



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- **Collecting the materials**

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Operational Risk Quantification

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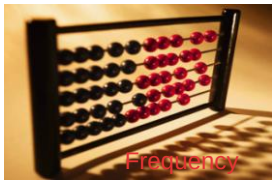
Operational Risk Quantification



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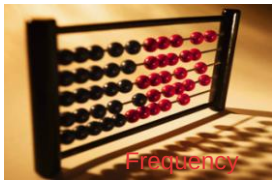
Operational Risk Quantification

Scenario 1



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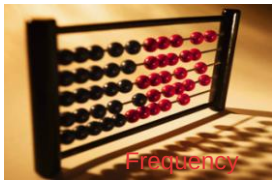
Operational Risk Quantification



Scenario 1

Scenario 2

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Operational Risk Quantification

Scenario 1

Scenario 2

Scenario 3

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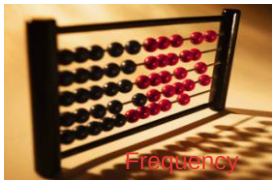
Operational Risk Quantification



Scenario 1

Scenario 2

Scenario 3

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Scenario *n*

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Operational Risk Quantification

Scenario 1

Scenario 2

Scenario 3

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Scenario *n*

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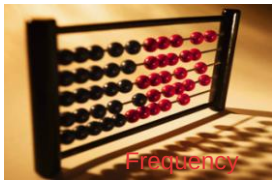
Operational Risk Quantification



Scenario 1

Scenario 2

Scenario 3

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Scenario *n*

Painting the picture | Collecting the material | Behind the scenes | Mixing the colours | Painting by numbers | Framing the canvas

Operational Risk Quantification

Frequency

Severity

Scenario 1

Scenario 2

Scenario 3

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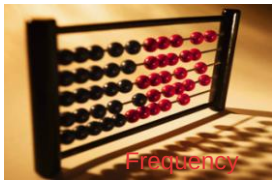
Scenario *n*

Painting the picture | Collecting the material | Behind the scenes | Mixing the colours | Painting by numbers | Framing the canvas

Operational Risk Quantification



Scenario 1

Scenario 2

Scenario 3

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Scenario *n*

Painting the picture | Collecting the material | Behind the scenes | Mixing the colours | Painting by numbers | Framing the canvas

Operational Risk Quantification

Frequency

Severity

Scenario 1

Scenario 2

Scenario 3

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Scenario *n*

What type of frequency and severity model should a company use to predict a correct operational risk exposure?

A Comprehensive overview

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A Comprehensive overview

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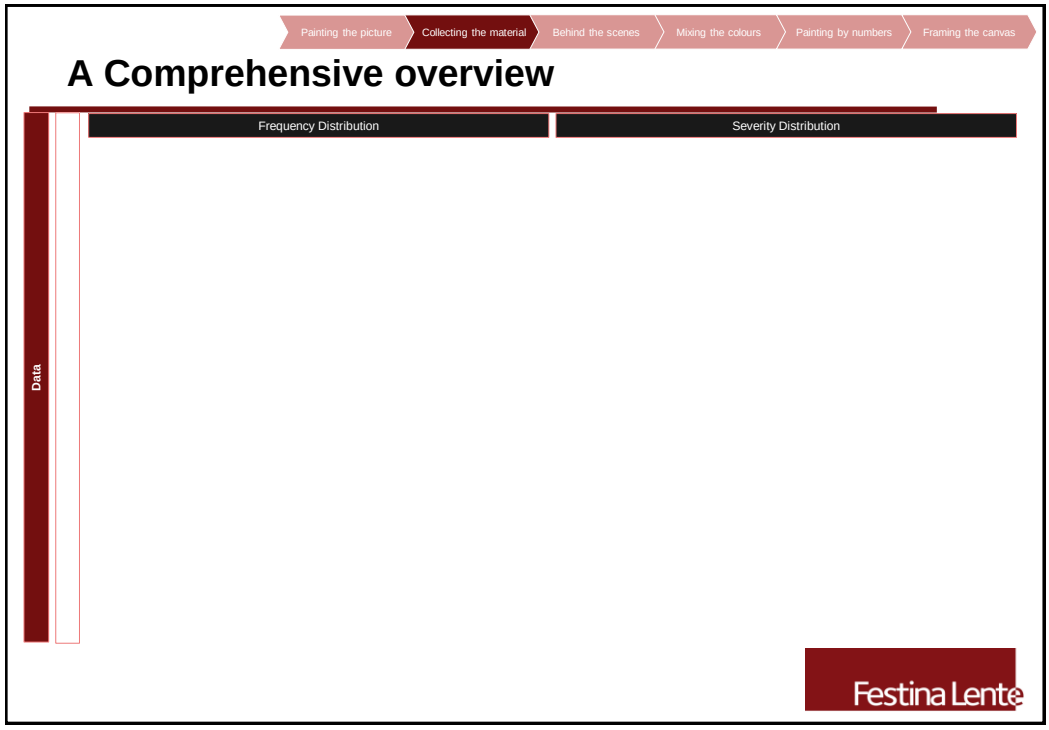
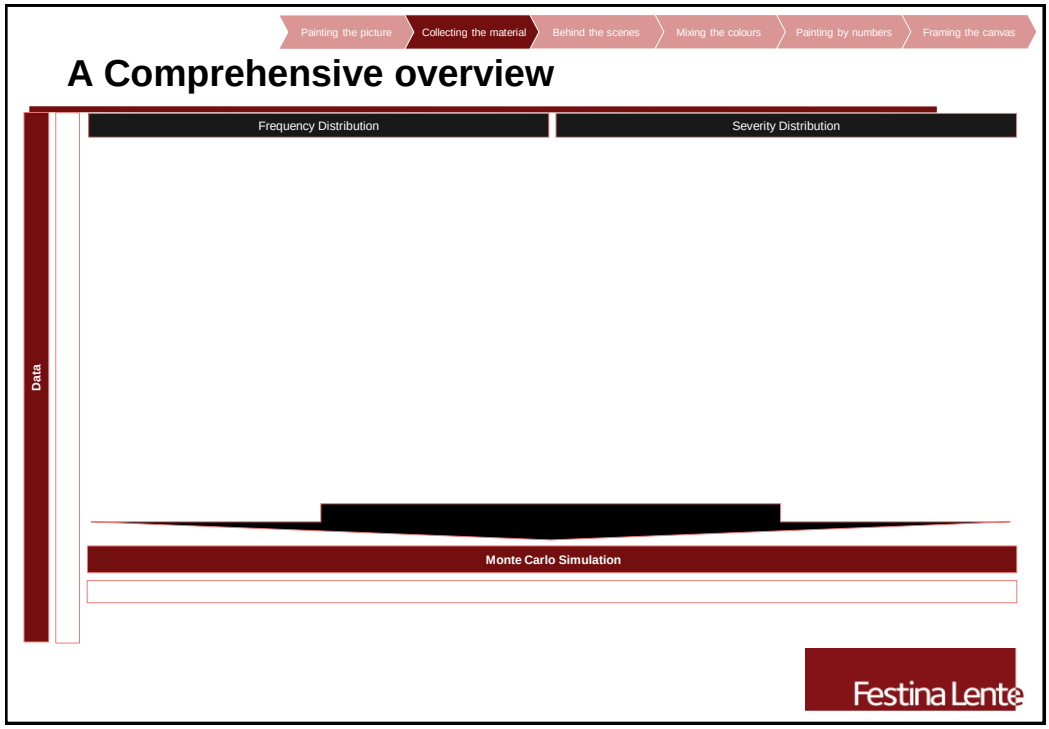
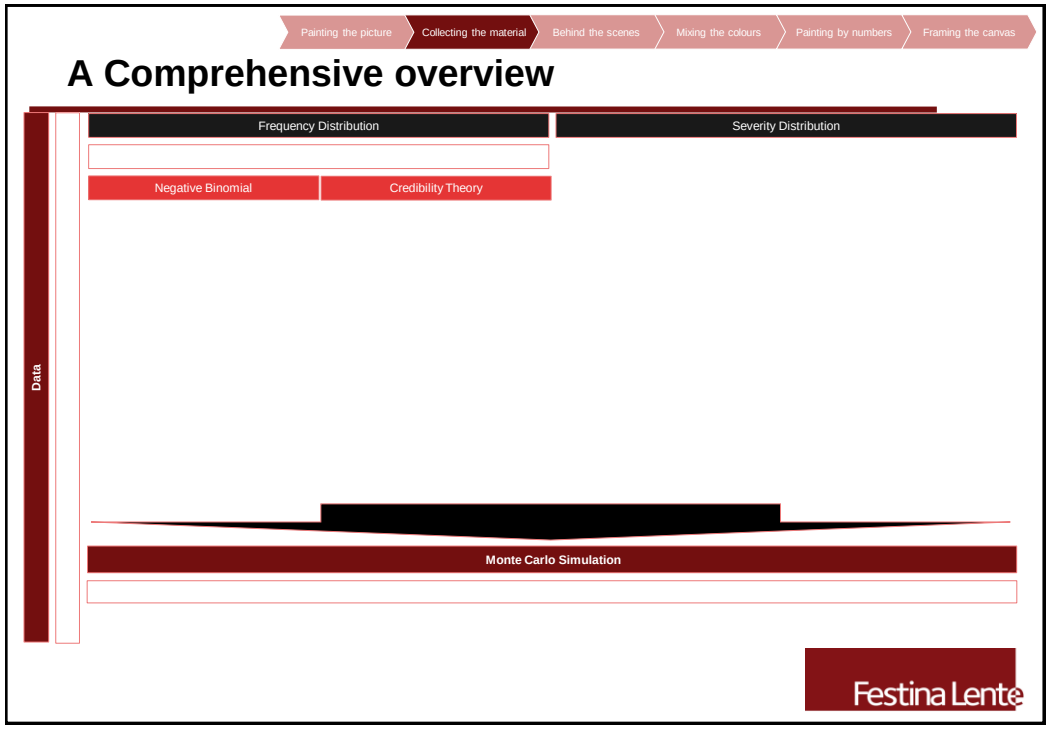

Painting the picture
Collecting the material
Behind the scenes
Mixing the colours
Painting by numbers
Framing the canvas
A Comprehensive overview
Frequency Distribution
Severity Distribution
Data
Festina Lente


Painting the picture
Collecting the material
Behind the scenes
Mixing the colours
Painting by numbers
Framing the canvas
A Comprehensive overview
Frequency Distribution
Severity Distribution
Data
Monte Carlo Simulation
Festina Lente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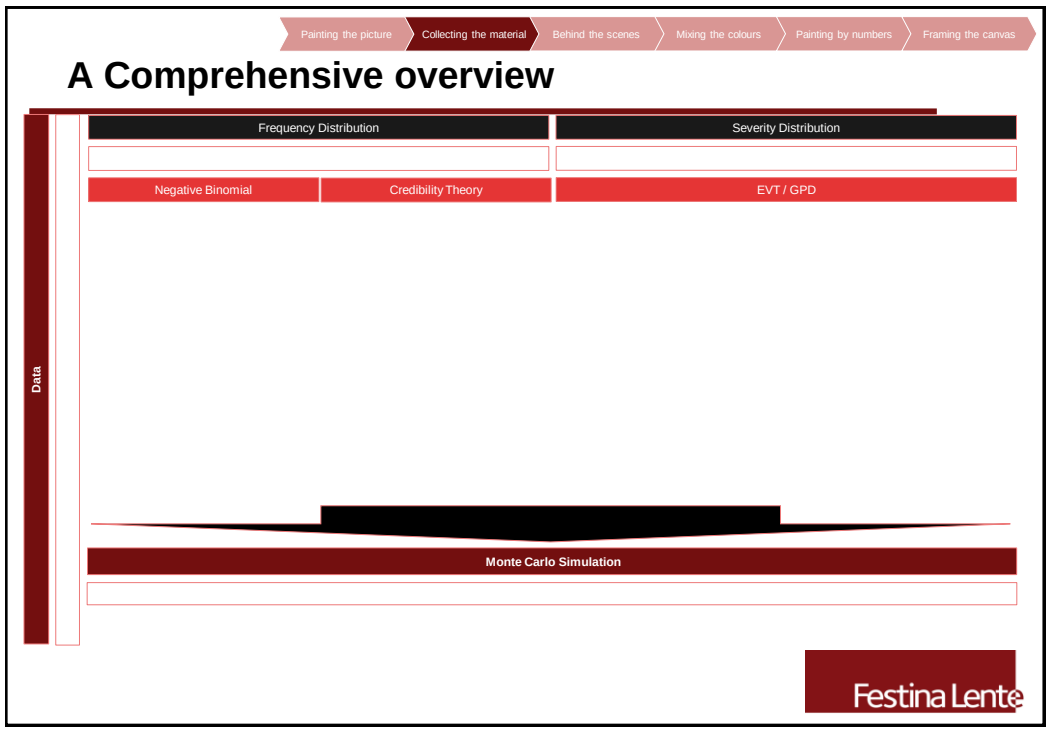
Collecting the material
Behind the scenes
Mixing the colours
Painting by numbers
Framing the canvas
A Comprehensive overview
Frequency Distribution
Severity Distribution
Negative Binomial
Credibility Theory
Data
Monte Carlo Simulation
Festina Lente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A Comprehensive overview
Frequency Distribution
Severity Distribution
Negative Binomial
Credibility Theory
EVT / GPD
Data
Monte Carlo Simulation
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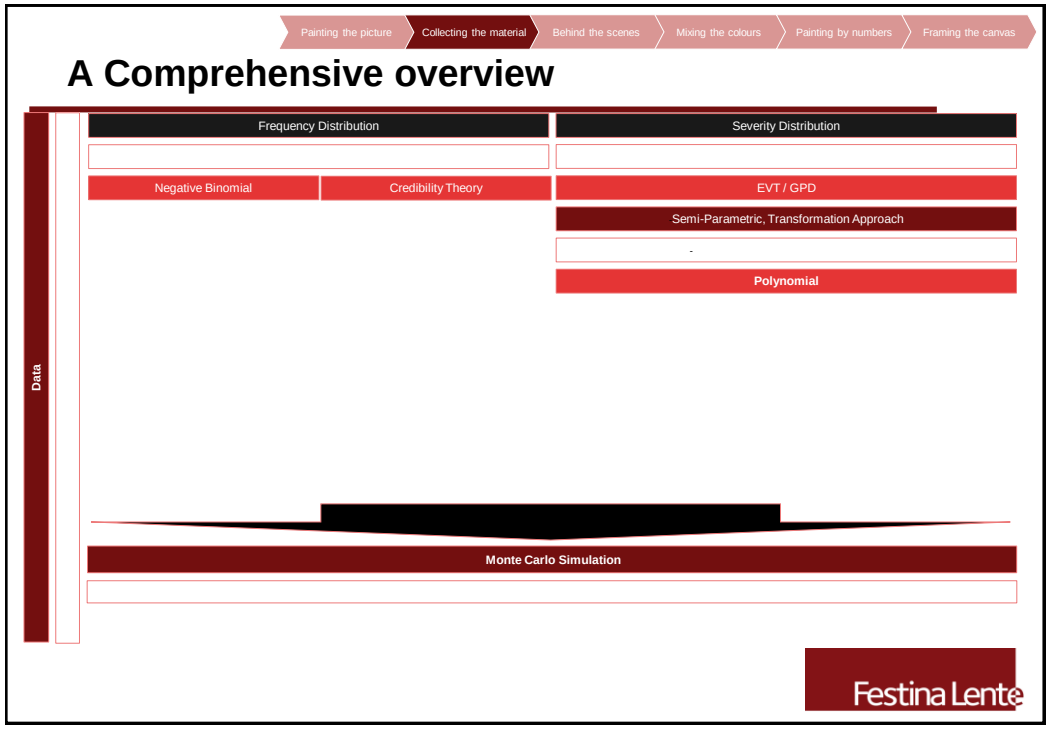
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A Comprehensive overview
Frequency Distribution
Severity Distribution
Negative Binomial
Credibility Theory
EVT / GPD
Semi-Parametric, Transformation Approach
Polynomial
Data
Monte Carlo Simulation
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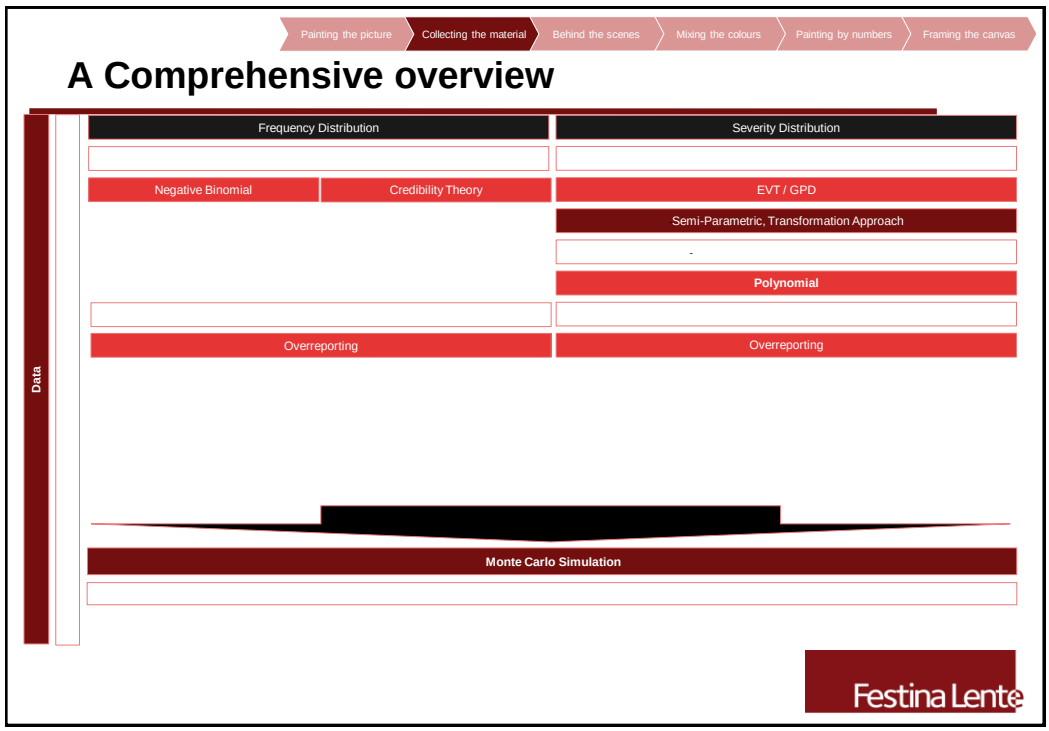
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Frequency Distribution
Severity Distribution
Negative Binomial
Credibility Theory
EVT / GPD
Semi-Parametric, Transformation Approach
Polynomial
Overreporting
Overreporting
Data
Monte Carlo Simulation
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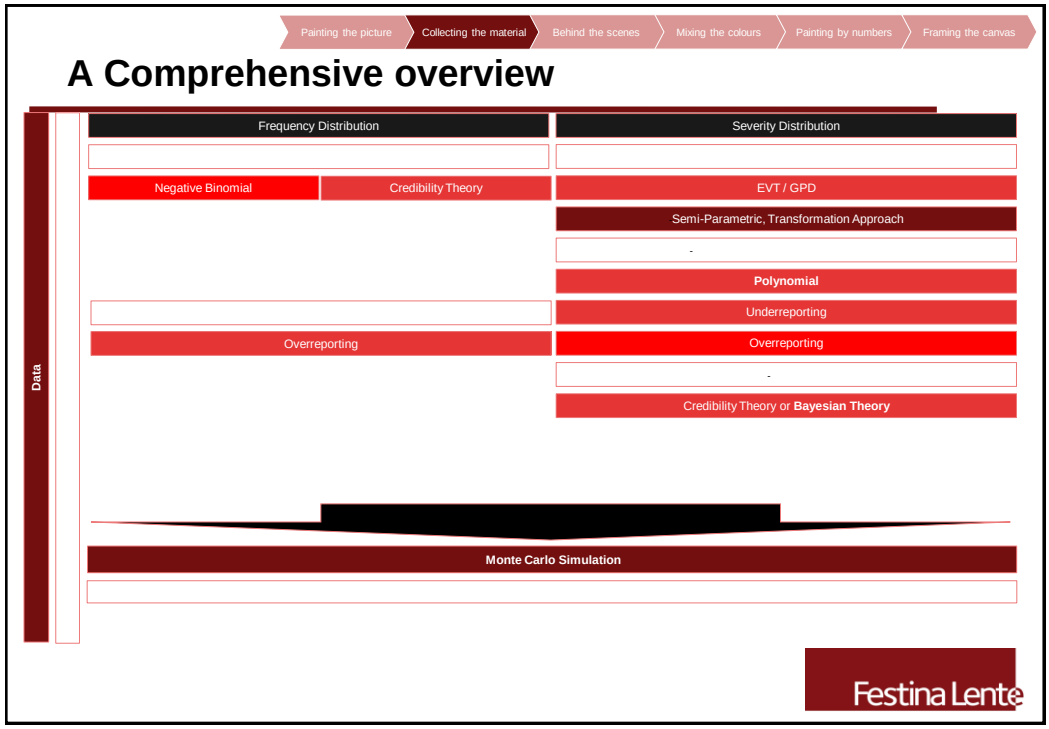
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Data
Frequency Distribution
Severity Distribution
Negative Binomial
Credibility Theory
EVT / GPD
Semi-Parametric, Transformation Approach
Polynomial
Underreporting
Overreporting
Overreporting
Credibility Theory or Bayesian Theory
Monte Carlo Simulation
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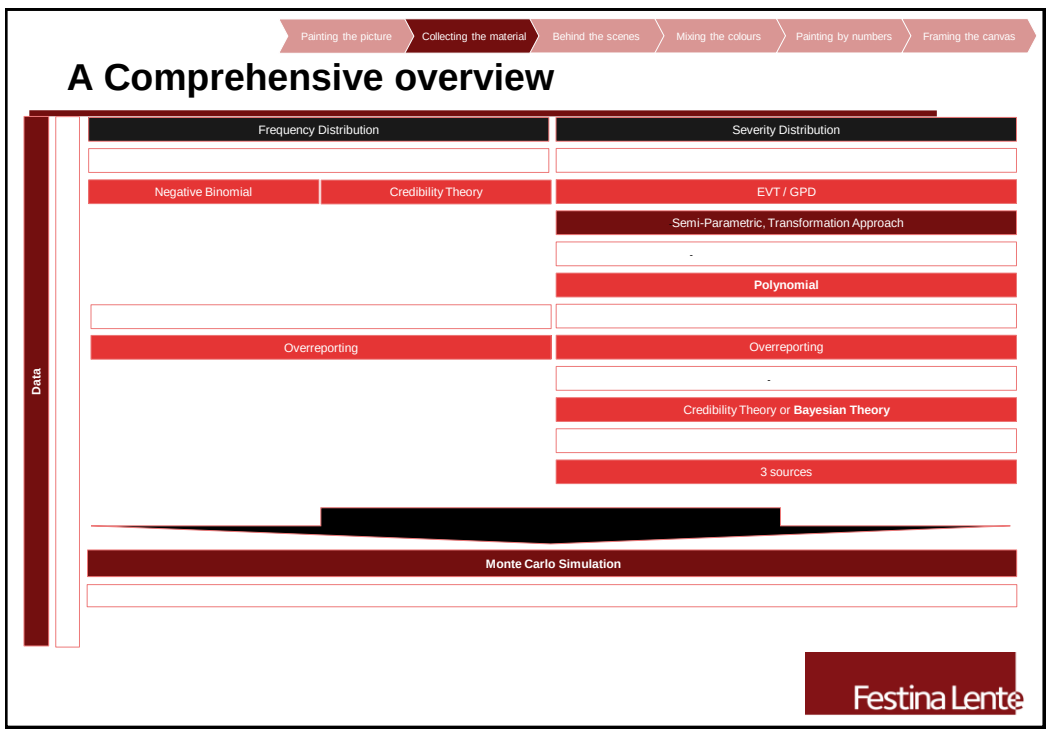
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Data
Frequency Distribution
Severity Distribution
Negative Binomial
Credibility Theory
EVT / GPD
Semi-Parametric, Transformation Approach
Polynomial
Overreporting
Overreporting
Credibility Theory or Bayesian Theory
3 sources
Monte Carlo Simulation
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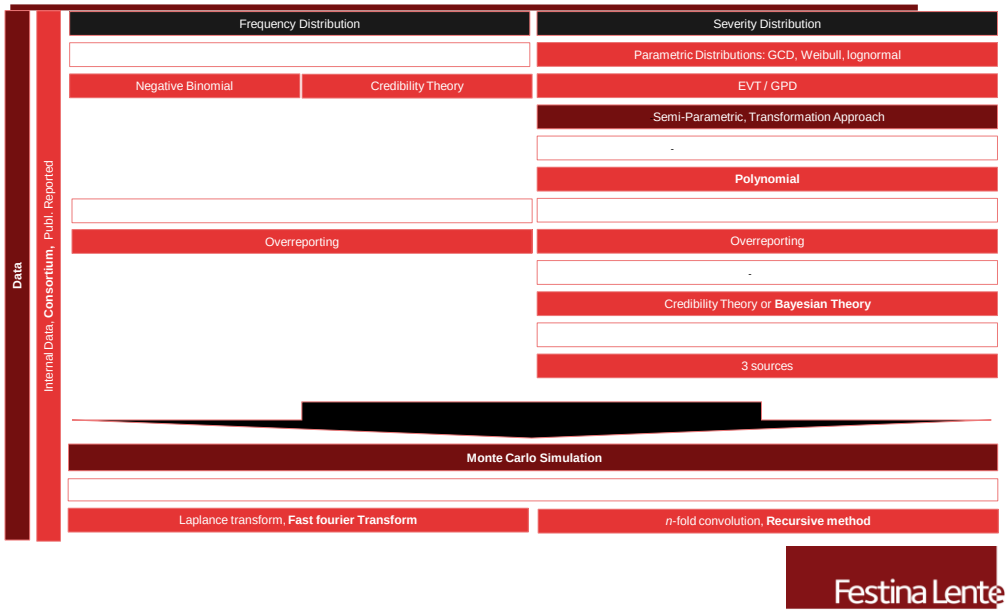
A Comprehensive overview



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➢Behind the scenes

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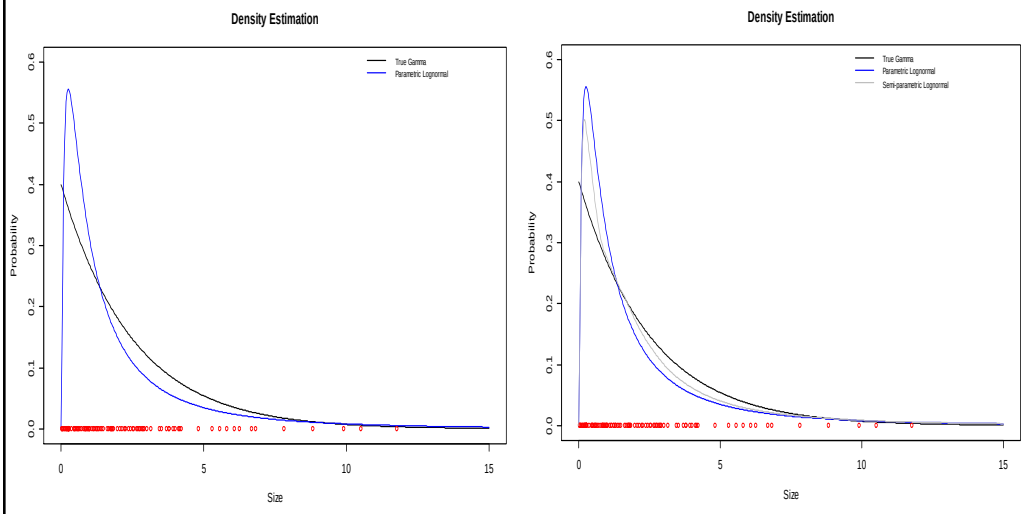
Semiparametric Transformation Estimator



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Painting the picture | Collecting the material | Behind the scenes | Mixing the colours | Painting by numbers | Framing the canvas

Semiparametric Transformation Estimator

- When data are limited, the model is close to a parametric model.
- As the number of losses increases, the model becomes more non-parametric.

Distribution Assumption. Estimate the distribution parameters on the data $(X_i)_{1\le i\le 100}$

Transform losses to the bounded support [0,1] with $Z_i = F_{\hat{\theta}}(X_i)$

KDE: $\hat{g}(z) = \frac{1}{100}\sum_{i=1}^{100} K_h(z_i - z)$ with $K(z) = \frac{3}{4}(1 - z^2)\mathbb{1}_{\{|z|<1\}}$ and $K_h(\cdot) = \frac{1}{h}K\left(\frac{\cdot}{h}\right)$

Semi-parametric density, $\hat{f}(x) = f_{\hat{\theta}}(x)\hat{g}(F_{\hat{\theta}}(x))$

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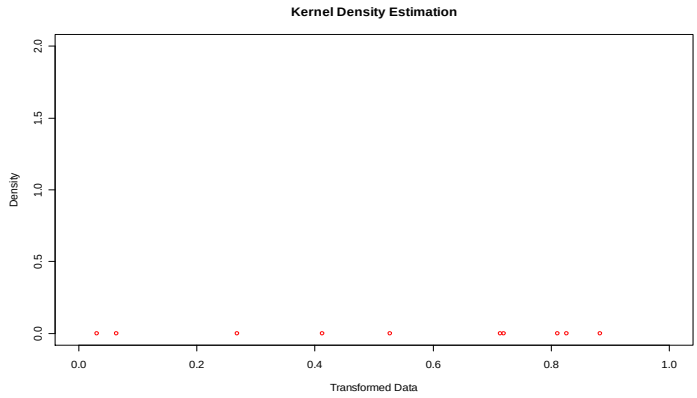
Semiparametric Transformation Estimator



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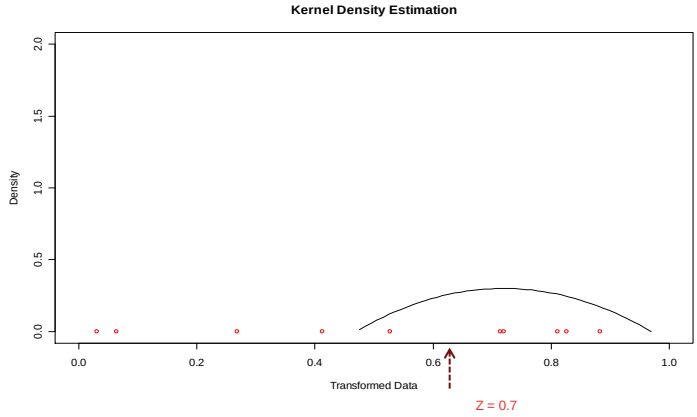
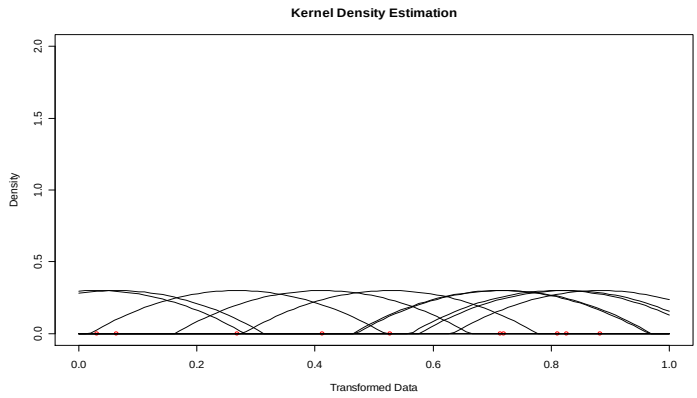
Painting the picture | Collecting the material | Behind the scenes | Mixing the colours | Painting by numbers | Framing the canvas

Semiparametric Transformation Estimator



Festina Lente

Semiparametric Transformation Estimator



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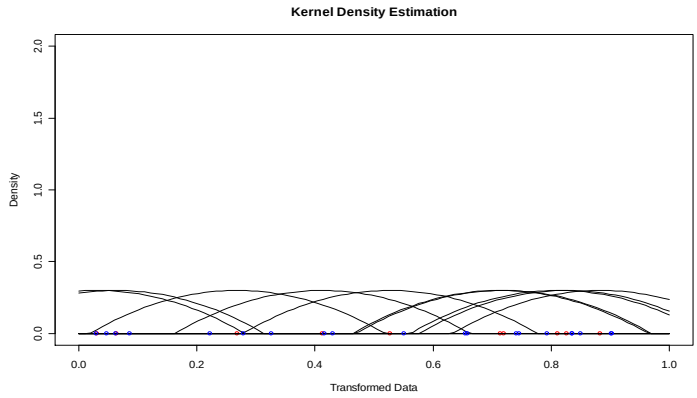

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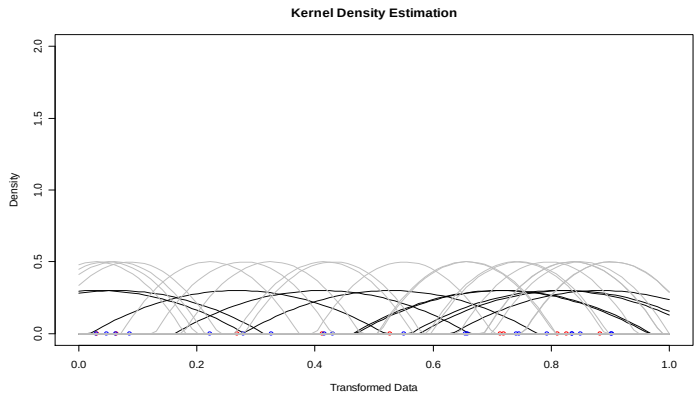

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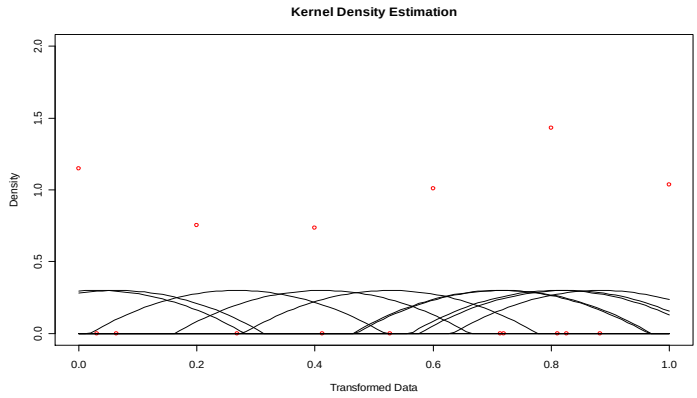

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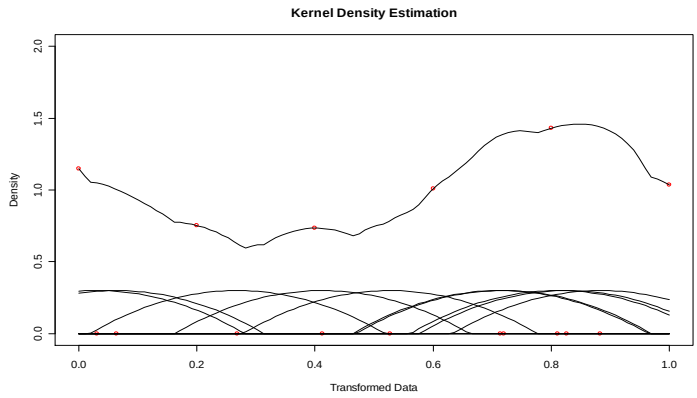

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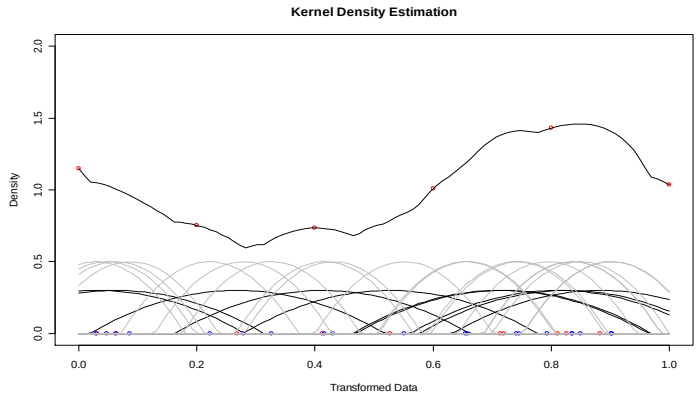

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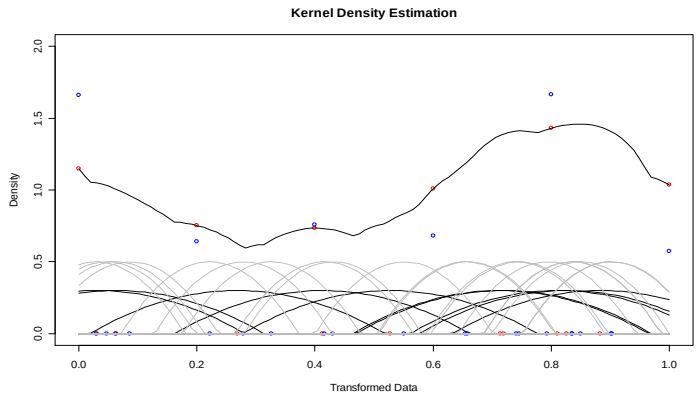

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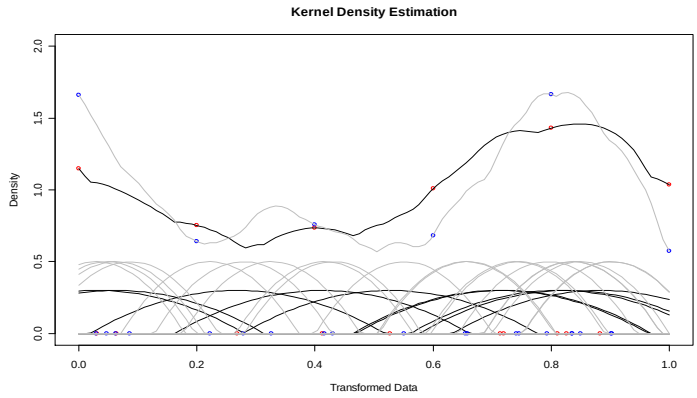

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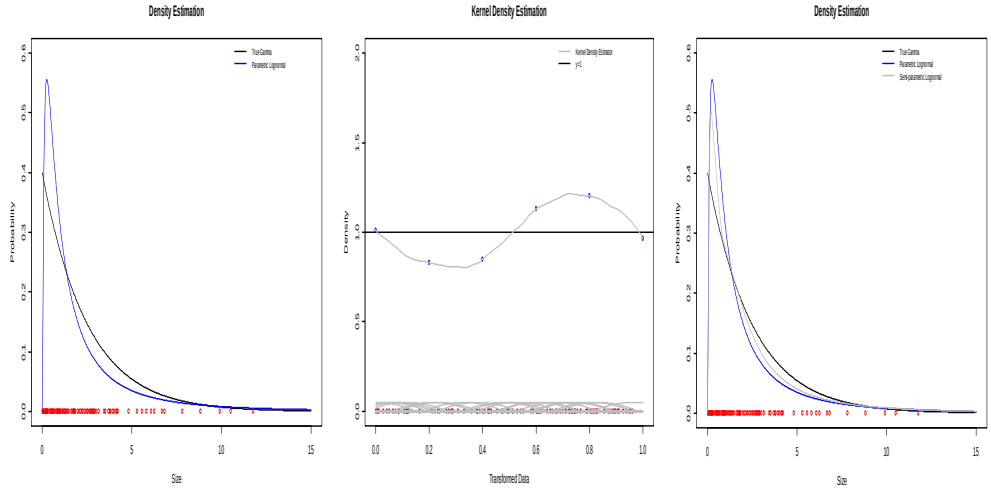

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➢**Mixing the colours**

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Underreporting Model

Underreporting means that not all losses in the company are reported.

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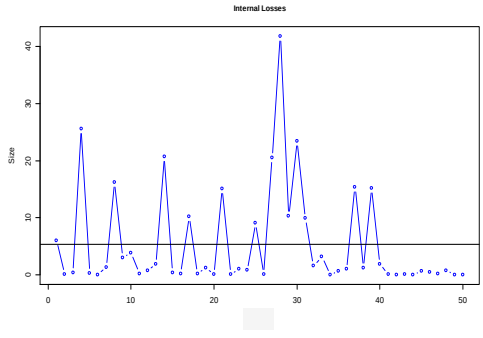

Occurred losses $(X_i)_{1 \le i \le 5000}$

Indicator function $I(i) = \begin{cases} 1 \text{ if } X_i \text{ is reported} \\ 0 \text{ otherwise} \end{cases}$

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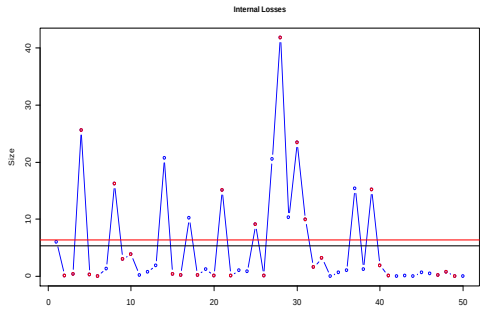
Underreporting Model

Losses could be hidden, ignored, unrecorded or reported elsewhere



Reported losses $(Y_j)_{1 \le j \le 27} \sim f$

Total number of reported: $N = \sum_{i=1}^{50} I(i)$

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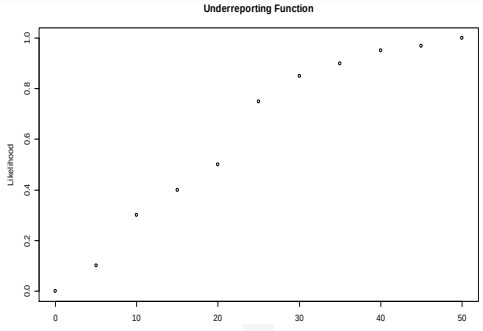
Underreporting Model

An underreporting function encodes the likelihood that a loss of a particular size is being reported



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Underreporting Model

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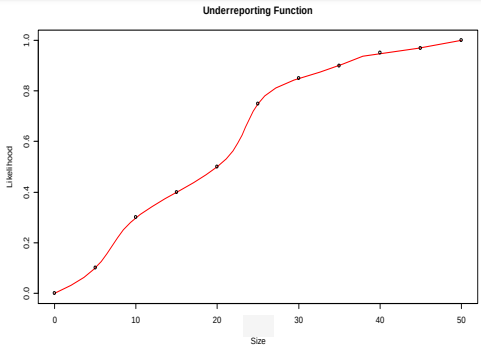

Define g as a function of f and underreporting function u

$$g(x) = \frac{f(x)\{u(x)\}^{-1}}{\int f(w)\{u(w)\}^{-1}dw}$$

The probability of observing an Operational risk loss

$$P = \int_0^\infty g(w)u(w)dw$$

Assume Poisson distribution, then occurred / reported losses

$$M \in Po(\quad) \qquad N \in Po(\quad \cdot P)$$

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Mixing Model

- Include prior knowledge from external data.
- Correct the external global start with internal observed data.

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Mixing Model

- Include prior knowledge from external data.
- Correct the external global start with internal observed data.

Distribution Assumption. Estimate the distribution parameters on the data $(Y_j)_{1\le j\le M}$

Transform losses to the bounded support [0,1] with $Z_i = F_{\hat{\theta}_y}(X_i)$

KDE: $\hat{g}(z) = \frac{1}{100}\sum_{i=1}^{100} K_h(Z_i - z)$ with $K(z) = \frac{3}{4}(1 - z^2)\mathbb{1}_{\{|z|<1\}}$ and $K_h(\cdot) = \frac{1}{h}K\left(\frac{\cdot}{h}\right)$

Semi-parametric density, $\hat{f}_M(x) = f_{\hat{\theta}_y}(x)\hat{g}(F_{\hat{\theta}_y}(x))$

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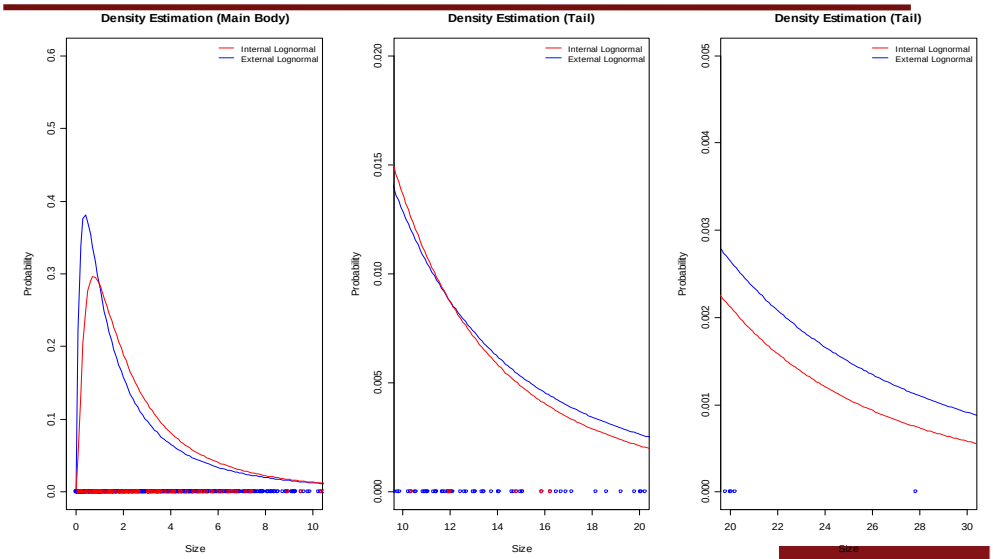
Mixing Model



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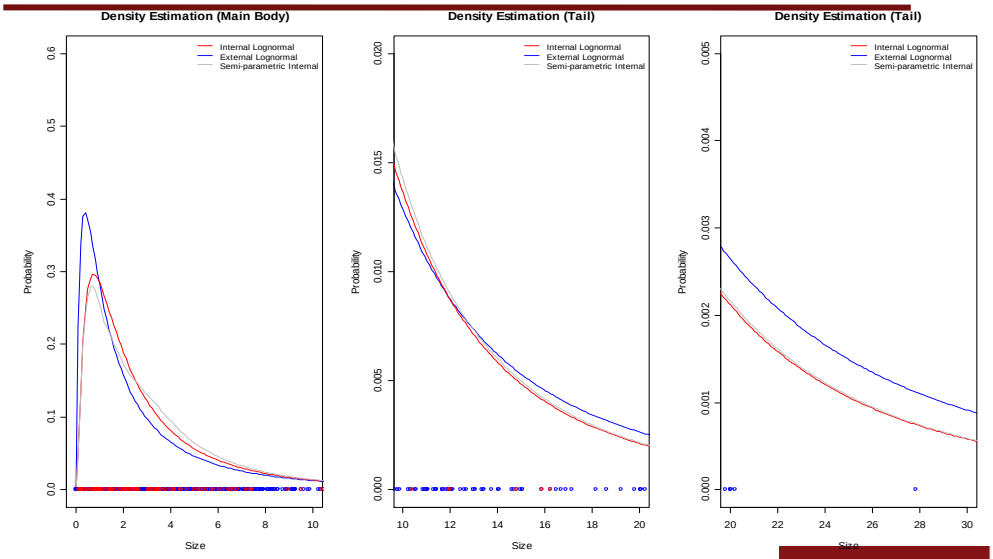

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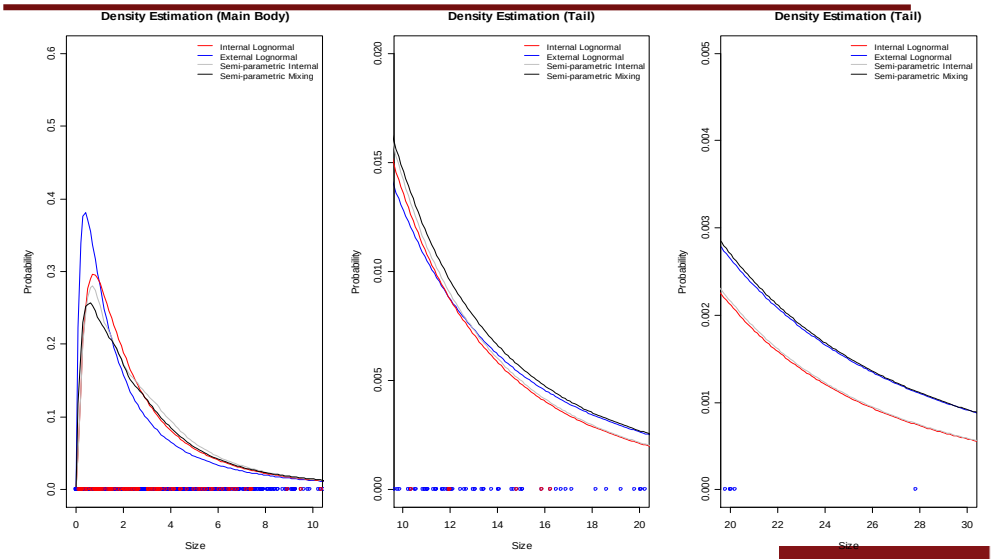

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Asymptotic Theory: Semiparametric Estimator

Let the transformation function *T* be two times differentiable known function. Assume that *f* is also two times differentiable. Then the bias of $\hat{f}$ is given by

$$\mathrm{E}\hat{f}(x) - f(x) = \mu_2(K) B_x b^2 + o(b^2)$$

$$= \frac{1}{2}\int w^2 K(w)dw \left[\left(\frac{f(x)}{T'(x)}\right)' \frac{1}{T'(x)}\right]' b^2 + o(b^2)$$

and the variance is given by

$$\mathrm{V}\hat{f}(x) = (nb)^{-1} R(K) T'(x) f(x) + o((nb)^{-1})$$

$$= (nb)^{-1} \int K^2(w)dw\, T'(x) f(x) + o((nb)^{-1})$$

where the asymptotics is given for $n \longrightarrow \infty.$

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Asymptotic Theory: Semiparametric Estimator corrected for UR

Let the transformation function *T* and the underreporting function *u* be two times differentiable known function. Assume that *g* is also two times differentiable. Then the bias of $\hat{g}$ is given by

$$\mathrm{E}\hat{g}(x) - g(x) = \mu_2(K)\left[\frac{B_x}{u(x)B} - \frac{A}{B^2}\int \frac{B_w}{u(w)}dw\right] b^2 + o(b^2)$$

where

$$A = \frac{f(x)}{u(x)},\ B = \int_0^\infty \frac{f(w)}{u(w)}dw \text{ and } B_x = \left[\left(\frac{f(x)}{T'(x)}\right)' \frac{1}{T'(x)}\right]'$$

and the variance is given by

$$\mathrm{V}\hat{g}(x) = \frac{R(K)T'(x)g(x)}{u(x)B\,m\,b} + o((mb)^{-1})$$

where the asymptotics is given for

$$m \longrightarrow \infty,\ b \longrightarrow 0 \text{ and } n = P \cdot m.$$

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➢Painting by numbers

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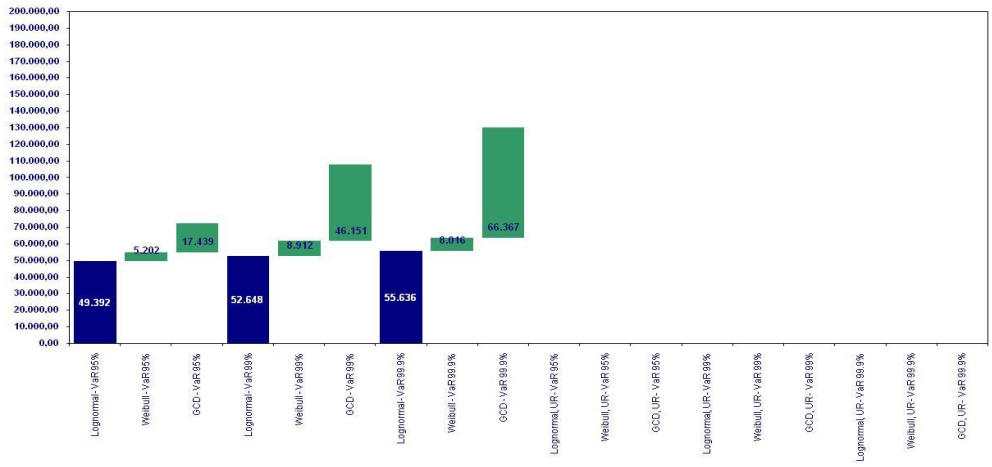
Results Paper A (20.000 Simulations)



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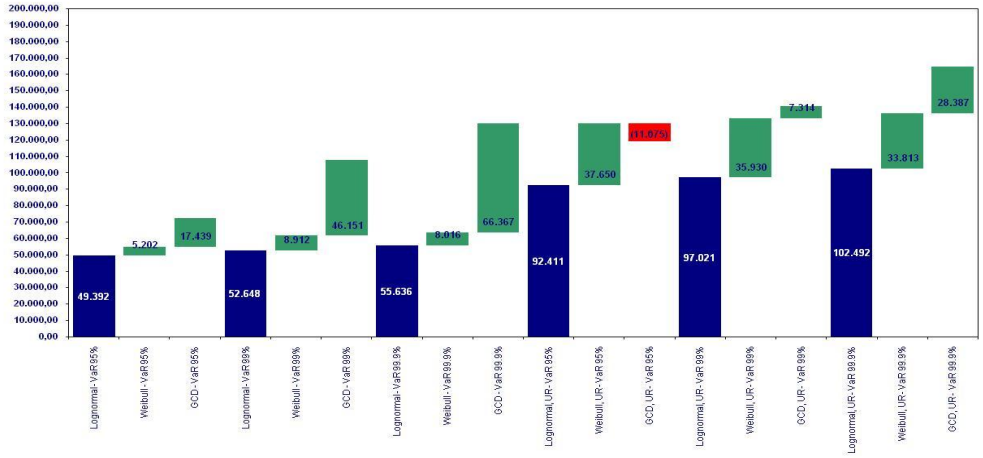
Results Paper A (20.000 Simulations)



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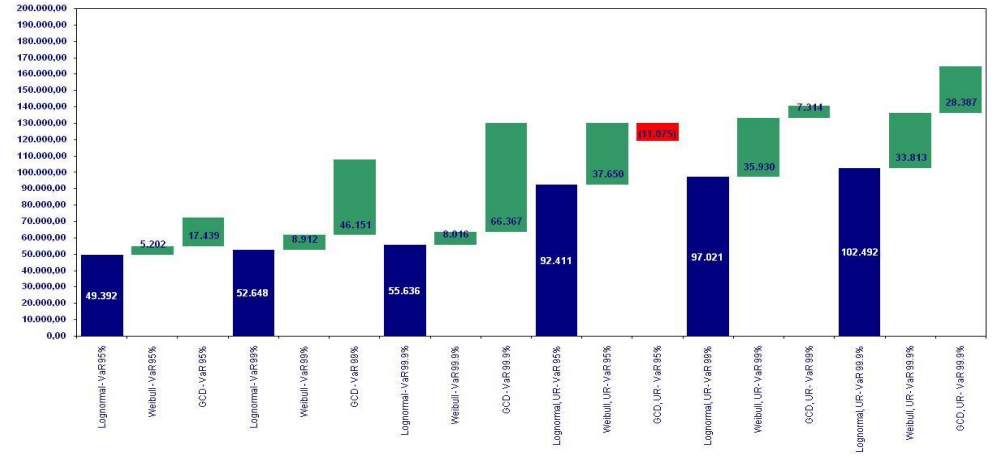
Results Paper A (20.000 Simulations)

20% 40% 49% 17% 20% 23%



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Key Findings Paper A

- Distribution dependent results
- Correction for underreporting increases the capital
- A small stabilizing effect by introducing a correction for underreporting

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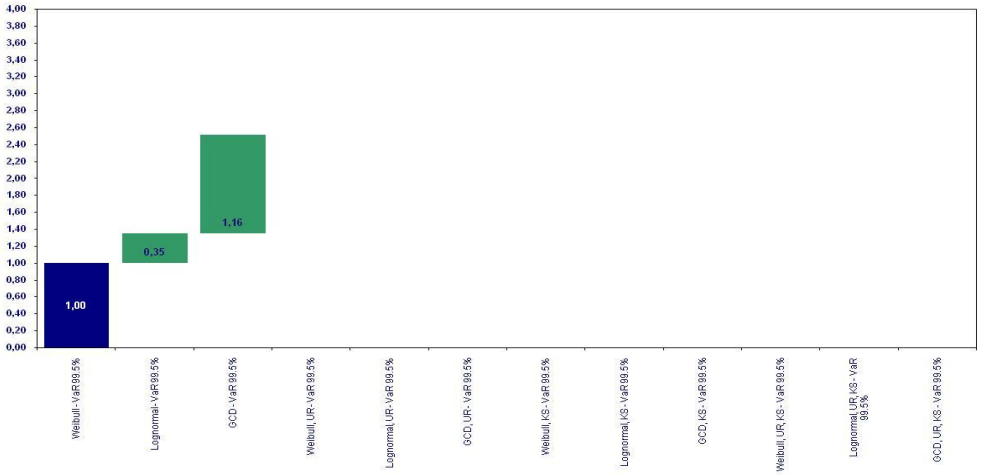
Results Paper B (10.000 Simulations)



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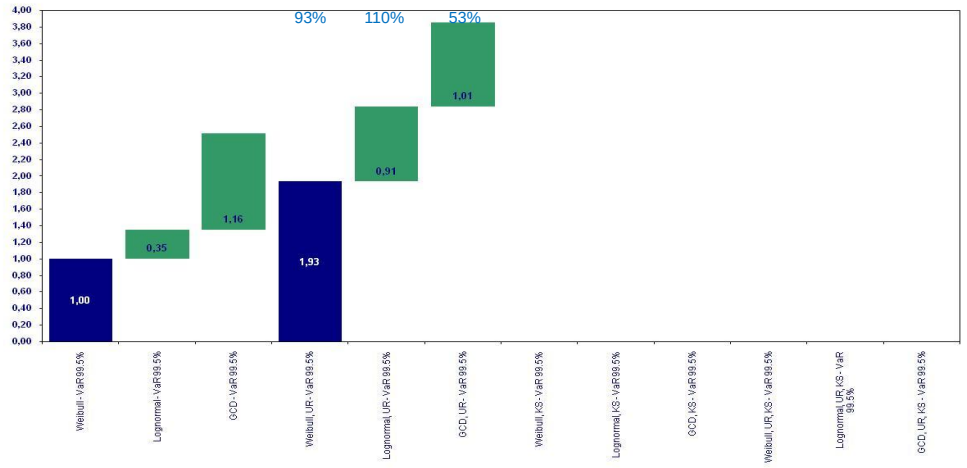
Results Paper B (10.000 Simulations)



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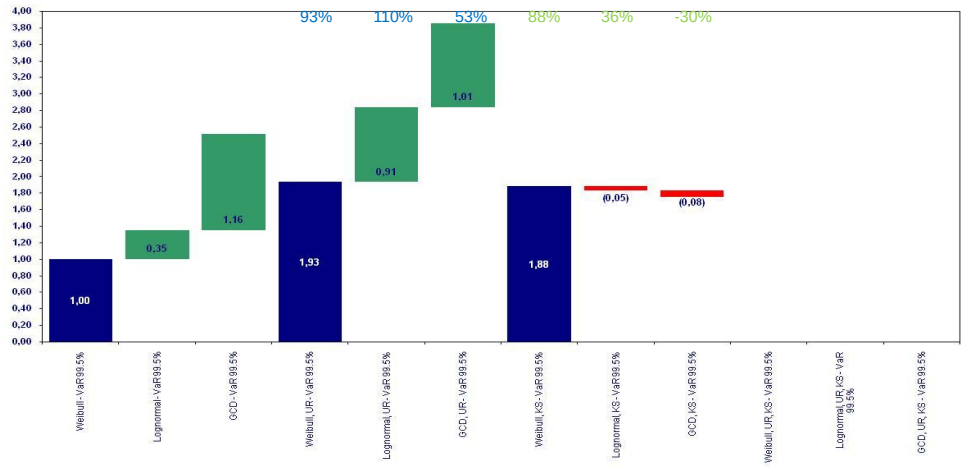

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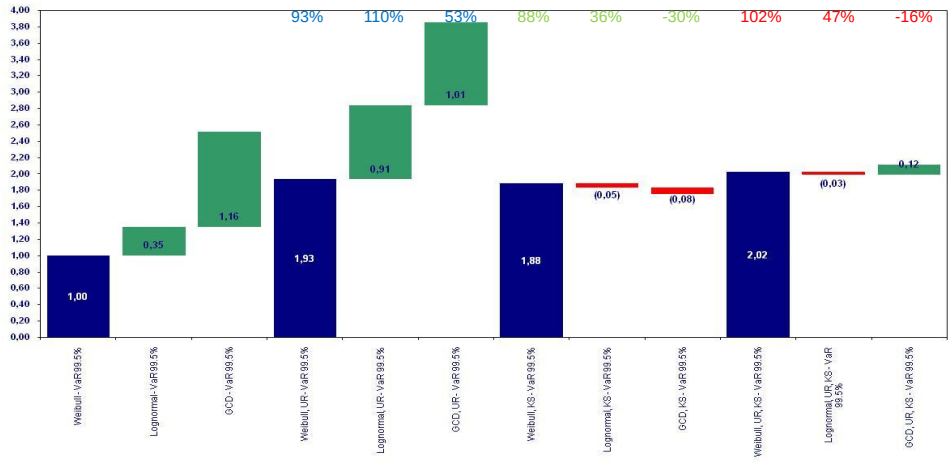

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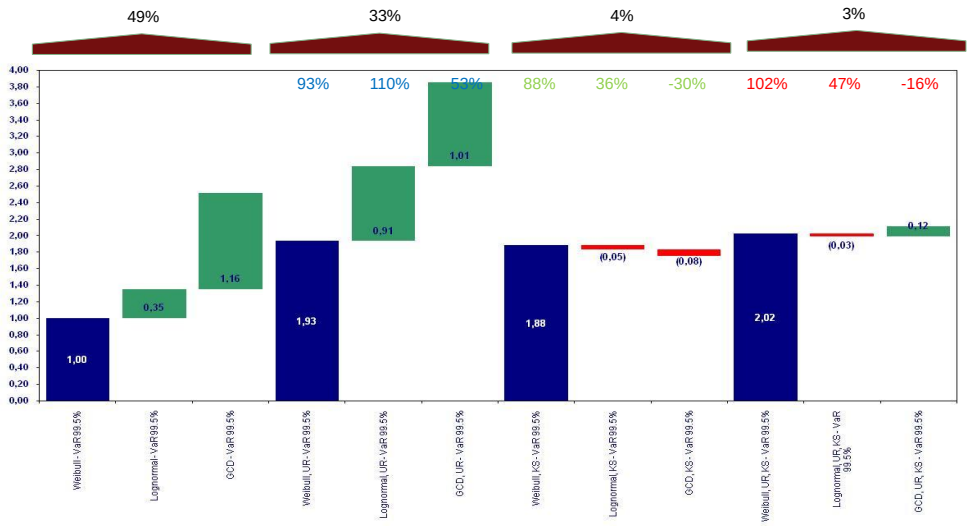

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Key Findings Paper B

- Consistentency with the findings in Paper A
- A stabilizing effect by introducing kernel smoothing
- Even more stabilizing effect by combining correction for UR and incorporate KS

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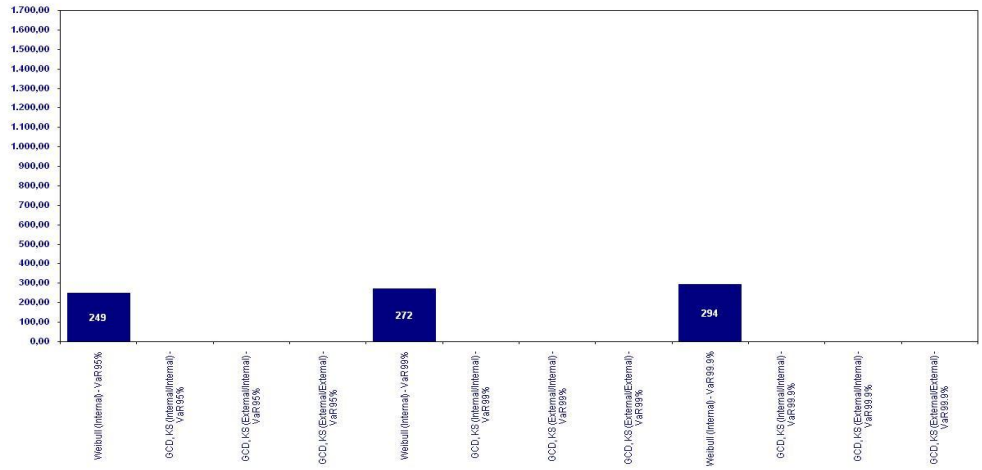
Results Paper C (10.000 Simulations)



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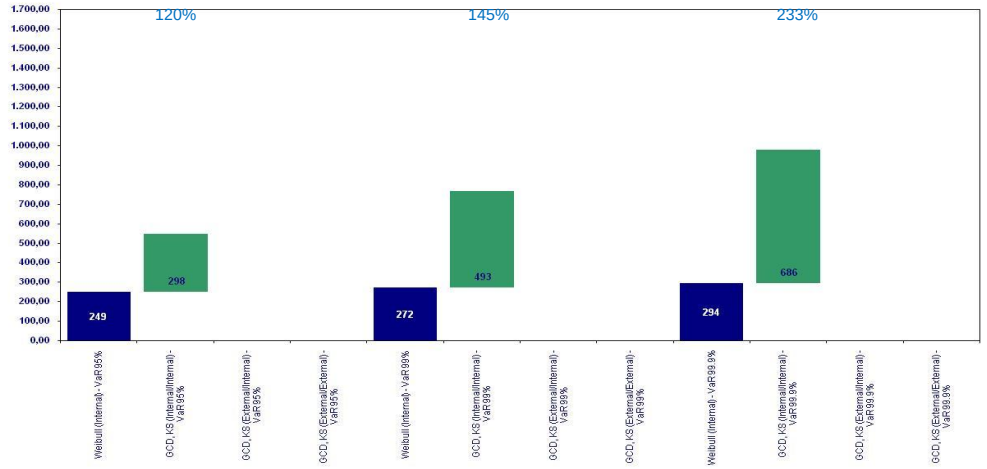
Results Paper C (10.000 Simulations)



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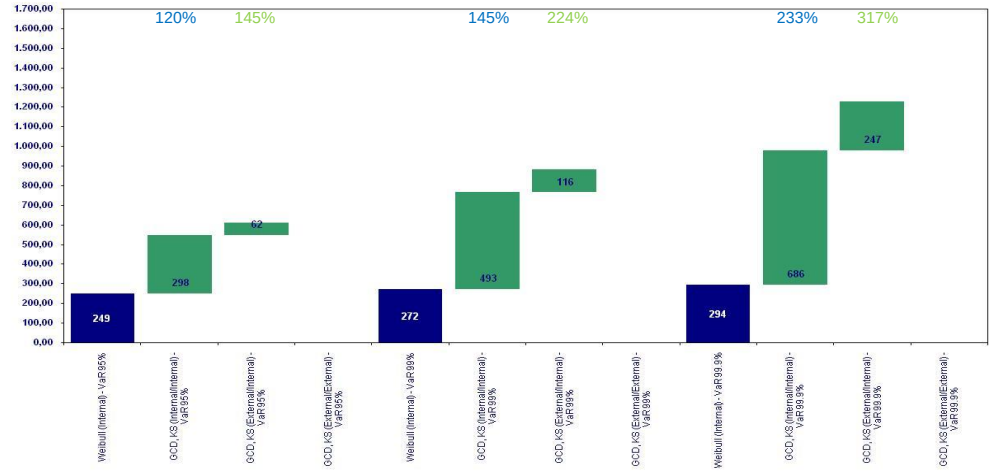

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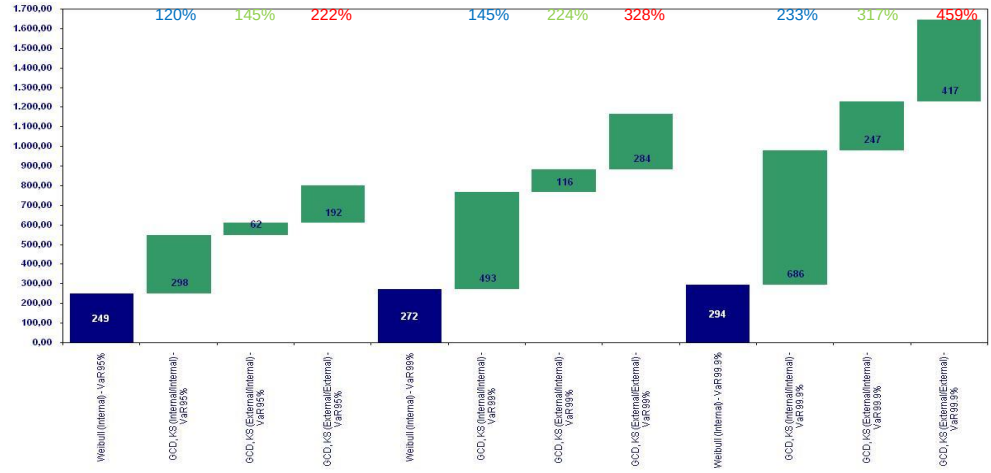

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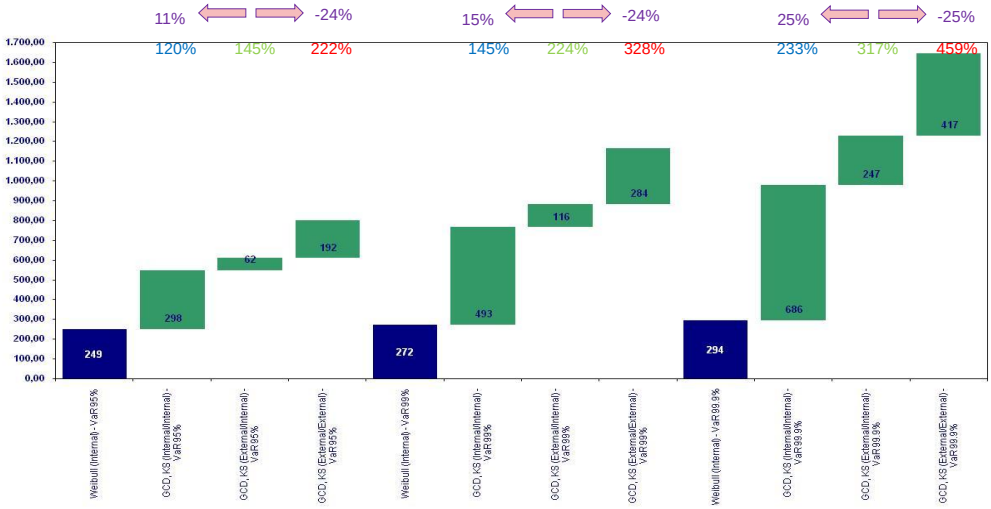

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Key Findings Paper C

- For lower quantiles, the mixing model resembles the internal model
- For higher quantiles, more prior knowledge from the external source is present.

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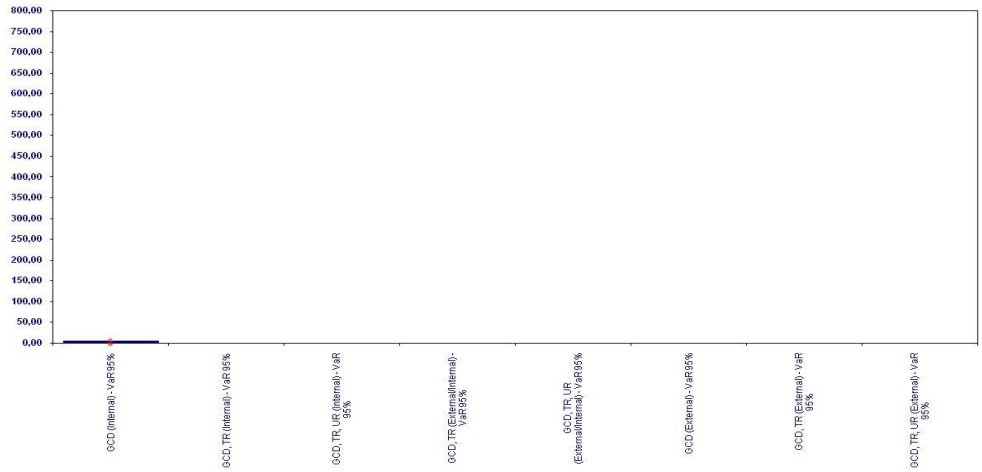
Results Paper D (20.000 Simulations)



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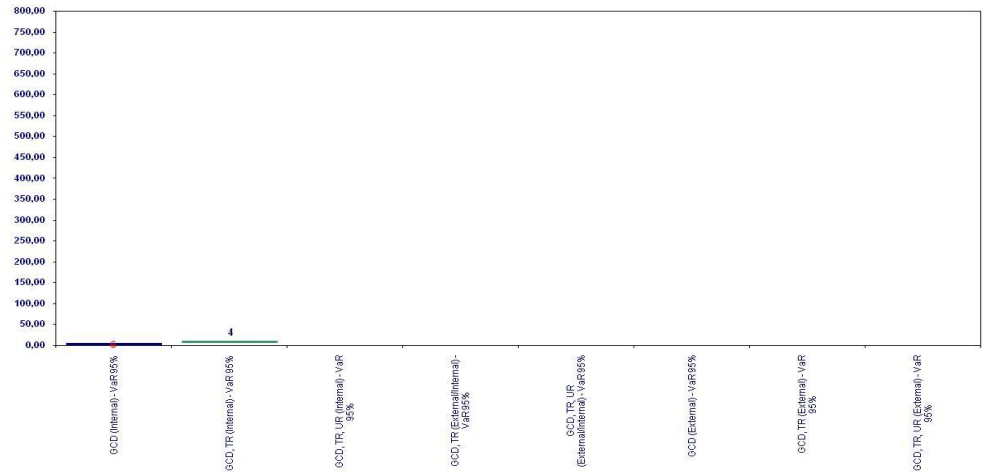
Results Paper D (20.000 Simulations)



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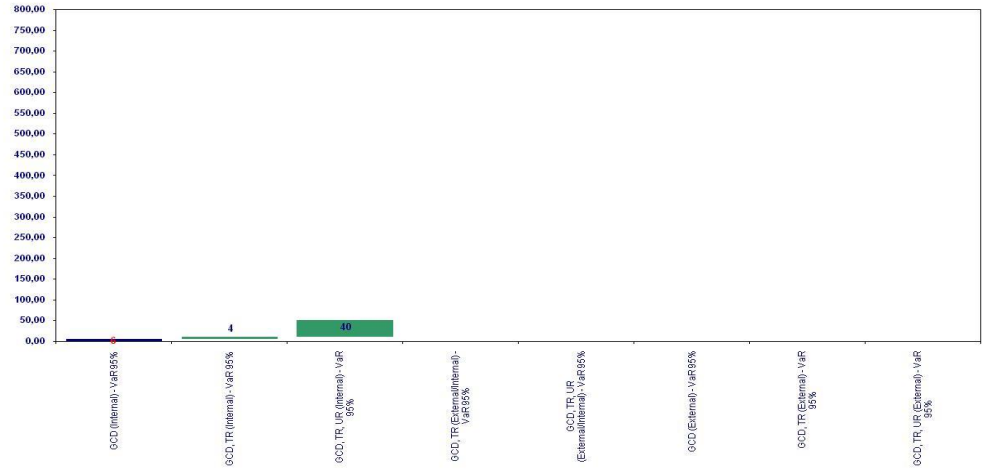
Results Paper D (20.000 Simulations)



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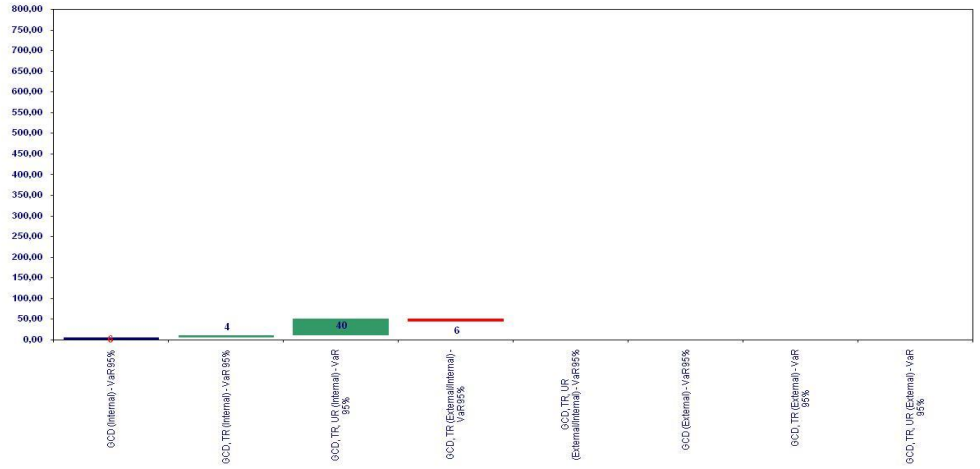

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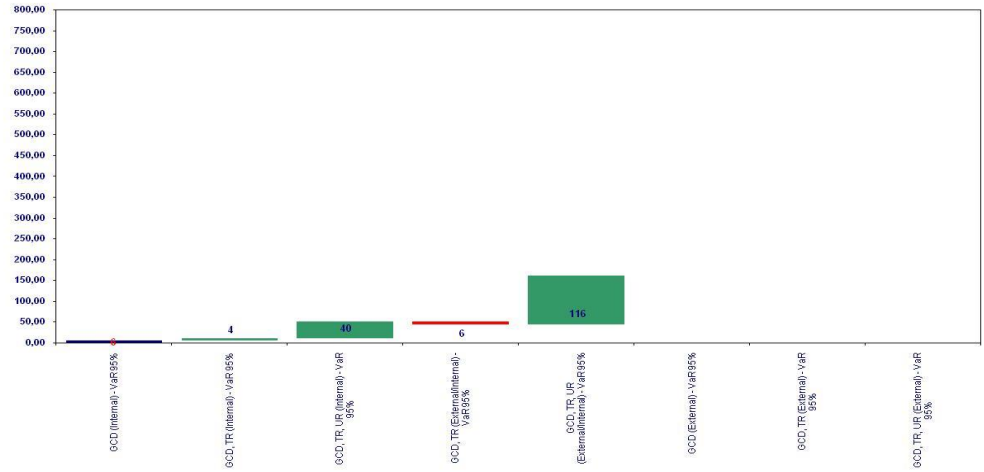

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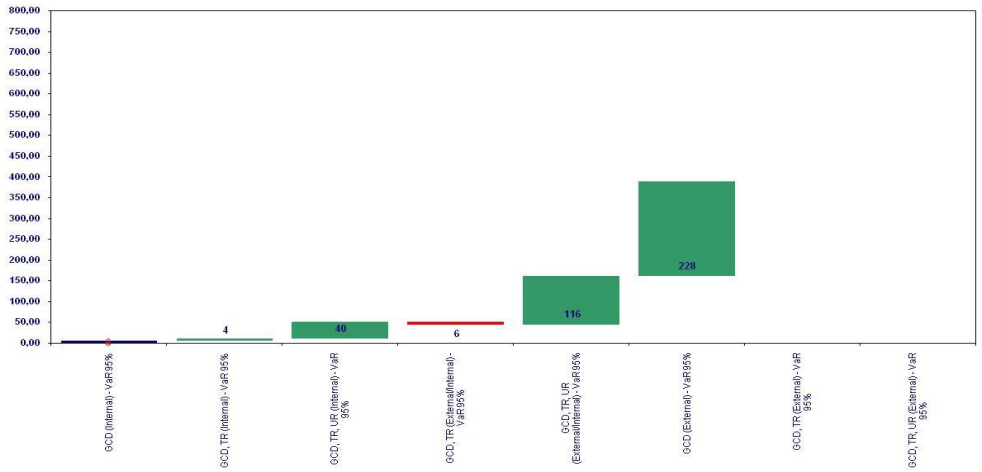

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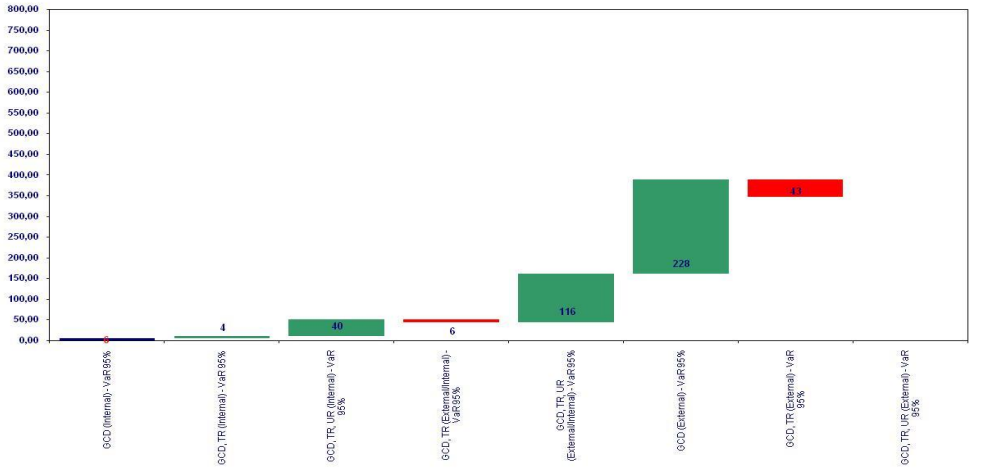

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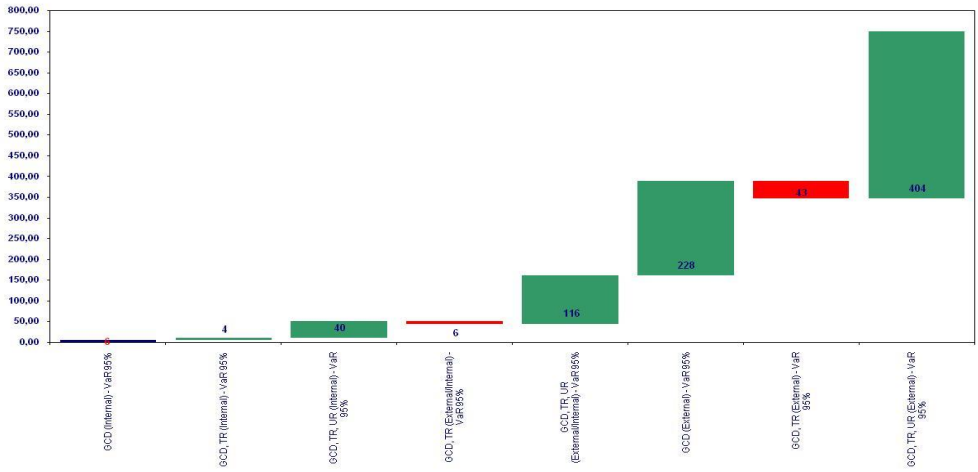
Results Paper D (20.000 Simulations)



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Key Findings Paper D

- Consistency with the findings in paper C:
  - Mixing model resembles the internal model for lower quantiles. For higher quantiles, more information from external data is present
- Consistency with findings in paper A and B:
  - Correction for underreporting increases the capital.

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➢Framing the canvas

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Main Findings and Conclusions

➢ The developed method can

- Pooling internal and external data to produce more credible capital estimates
- Incorporate correction for truncation (unrecorded losses) and random censoring (unreported losses)
- Robust capital method, not distribution dependent

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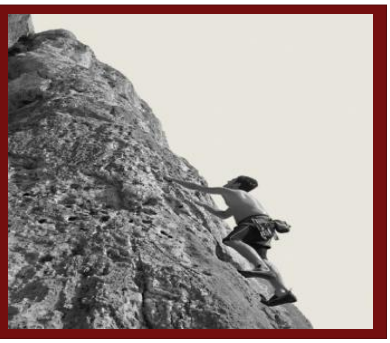
Considerations and future research

- Improve boundary correction, bandwidth selection and correction function
- Investigate and implement possible correlation between event risk categories
- Scaling and filtration (external data)
- Take into account insurance cover
- Compare against other mixing models



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Sponsorship / Consultancy proposal

- We are looking for two sponsors of 50K£ each to sponsor our upcoming book on operational risk
- The money is used to buy off the four authors (academics as well as practitioners) from other duties
- The sponsors receive two VERY VALUABLE opportunities:

1. Will play a key role when the book is launched at an event at Cass Business School

2. One week exclusive course in the book in Copenhagen, copy of the book and the software. Accomodation paid for (up to four people).

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THANK YOU!

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Questions or comments?

Expressions of individual views by members of The Actuarial Profession and its staff are encouraged.

The views expressed in this presentation are those of the presenter.