Operational Risk

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Outline of the presentation

The technology that is available has increased substantially the potential of creating losses

Alan Greenspan, March 1995

- What is operational risk: from thick fingers to rogue traders.
- Operational risk and Basel II: basic models.
- Operational risk and Basel II: advanced models.
- Practical issues.
- Using external data.

What Is Operational Risk?

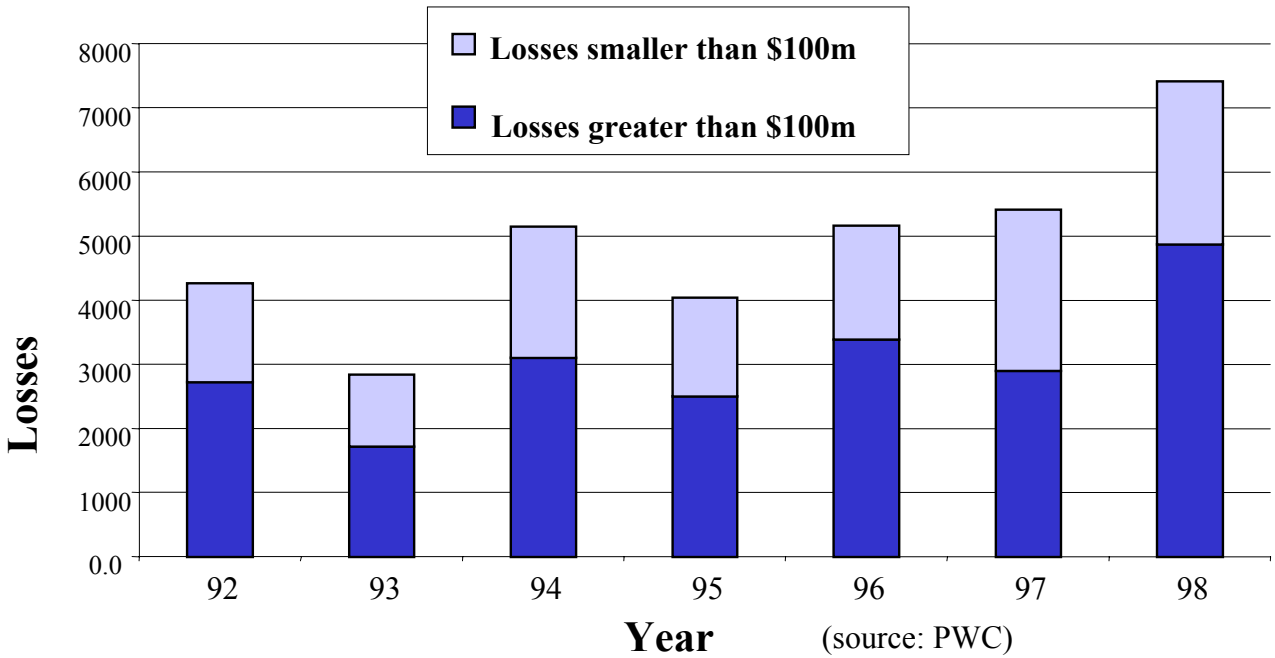
From thick fingers ...

Once is happenstance. Twice is coincidence. Three times is enemy action

Winston Churchill

- May 2001: an employee at Lehman Brothers negotiates an engagement of £300 million instead of 3 (his real goal). This error implied a fall of 120 points of the FOOTSE 100 (≈ £40 billion).
- November 2001: another erroneous operation with EuroStoxx futures had as consequence a fall of 800 points of the index.
- December 2001: a trader at UBS Warburg made an error (in the Japanese equities book), typing the price (per unit) instead of the number of units resulting in a net loss of $50 million.
- The automation of processes and the globalization of markets have converted these facts in usual.
- A trader may understand an order in an erroneous way and he is going to sell instead of buying. If in addition market moves the wrong way his error will result in a loss.
- In May 2002 there were more than 7.000 events of operational risk with losses of more than one million dollars each (a total of more than $272 billion).

Operational Risk Losses



(source: PWC)

In reality this kind of losses (database of public events) are not always very reliable. Nevertheless they indicate clearly the existence and magnitude of a real problem.

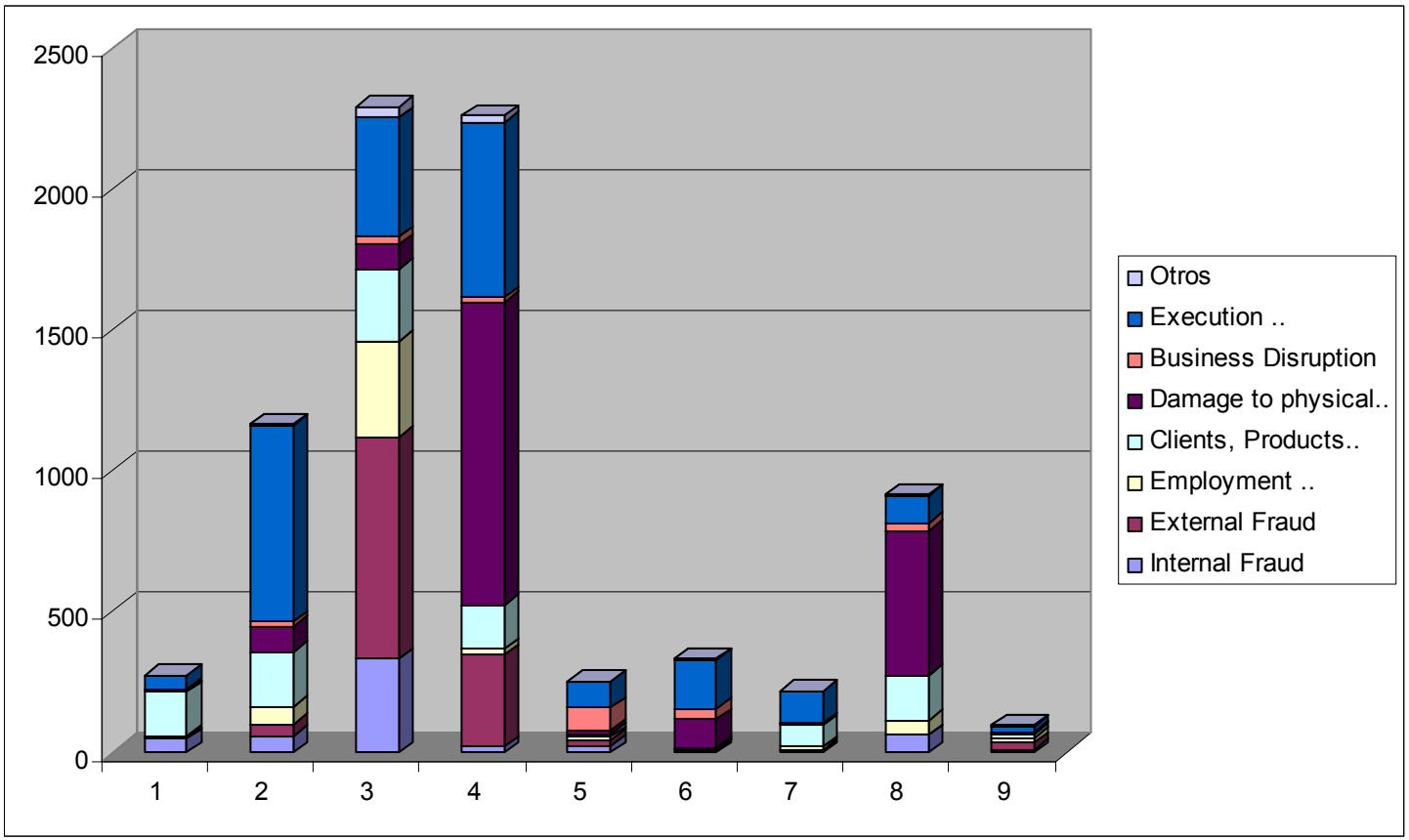
... To Rogue Traders

- **BCCI (1991, £27.000m: fraud)**: This is, without any doubt, the most amazing example of fraudulent use of a financial institution. Everything they did was wrong (criminal). The process began last year. There is a claim of £ 1 billion against the Bank of England.
- **Barings (1995, $1.300m + bankrupcy: unauthorized activity)**: during 2 years, Nick Leeson (derivative trader) accumulated non reported losses.
- In the case of **Daiwa (1995, $1.100m)** or **Sumitomo (1996, $2.600m)** the unauthorized activity was for a longer time: 11 and 3 years.
- **Natwest (1997, $127m: model error)**: Kyriacos Papouis (a swaption trader) used wrong volatilities in the model for swaption pricing.
- **Cantor Fitzgerald (**1998, Terrorrist attack against World Trade Center).
- **Bank of America** y **FleetBoston Financial (2004, $515m: bad practices)**: penalty for "after-market trading".
- **City Bank (2004, $5 billons)**: special reserve for possible lawsuit due to Enron case.

see http://www.riskdimensions.com/archive/).

The 2002 Loss Data Collection Exercise for Operational Risk

	Number of banks	Number of losses	Number of losses/bank
LCDE 2000	27	5.265	195
LCDE 2001	89	47.269	531



Amount=€7.8 billion, Number of events = 47.269

The Definition of Operational Risk

- A first approach was to define operational losses as any losses but market and credit risk losses.
- It is too vague a definition.
- The Basel Committee defines operational risk in the following way:

> the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events. This definition includes legal risk, but excludes strategic and reputational risk.

- Implicitly, there is a taxonomy of risks .
- In bank activity, there is also a variety of business lines.
- Basically, we need to merge the two concepts in a coherent way in order to calculate economic capital for operational risk.

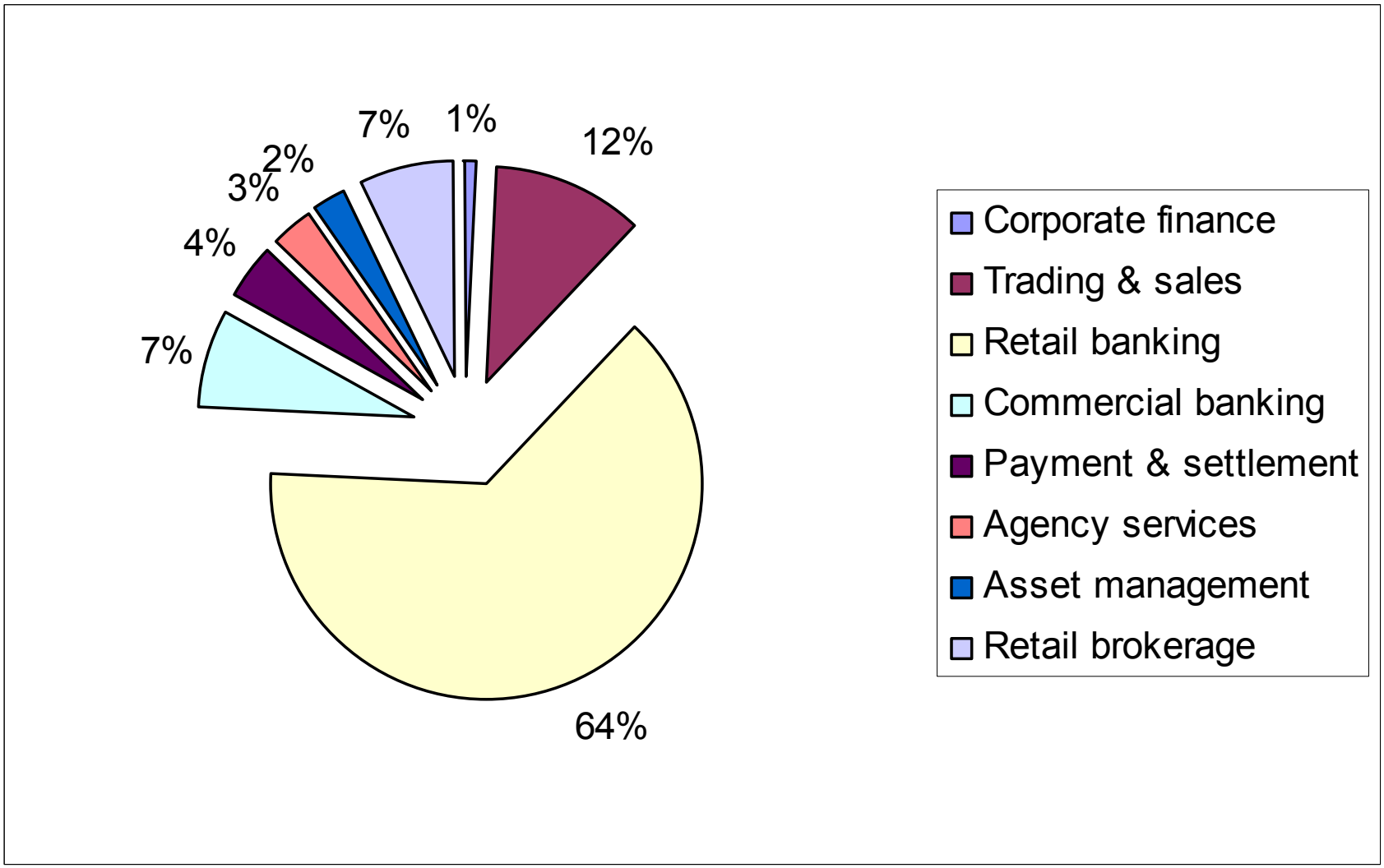
Business lines

- Any bank must map his activity to 8 business lines.
- In some cases, it is necessary to make political decisions which may have broad impact in capital level.

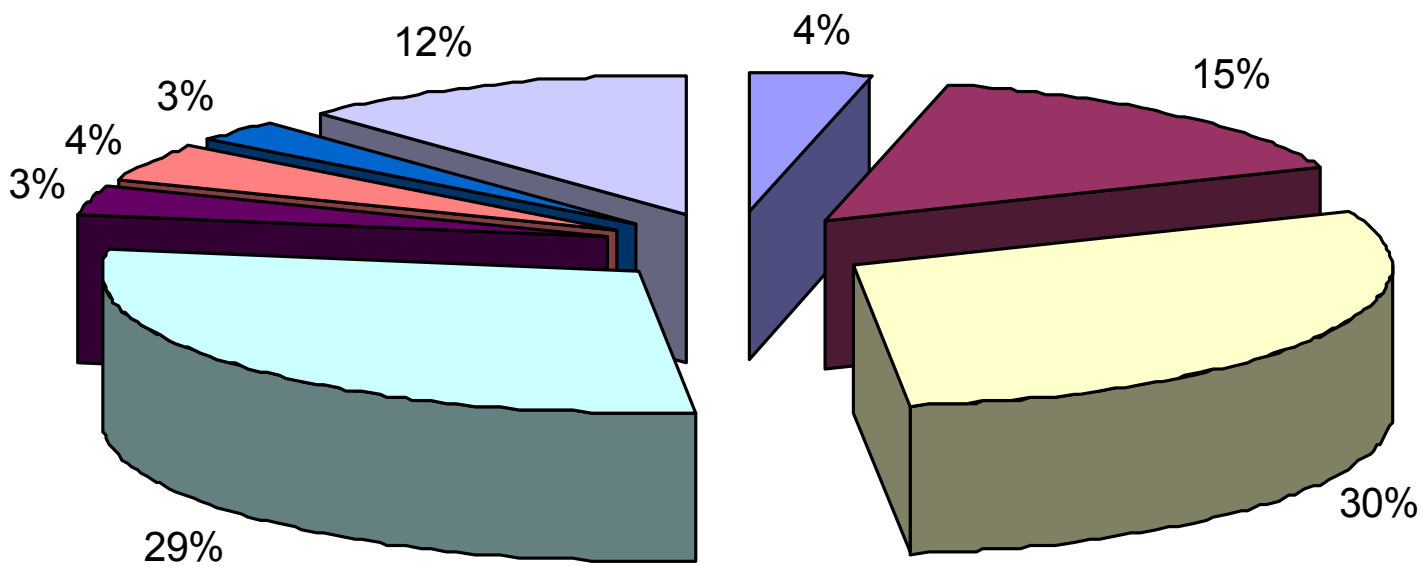
Level 1	Level 2	Activity Groups
Corporate Finance	Corporate Finance	Mergers and Acquisitions, Underwriting, Privatisations, Securitisation, Research, Debt (Government, High Yield), Equity, Syndications, IPO, Secondary Private Placements
	Municipal/Government Finance	
	Merchant Banking	
	Advisory Services	
Trading & Sales	Sales	Fixed Income, equity, foreign exchanges, commodities, credit, funding, own position securities, lending and repos, brokerage, debt, prime brokerage
	Market Making	
	Proprietary Positions	
	Treasury	

Retail Banking	Retail Banking	Retail lending and deposits, banking services, trust and estates
	Private Banking	Private lending and deposits, banking services, trust and estates, investment advice
	Card Services	Merchant/Commercial/Corporate cards, private labels and retail
Commercial Banking	Commercial Banking	Project finance, real estate, export finance, trade finance, factoring, leasing, lends, guarantees, bills of exchange
Payment and Settlement	External Clients	Clients Payments and collections, funds transfer, clearing and settlement
Agency Services	Custody	Escrow, Depository Receipts, Securities lending (Customers) Corporate actions
	Corporate Agency	Issuer and paying agents
	Corporate Trust	
Asset Management	Discretionary Fund Management	Pooled, segregated, retail, institutional, closed, open, private equity
	Non-Discretionary Fund Management	Pooled, segregated, retail, institutional, closed, open Retail
Retail Brokerage	Retail Brokerage	Execution and full service

Distribution of events by business lines (LDC 2002)



Distribution of losses by business lines (LDC 2002)



Corporate finance | Trading & sales | Retail banking | Commercial banking
Payment & settlement | Agency services | Asset management | Retail brokerage

Severity and frequency

- From previous figures, it is clear that two variables play a role in operational risk:
  - Severity
  - Frequency.
- In the following table, we can appreciate how these variables combine in the different business lines:

	Percentage number of events	Percentage gross losses
Corporate finance	1	4
Trading & sales	12	15
Retail banking	64	30
Commercial banking	7	29
Payment & settlement	4	3
Agency services	3	4
Asset management	2	3
Retail brokerage	**7**	**12**

Types of Risks (Basel II)

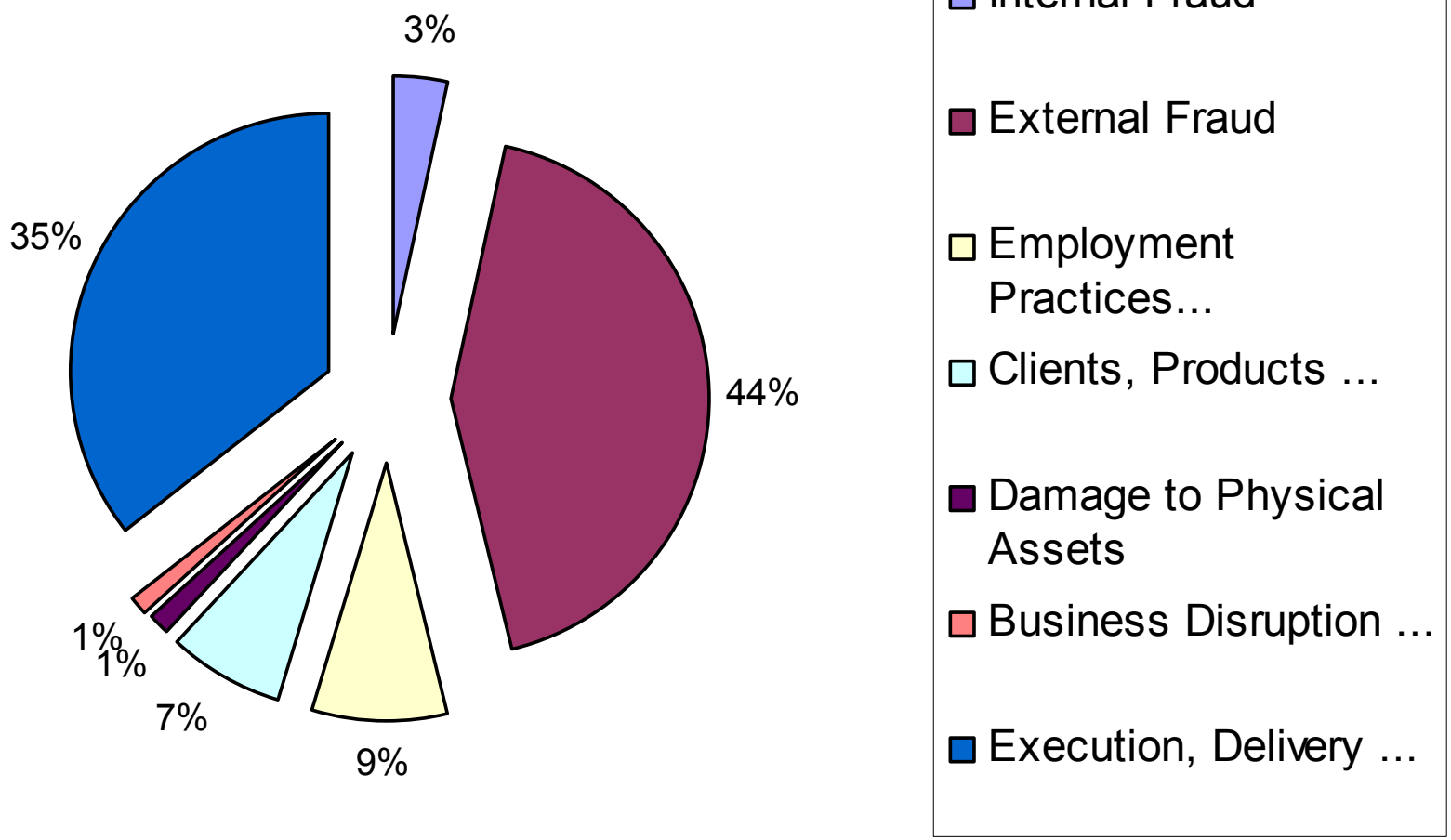
1. **Internal Fraud**: losses due to acts of a type intended to defraud, misappropriate property or circumvent regulations, the law or company policy, excluding diversity/discrimination events, which involves at least one internal party.
2. **External Fraud**: losses due to acts of a type intended to defraud, misappropriate property or circumvent the law, by a third party.
3. **Employment Practices & Workplace Safety**: losses arising from acts inconsistent with employment, health or safety laws or agreements, from payment of personal injury claims, or from diversity/discrimination events.
4. **Clients, Products & Business Practices**: losses arising from an unintentional or negligent failure to meet a professional obligation to specific clients (including fiduciary and suitability requirements), or from the nature or design of a product.
5. **Damage to Physical Assets**: losses arising from loss or damage to physical assets from natural disaster or other events.
6. **Business Disruption & System Failures**: losses arising from disruption of business or system failures.
7. **Execution, Delivery & Process Management**: losses from failed transaction processing or process management, from relations with trade counterparties and vendors.

Taxonomy of Risks (Basel II)

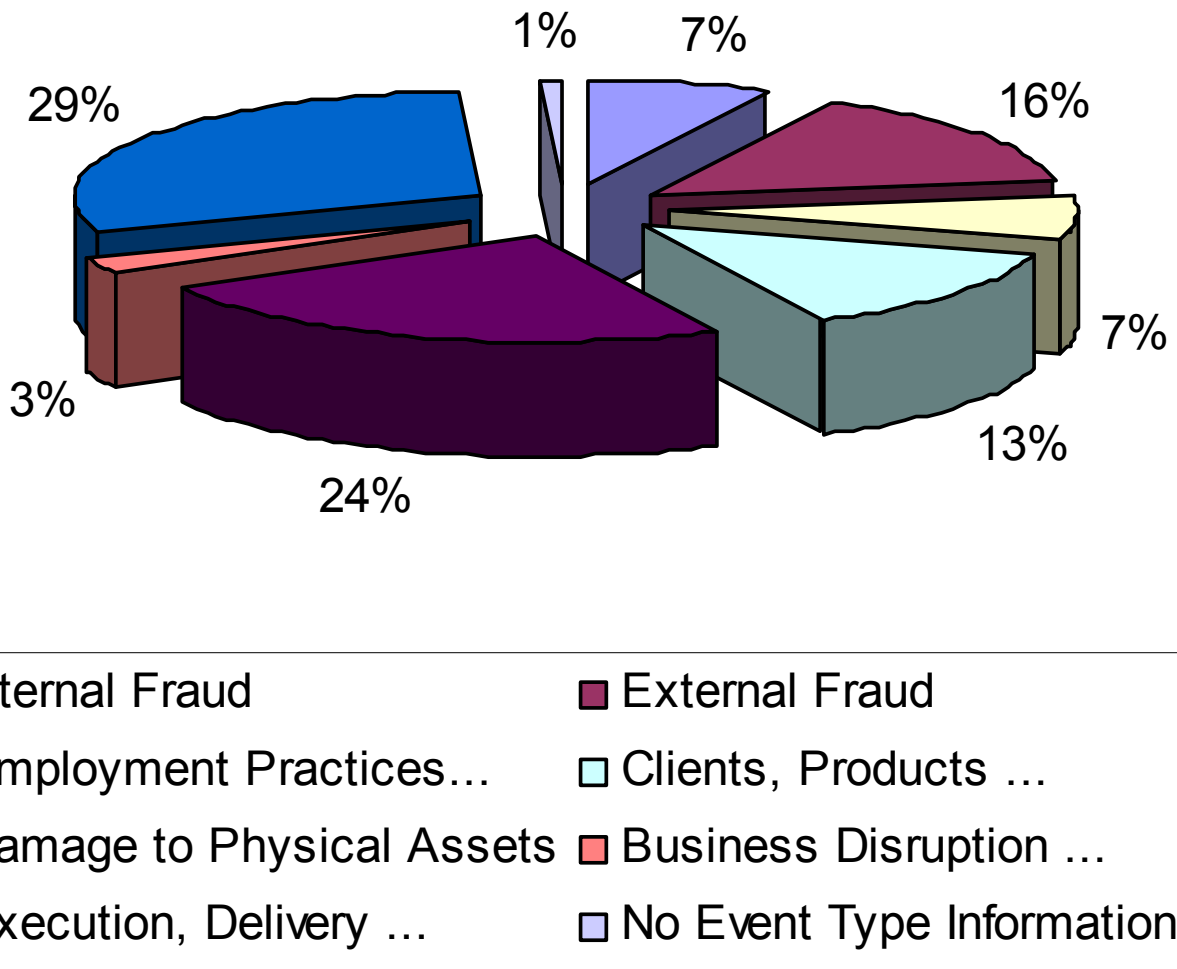
Event-Type category (Level 1)	Categories (Level 2)	Activity Examples (Level 3)
Internal fraud	Unauthorised Activity	Transactions not reported (intentional), Trans type unauthorised (w/monetary loss), Mismarking of position (intentional)
	Theft and Fraud	Fraud / credit fraud / worthless deposits; Theft / extortion / embezzlement / robbery; Misappropriation of assets; Malicious destruction of assets; Forgery; Check kiting; Smuggling; Account take-over / impersonation / etc.; Tax non-compliance / evasion (wilful); Bribes / kickbacks (sobornos/cohecho); Insider trading (not on firm's account)
External fraud	Theft and Fraud	Theft/Robbery; Forgery; Check kiting
	Systems Security	Hacking damage; Theft of information (w/monetary loss)
Employment Practices and Workplace Safety	Employee Relations	Compensation, benefit, termination issues; Organised labour activity
	Safe Environment	General liability (slip and fall, etc.); Employee health & safety rules events; Workers compensation
	Diversity&Discrimination	All discrimination types

Clients, Products & Business Practices	Suitability, Disclosure & Fiduciary	**F**iduciary Fiduciary breaches / guideline violations; **S**uitability / disclosure issues (KYC, etc.); **R**etail customer disclosure violations; **B**reach of privacy; Aggressive sales; **A**ccount churning; **M**isuse of confidential information; **L**ender Liability (responsabilidad del prestamista)
	Improper Business or Market Practices	Antitrust; Improper trade / market practices; Market manipulation; Insider trading (on firm's account); Unlicensed activity; Money laundering
	Product Flaws	Product defects (unauthorised, etc.); Model errors
	Selection, sponsorship & Exposure	**F**ailure to investigate client per guidelines; **E**xceeding client exposure limits
	Advisory Activities	**D**isputes over performance of advisory activities
Damage to Physical Assets	Disasters and other events	**N**atural disaster losses; **H**uman losses from external sources (terrorism, vandalism)
Business disruption and system failures	Systems	**H**ardware; **S**oftware; **T**elecommunications; **U**tility outage / disruptions
Execution, Delivery & Process Management	Transaction Capture, Execution & Maintenance	**M**iscommunication; **D**ata entry, maintenance or loading error; **M**issed deadline or responsibility; **M**odel / system misoperation; **A**ccounting error / entity attribution error; **O**ther task misperformance; **D**elivery failure; **C**ollateral management failure; **R**eference **D**ata Maintenance
	Monitoring and Reporting	**F**ailed mandatory reporting obligation; **I**naccurate external report (loss incurred)
	Customer Intake and Documentation	**C**lient permissions / disclaimers missing; **L**egal documents missing / incomplete
	Customer / Client Account Management	**U**napproved access given to accounts; **I**ncorrect client records (loss incurred); **N**egligent loss or damage of client assets
	Trade Counterparties	**N**on-client counterparty misperformance; **M**isc. non-client counterparty disputes
	Vendors & Suppliers	**O**utsourcing. **V**endor disputes

Distribution of Events by Type of Risk (LDC 2002)



Distribution of Losses by Type of Risk (LDC 2002)



Severity and Frequency by Type of Risk

- As in the case of business lines, severity and frequency have different behavior, depending of the type of risk:

	Percentage number of events	Percentage gross losses
Internal Fraud	3	7
External Fraud	44	16
Employment Practices...	9	7
Clients, Products ...	7	13
Damage to Physical Assets	1	24
Business Disruption ...	1	3
Execution, Delivery ...	35	29

The Basel II Array

	Type of risk						
Business line ↓	Internal fraud	External fraud	Employment Practices and Workplace Safety	Clients, Products & Business Practices	Damage to physical assets	Business disruption and system failures	Execution, Delivery & Process Management
Corporate Finance							
Trading & Sales							
Retail Banking							
Commercial Banking							
Payment and Settlement							
Agency Services and Custody							
Asset Management							

Some Remarks

- A first approach to the problem of computing operational risk capital consists in computing it for each cell of the array and then to take the sum of the 56 quantities..
- It is not a trivial goal.
- The typology of risks is really different across business lines and type of risk
  - ***External fraud*** (for retail banking) is different of ***damage to physical assets***.
  - Corporate finance use to be different of retail banking …
- And so are severity distributions.
- Even in each cell, the data are not homogeneous: look for example at "clients, products and business practices" type of risk.
- In fact, there are:
  - events of high frequency and low severity and
  - events of low frequency and high impact.
- We need data for all cells in order to be able to fit distributions and calculate operational risk capital.

Operational Risk and Basel II: Basic Models

The New Capital Agreement

- Basel II defines three (mutually reinforcing) pillars.
- **First pillar**: **Minimum Capital Requirements**
  - Specifies the rules for quantifying regulatory/economic capital. Operational risk is included as a new risk.
- **Second pillar: Supervisory Review Process**
  - Up to date, regulator has a quantitative function regarding the use of models.
  - The second pillar displays a strong qualitative element of supervision which reinforces the role of regulators.
- **Third pillar**: **Market Discipline**
  - The base of this pillar is the disclosure requirement.
  - Transparency will allow a deeper insight into an institution's risk profile.
  - In some sense this market discipline effect will lead to an additional banking supervision by market participants.

The Basic Indicator Approach

- In the BIA approach, the capital requirement (K_{BIA}) is calculated using the formula:

$$K_{\text{BIA}} = \alpha \times \text{EI}, \text{ where } \begin{cases} \alpha = 0.15 \\ \text{EI=gross income (mean of the last 3 years)} \end{cases}$$

- Only positive gross income may be taken into account.
- It is a very simple way to calculate the capital charge.
- No specific criteria for use of the Basic Indicator Approach are set out in this framework.
- Nevertheless, banks using this approach are encouraged to comply with the Committee's guidance on Sound Practices for the Management and Supervision of Operational Risk, February 2003.
- Of course, this approach can be very penalizing.

The Standardized Approach

- Under the TSA approach, the capital requirement (K_{TSA}) is calculated at the business line level:

$$K_{TSA} = \sum_{i=1}^{8} \beta_i \times EI_i, \text{ where } \begin{cases} \beta_i \text{ are defined by the regulator} \\ EI_i \text{ are the gross income for line i.} \end{cases}$$

Business line	Beta (%)
Corporate Finance	β_1=18
Trading & Sales	β_2=18
Retail Banking	β_3=12
Commercial Banking	β_4=15
Payment and Settlement	β_5=18
Agency Services and Custody	β_6=15
Asset Management	β_7=12
Retail Brokerage	β_8=12

Requirements for the Use of TSA*

Effective risk management and control

- The bank must have a well-documented, independent operational risk management and control process, which includes firm-level policies and procedures concerning operational risk and strategies for mitigating operational risk.
- The board of directors and senior management must be actively involved in the oversight of the operational risk management process.
- There must be regular reporting of relevant operational risk data to business unit management, senior management and the board of directors. Internal auditors must regularly review the operational risk management processes.
- This review should include both the activities of the business units and the operational risk management and control process.

Measurement and validation

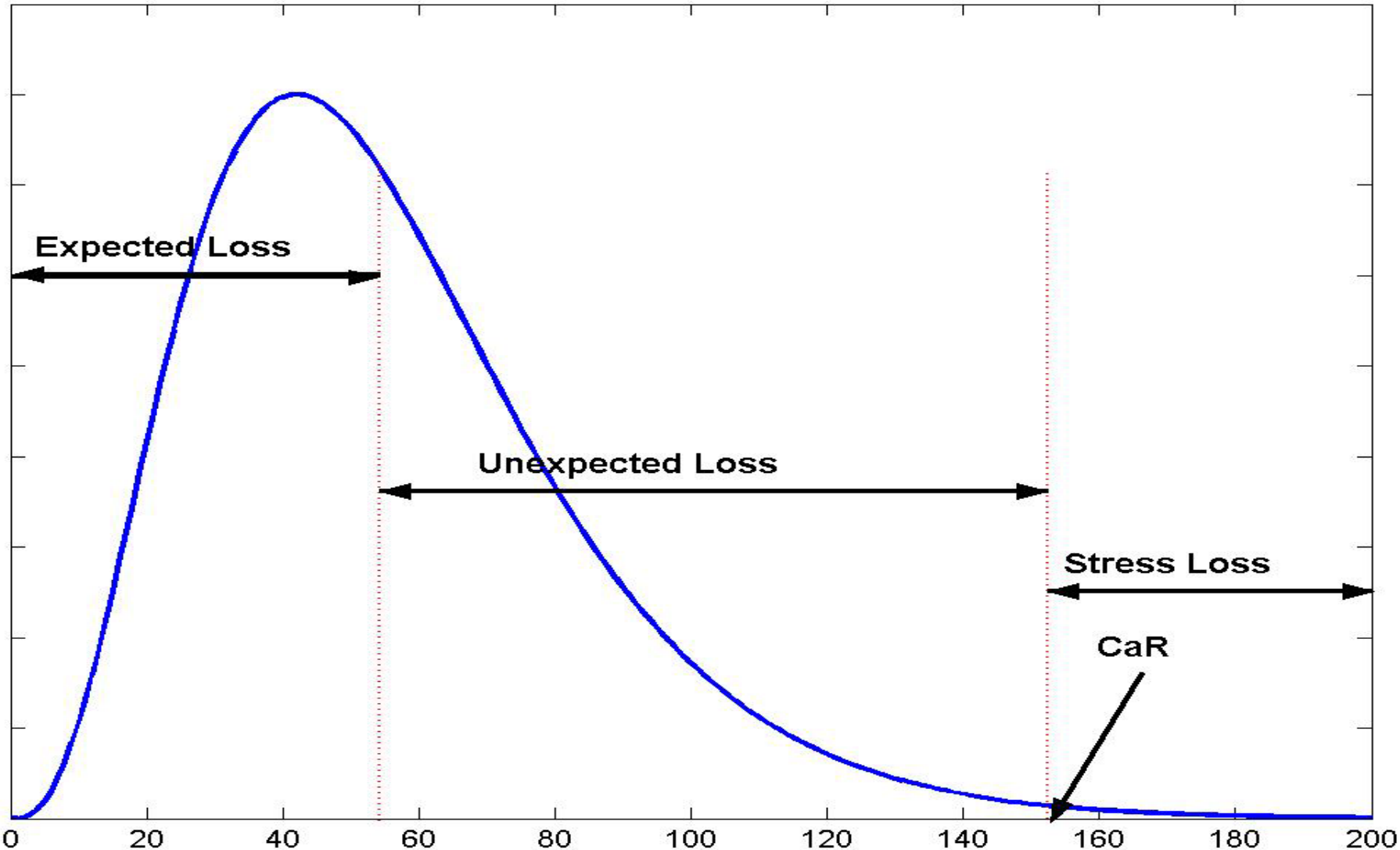
- The bank must have both appropriate risk reporting systems to generate data used in the calculation of a capital charge and the ability to construct management reporting based on the results.
- The bank must begin to systematically track relevant operational risk data, including internal loss data, by business line.
- The bank must develop specific, documented criteria for mapping current business lines and activities into the standardised framework.
- The criteria must be reviewed and adjusted for new or changing business activities and risks as appropriate.

(*) These conditions are exactly extracted from the Basel II agreement.

Advanced Measurement Approach

- In the working Paper nº 8 the Basel Committee defined three possible advanced approaches.
- **Internal Measurement Approach (IMA):**
  - It relies on the hypothesis of a lineal relation between expected and unexpected loss.
  - This method is not explicitly mentioned anymore , but may be useful for an understanding of the realities of operational risk.
- **Loss Distribution Approach**:
  - This is a powerful approach used in actuarial science.
  - The aggregate loss distribution is obtained by modeling the severity and the frequency distributions.
- **Scorecard approach**:
  - This approach seemed to be very popular among English banks.
  - It allows to begin operational risk measurement, based in self assessment and other instruments, when the bank does not have data for model fitting.

Measuring Operational Risk



The Internal Measurement Approach[1]

- The IMA model was explicitly mentioned in the first drafts of Basel II.
- It has the advantage of being sufficiently intuitive to be pedagogically useful.
- For each cell ij, we suppose a lineal relation between the expected loss (EL_{ij}) and the unexpected one (capital charge = K_{ij}):

$$K_{ij} = \gamma_{ij} \times \mathrm{EL}_{ij}$$

- The regulatory capital is then:

$$K_{\mathrm{IMA}} = \sum_{i,j} K_{ij}$$

- It is a one factor model (conservative point of view).
- To simplify, we shall consider one cell and forget subscripts.
- Let:
  - N be the number of events for which we can have an operational loss.
  - L se severity of the loss. It is a random variable with mean μ_L and standard deviation σ_L.

(1) For this approach, we follow **C. Alexander y J. Pezier**: *Binomial Gamma's*, Operational Risk, April 2001.

IMA: The Binomial Case

- Suppose L constant; if p is the probability of a loss the expected loss is:

$$\mu = L \times N \times p$$

- The aggregate loss distribution is binomial, so can suppose that

$$K = k\sigma = \gamma\mu$$

- k must be calibrated.

$$\sigma = L \times \sqrt{Np(1-p)} \approx L\sqrt{Np}, \ (p \text{ small})$$

- then

$$\gamma = \frac{k}{\sqrt{Np}} \quad \text{or} \quad K = kL\sqrt{Np}$$

- Observations:
  - We don´t need to estimate separately p and N.
  - γ is inversely proportional to p.

Example 1: High Frequency Events

- Let us consider high frequency and low impact events:
  - γ would be smaller than 1
  - It implies that K ($= \gamma\mu$) will be smaller than μ (expected loss).
- Risk management must focus more on the expected loss than on the unexpected one.
- **Example 1**: N=25.000, p=0,04, μ_L=1.000€
  - The expected loss is: μ = 1.000.000€ but,
  - for k=7, we get γ = 0,22;
  - So the capital requirement would be 220.000€.
- We can consider this example as a stylized representation of the back office situation (an error in transaction process).

(1) see **C. Alexander y J. Pezier**: *Binomial Gammas*. Operational Risk, April 2001

Example 2: Low Frequency Events[1]

- Let us consider now low frequency and high impact events:
  - γ would be greater than 1
  - It implies that K ($= \gamma\mu$) will be greater than μ (expected loss).
- Risk management must focus more on the unexpected loss rather than on the expected one.
- **Example 2**: N=50, p=0,005, μ_L = 4.000.000€
  - The expected loss (once again) is: μ = 1.000.000€ but,
  - for k=7, we get γ = 14;
  - So the capital requirement would be 14.000.000€.
- We can consider this example as a stylized representation of the corporate finance situation (unauthorized transaction).

(1) see **C. Alexander y J. Pezier**: *Binomial Gammas*. Operational Risk, April 2001

IMA: Random Losses

- If we take into account the randomness of L, we get:

$$\mu = Np \times \mu_L,$$
$$\sigma^2 = N \times \left[p(1-p)\mu_L^2 + p\sigma_L^2 \right] \approx Np(\mu_L^2 + \sigma_L^2)$$

- Then the value of γ is given by

$$\gamma = k\frac{\sigma}{\mu} \approx k\sqrt{\frac{1+(\sigma_L/\mu_L)^2}{Np}}$$

- And capital requirement is:

$$K \approx k\sqrt{Np(\mu_L^2 + \sigma_L^2)}$$

- For example for $\sigma_L \approx \mu_L$, the capital requirement is multiplied by $\sqrt{2}$
- Taking into account randomness, the difference between the two situations we described implies a factor of 90 in capital calculation.

IMA: Other Distributions -*

Poisson

- A natural extension of binomial models is the Poisson distribution (parameter λ).
- Then the expected loss is $\lambda\mu_L$ and variance is equal to $\lambda\mu_L^2$. We get:

$$\gamma \approx k\sqrt{\frac{1+(\sigma_L/\mu_L)^2}{\lambda}} \qquad \mathrm{K} \approx \mathrm{k}\mu_L\sqrt{\left[1+(\sigma_L/\mu_L)^2\right]\lambda}$$

Gamma

- A unique parameter may be insufficient in order to capture the variety of risks across the different business lines and type of risk..
- The gamma distribution Γ(α,β) may be a good choice in this case:

$$\text{density: } f(x)=\frac{x^{\alpha-1}}{\beta^{\alpha}\Gamma(\alpha)}e^{-x/\beta}; \quad \text{mean} = \beta\alpha; \quad \text{variance} = \beta^2\alpha$$

- Then:

$$\gamma \approx k\sqrt{\frac{1+(\sigma_L/\mu_L)^2}{\alpha}} \qquad \mathrm{K} \approx \mathrm{k}\mu_L\sqrt{\left[1+(\sigma_L/\mu_L)^2\right]\beta^2\alpha}$$

Calibration of k -*

- Because its definition, k must be the result of dividing unexpected losses by standard deviation.
- For standard normal distribution at 99,9%, k=3,1.
- For binomial distribution B(20, 0,05), we should have:

$$\sigma = 0,9747; \qquad 99,9 \text{ percentile} = 5,6818; \qquad k = \frac{5,6818 - 1}{0,9747} = 4,80.$$

- While for Poisson distribution with parameter λ=1,

$$\sigma = 1; \qquad 99,9 \text{ percentile} = 5,84; \qquad k = \frac{5,84 - 1}{1} = 4,84.$$

- For Poisson distribution with parameter λ=20, we should get k=3,51.
- In practice, k will be more sensitive to the type of risk (frequency) than to the kind of distribution used.

IMA: Final Observations -*

- This approach shows how to model operational risk in a simply way.
- Insurances may be taken in account: just substituting μ_L by μ_L- μ_R where μ_R is the mean amount recovered.
- It is easy to extend the model to another distributions.
- Some conclusions:
  - Low-frequency high-impact risks have the largest effects on bank's capital charges.
  - This approach underlines the importance of provisions for expected losses in order to reduce capital charges.
  - Capital is proportional to the square root of the number of events.
  - So it will be proportional to the square root of the size of the bank.
  - It is also proportional to the square root of the size of the time window.
  - IMA means there is no linearity.
  - It is a well known feature of operational risk losses (not always well modelized).

The Need of Internal Data Base -*

- As it was said, even banks who choose the Standardized Approach must begin to collect events, creating an internal data base of operational risk.
- Of course, more advanced (actuarial) models will depend on the quality of those data base.
- The creation and maintenance of such data base presents many practical problems:
  - Quality and quantity of data (in particular for being able to fit severity and frequency distributions).
  - Consistency of data: are data representative after some year and big changes in the business (merges, acquisitions, new business lines, better management, etc.)
  - Etc.
- Of course, part of the data base may be updated automatically.
- Nevertheless, big events need to be reported individually by the units responsible of them.
- A new culture of risk management is necessary.

Operational Risk and Basel II: Advanced Models

Different Approaches to Operational Risk

- We can divide the different models in two great families: **top-down** approach and **bottom-up** approach.
- **Top-down models**:
  - The goal is to compute regulatory capital at the highest possible level (for example, the whole entity).
  - Then the capital is allocated to business lines and business units.
  - Basic and Standard approach defined in Basel II agreement are top-down models.
- **Bottom-up models**:
  - The approach is the opposite one: the risk (capital) is measured at the lowest level.
  - Then the capital is aggregated for the whole entity.
  - One of the advantages of this kind of approach is that it allows to understand where the operational risk is produced.
  - It is a better election for risk management purpose.
- In this talk, we shall focus on the loss distribution approach, a bottom up approach.

Actuarial Models: Frequency and Severity

- We start at one of the positions in the Basel II array.
- Let, X represents the random variable (corrected) severity and φ be its probability density function (pdf):

$$P(X \le x) = \Phi(x), \qquad \Phi'(x) = \varphi(x)$$

- Given a time horizon (1 year is the usual choice), let *N* be the random variable which describes the number of events in this position and f its mass function:

$$P(N = m) = f(n), \qquad n = 0, 1, 2, \ldots.$$

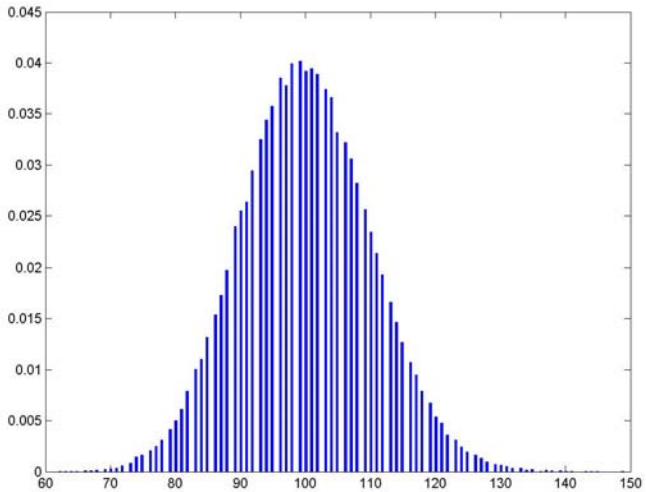
- The aggregated loss for one year period is then:

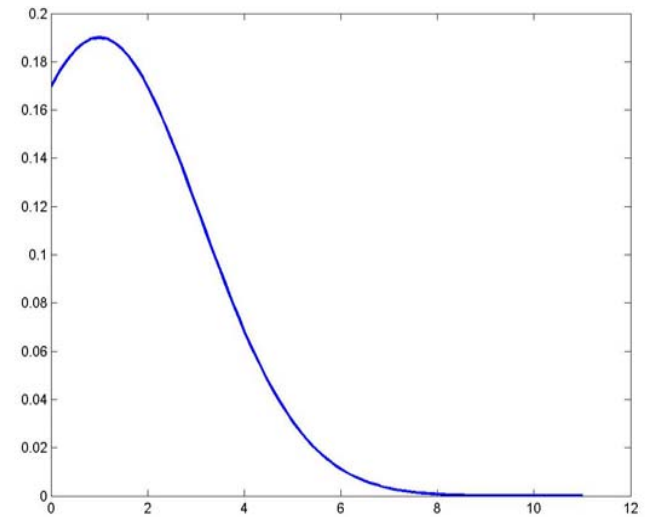
$$S_N = \sum_1^N X_i$$

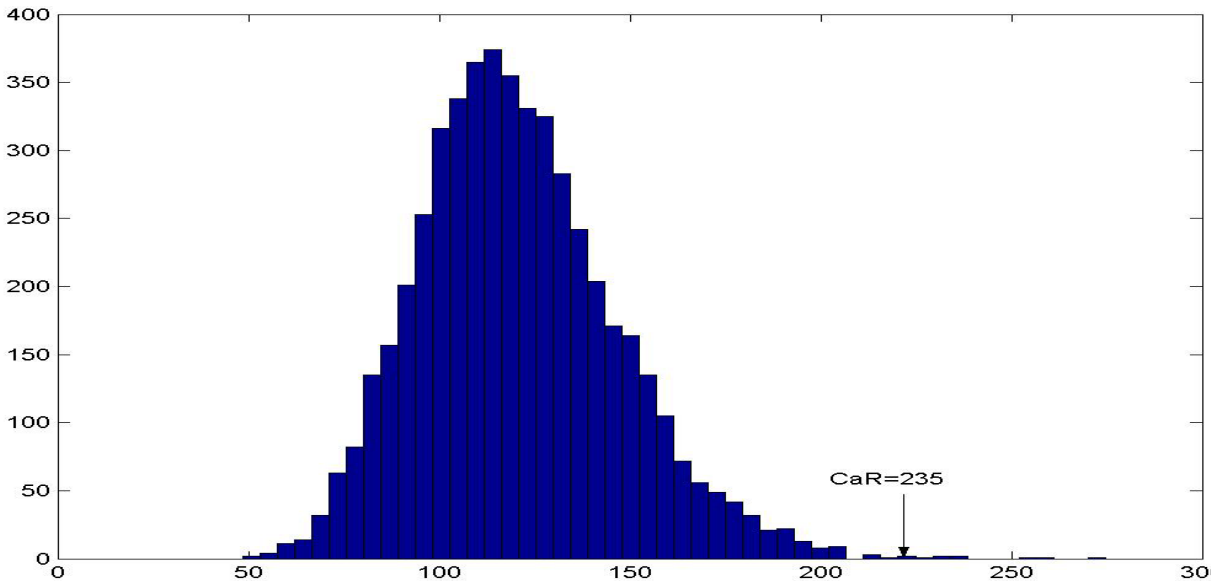
- It is easy to see that:

$$P(S_N \le s) = P(\sum_1^n X_i \le s) \times P(N = n), \text{ and } E[S_N] = E[X] \times E[N]$$

Aggregate Loss Distribution







Which Percentile?

- The Basel Committee has clearly defined what a bank must compute:

> "***A bank must be able to demonstrate that its approach captures potentially severe "tail" loss events. Whatever approach is used, a bank must demonstrate that its operational risk measure meets a soundness standard comparable to that of the internal ratings based approach for credit risk, (i.e. comparable to a one year holding period and a 99.9 percent confidence interval).***"

- A first approach to the problem suggests a one factor model:
  - Economic capital (capital charge) for each position in the array is determinate by calculating the percentile 99,9%.
  - The total capital is the sum of the capital for each position.
  - It is a conservative approach, but this is the underlying philosophy of the Basel Committee, also for credit risk or market risk capital charge.

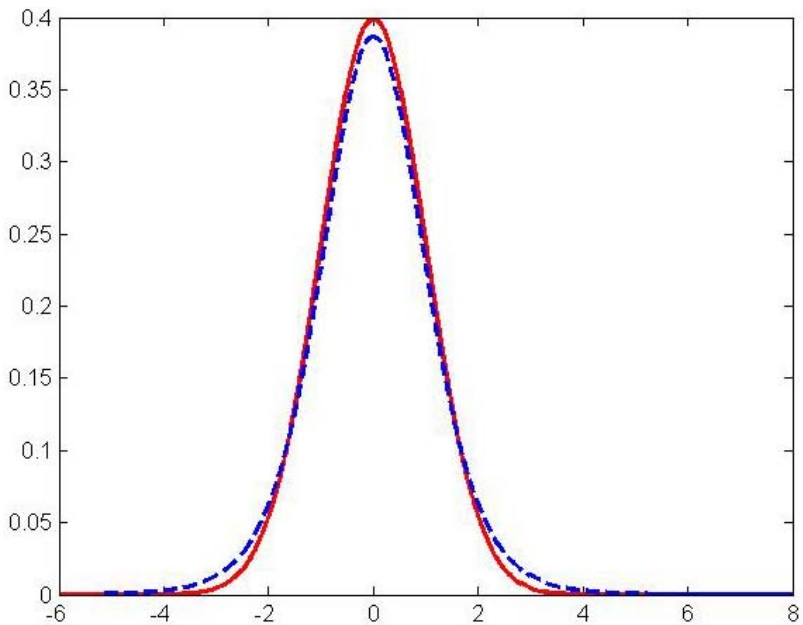
Models for Severity Distribution

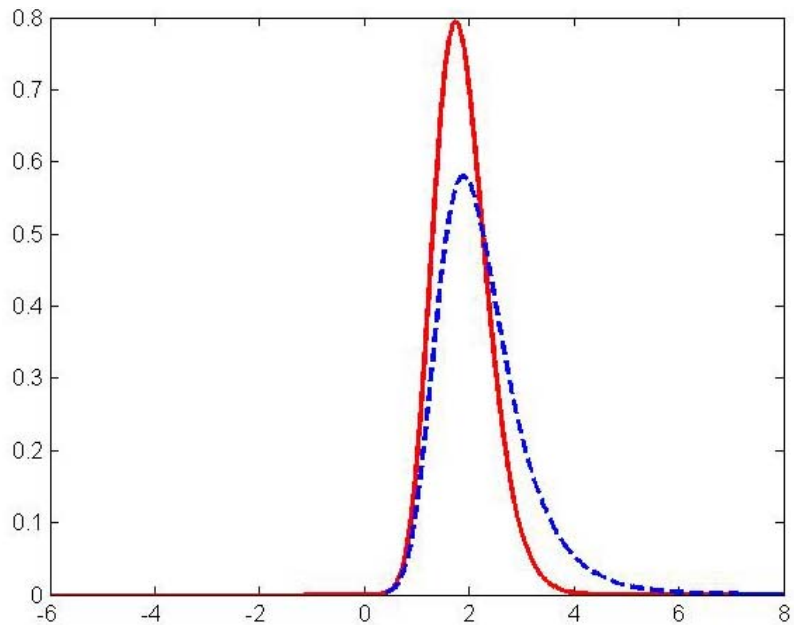
- We need a family of distributions for modeling the severity distribution.
- The most usual in actuarial sciences are:

Distribution	Expression	Parameters
Lognormal	$H(x) = N\left(\frac{\ln x - \mu}{\sigma}\right)$	μ, σ>0
GEV	$H(x) = \exp\left(-\left[1+\xi\frac{x-\alpha}{\beta}\right]_+^{-1/\xi}\right)$	α, β>0, ξ
Pareto gen.	$H(x) = 1-\left[1+\xi\frac{x-\alpha}{\beta}\right]_+^{-1/\xi}$	α, β>0, ξ
Weibull	$H(x) = 1-\exp\left(-\left[\frac{x-\alpha}{\beta}\right]_+^{\xi}\right)$	α, β>0, ξ
Gamma	$H(x) = (x-\gamma)_+^{\alpha-1}[\beta^{\alpha}\Gamma(\alpha)]^{-1}\,\mathrm{e}^{-(x-\gamma)/\beta}$	α>0, β>0, γ>0

How to Choose Which Distribution to use -*

- It depends how much we want to emphasize the tails of the distributions.
- The use of order statistics may help to decide.



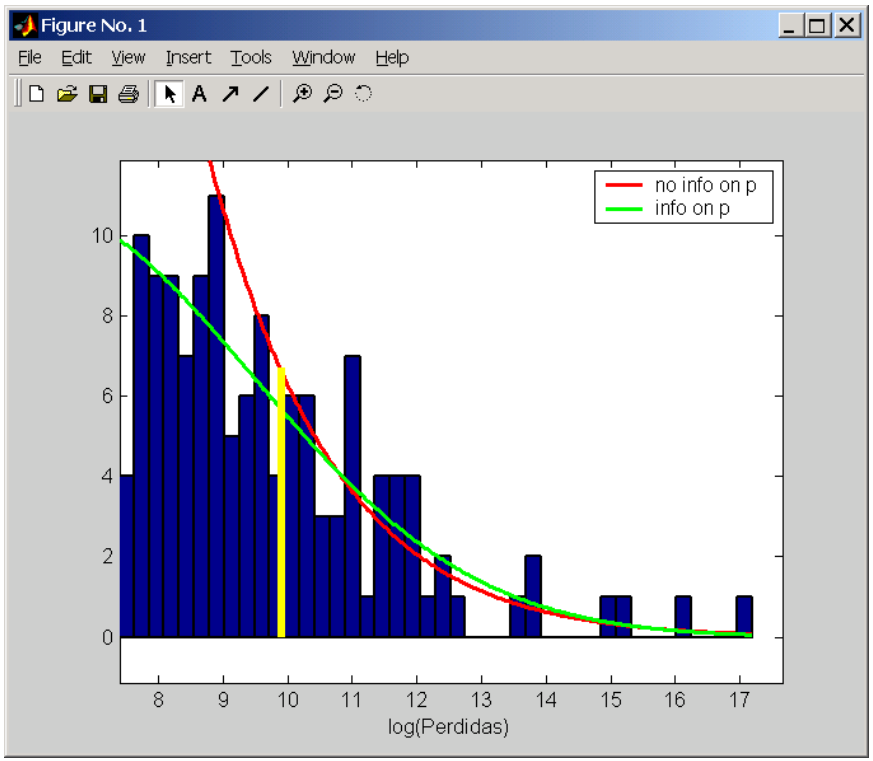


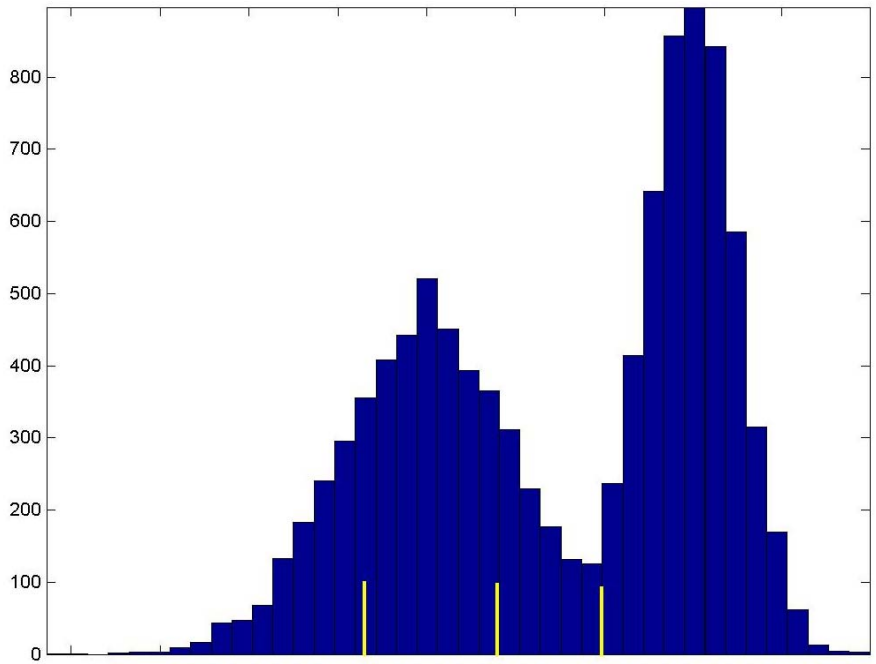
Standard normal distribution and t-Student (4 degrees of freedom) may seem very similar, nevertheless order statistics (20) allow clearly the discrimination.

Critical Issue: the Choice of the Threshold -*

- A first problem is what threshold we must use for fitting severity distribution?
- Many authors think that a high threshold (≥10.000€) is fine.
  - You need less data;
  - It is easy to fit the tail;
  - Poisson distribution seems to fit fine frequency distribution.
- Our experience is different: the lower is the threshold the most complete is the information about the real distribution and the more economical (in opposition to regulatory) will be the calculation of capital charge.
- A study done at RiskLab-Madrid with a many sets of lognormal (synthetical) data and thresholds at 0, 6, 60, 600, 1200, 6000, 10000 shows:
  - There are big variations in the parameters of severity fitted (MLE) distributions.
  - The practical consequences are important variations in capital charge: up to 30% depending on the standard deviation of the lognormal distribution.
- With real data things may be worst.

The Threshold Effect -*

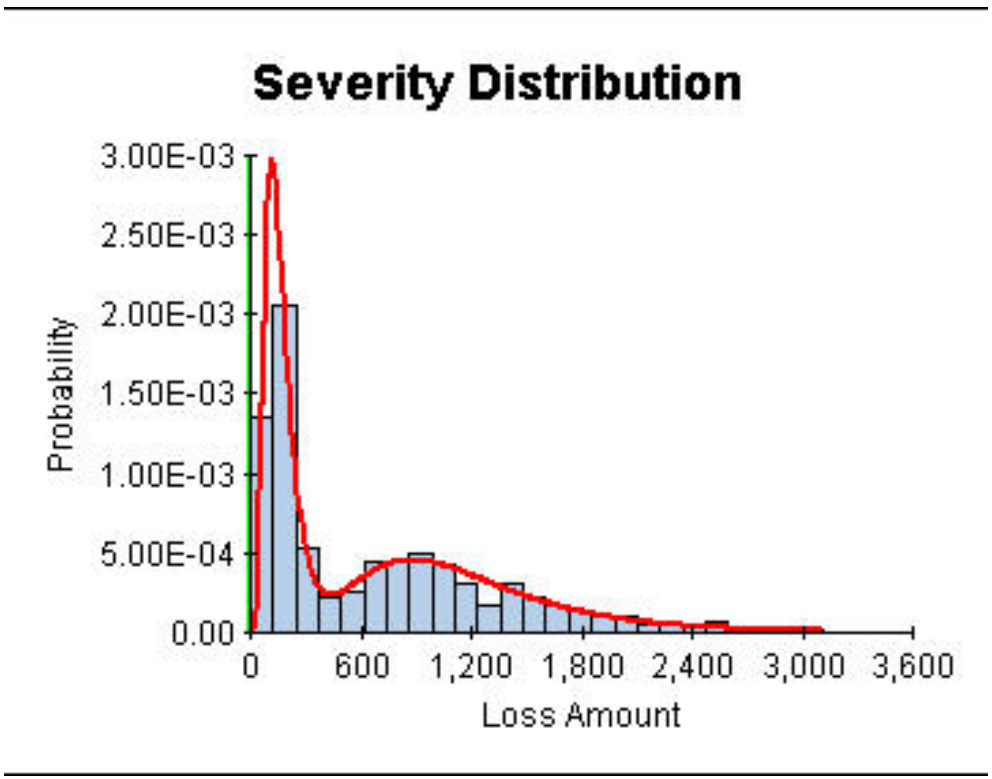




The threshold may have a big impact both on expected and unexpected losses.

The Real Dirty World

- In practice, we shall have more complicated situations:



- So we need also mixtures of these distributions.

Critical Issue: the Use of Extreme Value Theory -*

- Operational risk data exhibit very fat tails: usually more than 90% of the capital charge is explained by a very small quantity of events.
- Many authors suggest the use of extreme EVT distributions in order to fit real data.
- The inconvenient of such an approach is that you may get a charge so big that it really have no economical sense.
- In fact, most of such big events are typically unique: because they occurred once, a repetition is almost impossible.
- It is a misunderstanding of Basel II recommendation ("***However, a bank must be able to demonstrate that its approach captures potentially severe tail loss events").***
- In fact, fat tails are captured by the way of calculating the 99,9 percentile as capital charge in each array and taking the sum for the 56 cell of Basel array.
- Something similar occurs in market risk when computing the capital charge as three times the VaR (normal).
- May be for models able to take in account dependence structure a more precise fitting of the tail of severity distributions will make sense.

Models for Frequency Distribution

- The Poisson distribution is a natural candidate for such a purpose.
- Nevertheless it is not the only possible choice.
- The following table summarizes the characteristics of other candidates

Distribution	Expression	Parameters
Poisson, P(λ)	$P(N=n)=\frac{\lambda^n}{n!}e^{-\lambda}$	$\lambda>0$
Binomial, B(N,p)	$P(N=k)=\binom{N}{k}p^k(1-p)^{N-k}$	$N,k\in\mathbb{N}, p\in(0,1)$
Negative Binomial, B(r,p)	$P(N=k+r)=\binom{k+r-1}{r-1}p^{\mathbf{r}}(1-p)^{\mathbf{k}}$	$k\in\mathbb{N}, r>0, p\in(0,1)$

- In fact, the negative binomial is a mixture of Poisson's distributions.
- For more complex situations (in the future, with a lot of data for fitting) Cox processes may be good candidates.

Critical Issue: accounting seasonality -*

- In practice, the fitting of frequency distribution presents a problem.
- Most part of banks use accounting date for characterization of operational risk events.
- Of course, by this way, a false seasonality is introduced in data frequency.
- It may have important consequences for the fitting of frequencies distributions.
- Events which seem Poisson when using the date when it take place are transformed and you need negative binomial for a good fitting.
- Fortunately, the election of the frequency distribution doesn't seem to have dramatical effects on capital charge calculation.
- Nevertheless, it seems a good idea (for goodness of fit purposes) to use both date in the internal data base of a bank.
- When designing from the beginning the operational risk framework, it is a small additional effort.

Practical Issues

Discretization of the Severity Distribution: Concentration Method

- Of course, for computational purposes, we need a discrete version of the severity distribution[1].
- There are different methods for doing it.
- In our case, we must basically choose between:
  - The **method of concentration**,
  - The **method of local moments**.
- The idea for the first approach is very simple:
  - We need to define a mesh in $\mathbb{R}^+$: *jh, j=0, 1, 2, ...*
  - The mass of the density function is concentrated on these points.

$$f_0 = P(X < h/2) = F_X(h/2),$$
$$f_j = P(X = jh) = P(jh - h/2 \le X < jh + h/2) = F_X(jh + h/2) - F_X(jh - h/2), \quad j = 1, 2, \ldots$$

- It is an easy and very fast method.

See **Klugman**, **Panjer**, **Willmot**: *Loss Models, From Data to Decisions*. John Wiley & Sons. 1998.

Discretization of the Severity Distribution: Moment Method

- In this case we want to fit the p first local moments.
- The mesh is defined, for a given h, in the following way:

$$x_{k+1} = x_k + ph$$

- We allocate the probability to the points of $[x_k, x_{k+1})$:

$$x_k, x_k + h, \ldots, x_k + ph \rightarrow m_0^k, m_1^k, \ldots m_p^k$$

- Such that:

$$\sum_{j=0}^{p} m_j^k (x_k + jh)^r = \int_{x_k-}^{x_k+ph-} x^r dF_X(x), \quad r = 0,1,2,\ldots,p$$

- In practice, for $p=1$, the result is equivalent to the concentration method.
- For $p=2$ the fitting of the distribution is much better.
- For greater p's the improvement is small.
- For p=2 the probability density function is defined by

$$f_0 = m_0^0,\ f_1 = m_1^0,\ f_2 = m_2^0 + m_0^1,\ f_3 = m_1^1,\ \ldots,\ m_j^k = \int_{x_k}^{x_k+2h} \prod_{i \neq j} \frac{x - x_k - ih}{(j-i)h} dF_X(x),\ j = 0,1,2$$

A Class of Frequency Distributions

- If we define:

$$p_k = P(N = k)$$

- It is easy to verify that Poisson's distribution satisfies:

$$\frac{p_k}{p_{k-1}} = a + \frac{b}{k}, \quad \text{para } k = 1, 2, ...$$

- With $a = 0$, $b = \lambda$ and $p_0 = e^{-\lambda}$.
- The other distributions we mentioned before have the same property:

Distribution	**a**	**b**	$\mathbf{p_0}$
Binomial	$-\frac{p}{1-p}$	$(N+1)\frac{p}{1-p}$	$(1-q)^N$
Negative Bin.	$1-p$	$(r-1)(1-p)$	p^r

- They belong to the class (a,b,0).

Recursive Method of Panjer

- It is possible to get an explicit formula for the pdf of the aggregate loss distribution *S*, if:
  - We have the discrete version of the severity random variable *X*.
  - The pdf of the frequency distribution if it belongs to class (a,b,0)
- The Panjer recursive formula is:

$$f_S(x) = \frac{\sum_{y=1}^{x} (a + \frac{by}{x}) f_X(x) f_S(x-y)}{1 - a f_X(x)}$$

- In particular, in the case of the Poisson distribution with parameter λ, we get:

$$\begin{cases} f_S(x) = \frac{\lambda}{x} \sum_{y=1}^{x} y f_X(y) f_S(x-y), \; x = 1,2,... \\ f_S(0) = e^{-\lambda[1-f_X(0)]} \end{cases}$$

- That gives the complete description of the aggregate loss distribution for each position in the Basel II array.

Where is the Difficulty?

- Let's suppose the severity distribution is lognormal with parameters μ and σ.
- In the real life σ is often big (more than 2,5).
- The capital charge (percentile) is a very big amount of money.
- The problem is then how to compute this percentile.
- We need too many steps in the Panjer algorithm.
- It may turn the method impracticable (inefficient, even unfeasible).
- What can we do?
- Monte Carlo simulation?
- Some kind of (new?) Thauberian theorems?
- Can Econophysics bring some new light to this problem?

We Can´t Bypass the Monte Carlo Method

- Banks are allowed and need to mitigate their losses using insurances.
- An insurance means the use of at least 4 parameters:
  - Lower and upper thresholds which delimitate the reimbursement, in case of loss.
  - A probability coefficient which allows you to take into account the time remaining in your insurance contract.
  - A percentage of mitigation which allows you to take into account the fact that insurance companies don't like to pay without discussion.
- Definitely, we need to use Monte Carlo simulation.
- Among many advantages of this method, it allows to compute directly the marginal contribution of each position in the Basel II array.
- In addition it is possible to take into account the diversification effect (multifactor model) using copulas for modeling the joint distribution of the 56 positions.
- Nevertheless, arbitrage between numerical algorithms and the Monte Carlo approach is not so easy.
- In the case of big σ, we need a lot of simulations in order to get a stable estimation of the percentile 99.9.

Capital Allocation -*

- One of the goal of risk management is to be able to allocate (charge of) capital to the different business lines and business units.
- We need this kind of approach after insurance mitigation or qualitative analysis.
- How to do that with operational risk?
- A first approach (proposed by Roncally et all) consist in a two step computation:
  - First we get the allocation of each business line:

$$EC_i = \delta_i \times CaR, \text{ with } \delta_i = \frac{CaR_i}{\sum_{j=1}^{7} CaR_j}$$

  - Now we can calculate the allocation for the cell ij:

$$EC_{ij} = \delta_{ij} EC_j, \text{ with } \delta_{ij} = \frac{CaR_{ij}}{\sum_{l=1}^{8} CaR_{lj}}$$

- Another approach, based on marginal OpVaR, seems more natural when taking in account correlations.

Using External Data

Using External Data

- *"Any risk measurement system must have certain key features to meet the supervisory soundness standard set out in this section. These elements must include the use of internal data, relevant external data, scenario analysis and factors reflecting the business environment and internal control systems." (629)*
- *"A bank's operational risk measurement system must use relevant external data (either public data and/or pooled industry data), especially when there is reason to believe that the bank is exposed to infrequent, yet potentially severe, losses." (634)*
- *"These external data should include data on actual loss amounts, information on the scale of business operations where the event occurred, information on the causes and circumstances of the loss events or other information that would help in assessing the relevance of the loss event for other banks." (634)*
- *"A bank must have a systematic process for determining the situations for which external data must be used and the methodologies used to incorporate the data ..." (634)*

Scaling External Data

- External data are shared through specialized consortia (ORX, Gold, …).
- In order to use external data (from other banks) a double scaling process must be employed in order to guarantee that:
  - The data are really anonymous.
  - They make sense for each bank
- After Basel II, gross income seems to be the exposition indicator (*EI*) for such scaling.
- Let us consider two banks A and B, with exposition indicators EI_A y EI_B.
- A loss L_B from bank B must be scaled in order to be considered as a possible loss of the bank A:

$$L_A = L_B \left[1 + b \cdot \left(\left(\frac{EI_A}{EI_B} \right)^a - 1 \right) \right]$$

- Taking $b=1$ we get a simplified version of the model.
- a must be determinate by regression techniques.

Using internal and External Data for Fitting Severity

- The mathematical problem is easy to understand.
- Let's suppose the threshold for the external database is *H*.
- Let ζ (respectively ζ^*) be the random variable which represents internal losses (respectively external losses). Then our hypothesis is that:
  - $\zeta \sim f_\theta$
  - $\zeta^* \sim f_{\theta/H}$, the density of the severity, conditioned to the fact that this severity is greater than *H*.
- Of course:

$$f_{\theta/H}(x) = \frac{f_\theta(x)}{\int_H^\infty f_\theta(u)du}$$

- Let us introduce the following notations:

$\{\zeta_j ; j \in J\}$ represents internal data, $\{\zeta_j^* ; j \in J^*\}$ represent external data

- We need to compute the pair *(θ,H)* which maximize the value of:

$$\sum_{j\in J} \log f_\theta(\zeta_j) + \sum_{j\in J^*} \log f_{\theta/H}(\zeta_j^*)$$

Frequency and Thresholds -*

- If the fitting to internal data is done with a determinate threshold (set *H*, for example), the parameters of the fitting distribution must be scaled in consequence.
- For example, in the case of a Poisson distribution the "true" parameter λ is estimated as:

$$\lambda = \frac{\lambda_{sample}}{P(X > H)}$$

- Similar formula exist for other distributions for frequency.
- Nevertheless, frequencies are not scaled to external data.
- Threshold of external data base have no impact on frequency distribution.
- We shall only use internal data of the bank for the fitting of distributions.
- The reason is that those data are information on the tail of the distribution.
- If necessary, we can use the external data for stress scenarios (including frequencies).

Stochastic Threshold -*

- In practice, the threshold H is not necessarily constant through the different banks of the consortium.
- In order to take in account this fact, we shall modifie the conditional distribution from

$$f_{\theta/H}(x) = \frac{f_\theta(x)}{\int_H^\infty f_\theta(u)du}$$

- To

$$1_{\{x \geq H\}} \times \frac{f_\theta(x)}{\int_H^\infty f_\theta(u)du}$$

- The likelihood function has then e new term (for correction of reporting bias):

$$\sum_{i=1}^{n} \ln 1_{\{\zeta_i \geq H\}}$$

- This approach can be use also for internal data.

Complements

Sound Practices (1)

Developing an Appropriate Risk Management Environment

- **Principle 1**: The board of directors4 should be aware of the major aspects of the bank's operational risks as a distinct risk category that should be managed, and it should approve and periodically review the bank's operational risk management framework. The framework should provide a firm-wide definition of operational risk and lay down the principles of how operational risk is to be identified, assessed, monitored, and controlled/mitigated.
- **Principle 2**: The board of directors should ensure that the bank's operational risk management framework is subject to effective and comprehensive internal audit by operationally independent, appropriately trained and competent staff. The internal audit function should not be directly responsible for operational risk management.
- **Principle 3**: Senior management should have responsibility for implementing the operational risk management framework approved by the board of directors. The framework should be consistently implemented throughout the whole banking organisation, and all levels of staff should understand their responsibilities with respect to operational risk management. Senior management should also have responsibility for developing policies, processes and procedures for managing operational risk in all of the bank's material products, activities, processes and systems.

Sound Practices (2)

Risk Management: Identification, Assessment, Monitoring, and Mitigation/Control

- **Principle 4**: Banks should identify and assess the operational risk inherent in all material products, activities, processes and systems. Banks should also ensure that before new products, activities, processes and systems are introduced or undertaken, the operational risk inherent in them is subject to adequate assessment procedures.
- **Principle 5**: Banks should implement a process to regularly monitor operational risk profiles and material exposures to losses. There should be regular reporting of pertinent information to senior management and the board of directors that supports the proactive management of operational risk.
- **Principle 6**: Banks should have policies, processes and procedures to control and/or mitigate material operational risks. Banks should periodically review their risk limitation and control strategies and should adjust their operational risk profile accordingly using appropriate strategies, in light of their overall risk appetite and profile.
- **Principle 7**: Banks should have in place contingency and business continuity plans to ensure their ability to operate on an ongoing basis and limit losses in the event of severe business disruption.

Sound Practices (3)

Role of Supervisors

- **Principle 8:** Banking supervisors should require that all banks, regardless of size, have an effective framework in place to identify, assess, monitor and control/mitigate material operational risks as part of an overall approach to risk management.
- **Principle 9:** Supervisors should conduct, directly or indirectly, regular independent evaluation of a bank's policies, procedures and practices related to operational risks. Supervisors should ensure that there are appropriate mechanisms in place which allow them to remain apprised of developments at banks.

Role of Disclosure

- **Principle 10:** Banks should make sufficient public disclosure to allow market participants to assess their approach to operational risk management**.**

La razón de Cooke

- Propuesto en 1988 por el Comité de Basilea.
- Se definen varios niveles para los fondos propios(*):
  - Los fondos propios de base FP_1 o núcleo duro (TIER 1),
  - Los fondos propios complementarios FP_2 (TIER 2),
- La relación entre estas variables y el riesgo de crédito ponderado es la siguiente:

$$FP_2 \leq FP_1$$
$$FP_1 / EPC \geq 4\%$$
$$(FP_1 + FP_2) / EPC \geq 8\% \quad \text{(razón de Cooke)}$$

(*) Para más información acerca de los "Tier" ver el libro de VaR de Jorion p 45 y el documento de Basilea (bcbsca01) p. 13.

La razón de McDonough

- El nuevo acuerdo de Basilea ha definido una nueva razón de solvencia: la razón de MacDonough definida de la manera siguiente:

$$\frac{FP_1 + FP_2}{\text{riesgo de crédito+riesgo de mercado+riesgo operacional}} \geq 8\%$$

- Las exigencias en fondos propios venía distribuida entonces según la siguiente tabla:

Riesgo	FP	Reparto
Crédito	6%	75%
Mercado	0,4%	5%
Operacional	1,6%	20%
total	8%	100%

SELECTED EXAMPLES

FIRM NAME	BUSINESS LINE - LEVEL 1	BUSINESS LINE - LEVEL 2	LOSS AMOUNT ($M)	DESCRIPTION	EVENT RISK CATEGORY	SUB RISK CATEGORY	COUNTRY OF DOMICILE	SETTLEMENT YEAR
Nomura Securities International Incorporated	Trading & Sales	Sales	47.90	In July 1998, Nomura Securities International Inc, the US brokerage unit of Nomura Securities of Japan, reported that it had agreed to pay $47.9M in settlement of charges stemming from the Orange County's bankruptcy lawsuit. The suit was filed against the firm for investing municipal county funds in high risk derivatives and municipal bond trading that was illegal under California law. The Securities Exchange Commission reported that Nomura was one of the brokerage firms responsible for the county's bankruptcy. Orange County claimed to have lost $1.64 billion. The SEC stated that Nomura had lent the county huge sums of money, which it reinvested in search of high returns. Nomura also supplied the risky securities favoured by then county Treasurer and Tax Collector Robert L. Citron that plunged in value when interest rates rose sharply in 1994. The SEC also charged the firm for its role in underwriting key bonds for the county and accused Citron of illegally investing in volatile securities that were unsuitable for public funds.	Clients, Products & Business Practices	Suitability, Disclosure & Fiduciary	Japan	1998
ABN Amro Holding NV	Agency Services	Corporate Trust	141.00	In November 1998, ABN Amro Holding NV, a Netherlands full services bank and Europe's eighth largest banking firm, reported that it had realized a loss of 174M guilders ($141M) due to forgery, embezzlement and fraud perpetrated by four of its former employees. The four allegedly committed about 600 fraudulent transactions, making improper use of about 30 client accounts. The bank said that after uncovering the irregularities, it fired the employees and notified law enforcement officials in February, 1997. The transactions took place within the bank's trust department, whose functions included maintaining bank accounts for 600 to 800 clients living abroad. Its products included numbered bank accounts for clients whose identities were known only within the department. Employees also executed orders solely on the basis of telephone instructions. The bank said that, upon inspection, some packages in custody that supposedly contained diamonds turned out to contain false diamonds, and diamond shipment orders given by clients were sometimes accompanied by falsified invoices.	Internal Fraud	Theft & Fraud	Netherlands	1998
Merrill Lynch & Company	Trading & Sales	Sales	100.00	In December 1997, Merrill Lynch & Co, a US broker-dealer, reported that it had agreed to pay $100M in fines to settle charges of price fixing on the Nasdaq stock market. The Securities and Exchange Commission fined 30 Wall Street firms more than $910M in this regard. The lawsuit alleged that as many as a million investors lost billions of dollars because of collusion among the firms between 1989 and 1994. This collusion caused an artificial widening of spreads, the gap between the purchase and selling prices of stocks, thereby adding to dealer profits. The settlement also required the firms to improve trading policies and procedures. The case began in 1994, when the SEC and the Justice Department accused major Nasdaq dealers of conspiring to fix the bid-ask spreads on stock quotes resulting in extra costs to ordinary investors on their stock trades. Under the settlement, the brokerage firms with the most alleged violations agreed to pay higher fines. In making its original case, the SEC charged that major Nasdaq dealers harassed or refused to trade with others who tried to offer investors a better price for a stock.	Clients, Products & Business Practices	Improper Business or Market Practices	United States	1997
WGZ Bank	Trading & Sales	Proprietary Positions	200.37	In October 1998, Westdeutsche Genossenschafts-Zentralbank AG (WGZ-Bank), a German commercial bank, reported that it had realised a loss of DM 377 ($200.4M) due to computer fraud perpetrated by two employees over the past sixteen months. The bank has initiated a case against the two employees, who used a loophole in the bank's computer system for currency derivatives. They entered unrealistic intermediary values, which the system failed to document and managed to realise the profits in their derivative securities. The fraud was only discovered after the installation of an updated system, required under a new law, which eliminates the opportunity for such manipulation.	Internal Fraud	Systems Security	Germany	1998
Korea First Bank	Commercial Banking	Commercial Banking	93.00	In April 1998, Korea First Bank, a South Korean commercial bank with operations in the US, reported that it had agreed to pay $93M in settlement of a lawsuit that charged it with wrongfully dishonoring its irrevocable letter of credits. The New York Appellate Court ruled in favour of CalEnergy Company Inc, a global energy company that manages and owns an interest in over 5000 megawatts of power generation capability among various facilities in operation, construction and development worldwide. Casecnan Water and Energy Company Inc, a subsidiary of Calenergy was executing a power project in the Philippines. Hanbo Corporation had been acting as the turnkey contractor and guarantor for the Casecnan project.KFB's letter of credit was issued as financial security for the obligations of Hanbo. The contract with Hanbo Corp. was terminated by Casecnan due to Hanbo's insolvency and other misperformance in the project, at which time Casecnan made an initial draw on the KFB letter of credit securing Hanbo's performance under the contract. Furthermore, Casecnan had made three susbsequent draws on the letter of credit, all of which were opposed by Hanbo and draws under the letter of credit were dishonoured by Korea First Bank.	Clients, Products & Business Practices	Improper Business or Market Practices	South Korea	1998
Citibank	Commercial Banking	Commercial Banking	30.00	In September 1999, Citibank, a US commercial bank with global operations and unit of Citigroup, reported that it had realized a loss of $30M due to credit fraud. The firm's UK branch was one of 20 financial institutions operating in the Middle East which were the victims of fraud. Madhav Patel, an Indian businessman, allegedly deceived the bank by using forged documents to secure letters of credit guaranteeing payment for bogus transactions. The alleged fraud came to light earlier this year when Patel's British registered firm, Solo Industries, ran into financial difficulties in the Middle East. Patel, who ran several metal smelting businesses in Dubai, secured letters of credit from the firm as well as other banks to guarantee payments on shipments of metal to the United Arab Emirates. Police believe the shipments were bogus and the money was diverted elsewhere. Patel moved to London after his business collapsed in May. He has since disappeared.	External Fraud	Theft & Fraud	United States	1999
Credit Suisse First Boston Corporation	Corporate Finance	Corporate Finance	4.00	In May 1997, Credit Suisse First Boston Corp., a US investment bank and unit of Credit Suisse Group, reported that it had agreed to pay $4M in a settlement with 33 former investment bankers in its municipal bond unit. The former employees claimed that the firm improperly refused to pay them annual bonuses when they were terminated. CSFB took the unusual step of offering no bonuses to laid off municipal bond investment bankers after the firm shut its municipal unit in 1995, even though the bankers had worked through 1994 and had generated profits for the company. At the same time, some bankers in the mortgage-backed securities unit were paid bonuses despite a loss of about $40M at that unit.	Employment Practices and Workplace Safety	Employee Relations	Switzerland	1997
Chase Manhattan Bank	Payment and Settlement	External Clients	1.45	In January 1995, Chase Manhattan Bank, a US commercial bank, reported that it had agreed to pay $1.5M in settlement with a publishing company for having improperly endorsed checks used in an embezzlement scheme. Knight Publishing lost nearly $2M between 1985 and 1992 in a scheme run by Oren Johnson, a production supervisor at the newspaper. Johnson admitted authorizing the company to issue checks to Graphic Image, a commercial printing firm, for supplies that were never delivered. He split the money with two other men and all three pled guilty to mail fraud, money-laundering and conspiracy. Knight Publishing claimed Chase Manhattan should not have honored the checks because the endorser's name did not match the name on the checks.	Execution, Delivery & Process Management	Transaction Capture, Execution & Maintenance	United States	1995
Phatra Thanakit	Retail Brokerage	Retail Brokerage - Secondary markets	1.60	In November 1993, Phatra Thanakit, a Thailand brokerage firm, reported that it had agreed to pay 40M Bhat($1.6M) in fines as settlement of Securities Exchange of Thailand (SET) charges alleging violations of trading rules. The fine was levied over the firm's role in a technical error during trading operations. The firm, one of the five biggest brokers in the Thai stock market, was responsible for an error involving a sale order for 200 million shares in Ayudha Investment (AITCO) which had only 25 million shares outstanding. The firm said that one of its subbrokers placed a sell order for 2000 shares but a computer fault converted the order to 200 million shares. The company tried to cancel the order about 20 minutes after the order was placed on SET's computerized board and notified the exchange of the technical error. However, some 18 million shares, worth more than 2.3 billion baht, had already been matched with buying orders. The exchange called an emergency meeting at the end of the day's trading and decided to void the transactions for the 18 million shares.	Business Disruption and System Failures	Systems	Thailand	1993