ADVANCED OPERATIONAL RISK MODELING IN BANKS AND INSURANCE COMPANIES

Prof. Marco Micocci
marco.micocci@studiomicocci.it

ABI – Dipo 26/27 june 2012

Agenda

- References
- Definition and Classification
- Model Description
- Model Application

Micocci & Partners
Attuariato e Finanza

Agenda

- References
- Definition and Classification
- Model Description
- Model Application

Micocci & Partners
Attuariato e Finanza

Recent papers about Operational Risk Modeling

- Agostini, A., & Talamo, P. (2010). Combining operational loss data with expert opinions through advanced credibility theory. *The Journal of Operational Risk* , *5* (1), p. 3-28.
- Bardoscia, M., & Bellotti, R. (2011). A dynamical approach to operational risk measurement. *The Journal of Operational Risk* , *6* (1), p. 3-19.
- Chaudhury, M. (2010). A review of the key issues in operational risk capital modeling. *The Journal of Operational Risk* , *5* (3), p. 37-66.
- Dahen, H., Dionne, G., & Zajdenweber, D. (2010). A practical application of extreme value theory to operational risk in banks. *The Journal of Operational Risk* , *5* (2), p. 63-78.
- **Micocci, M., & Masala, G. (2009).** Advanced Operational Risk Modeling in Banks and Insurance Companies. *Investment Management and Financial Innovations* , *2(c)*.
- **Micocci, M., Angela, C., & Masala, G. (2008).** Advanced models for the quantification of operational risk in financial institutions under the loss distribution approach. *Journal of Financial Transformation* , *22*.
- Shevchenko, P. V. (2010). Calculation of aggregate loss distributions. *The Journal of Operational Risk* , *5* (2), p. 3-40.

Micocci & Partners
Attuariato e Finanza

Main references

- Copula functions:

Di Clemente A., Romano C., 2003, "A Copula-Extreme Value Theory Approach for Modelling Operational Risk", chapter in Operational Risk Modelling and analysis: Theory and Practice (Risk Books, London)

Embrechts P., Lindskog F., McNeil A.J., 2001, "Modelling dependence with Copula and application to risk management", ETH Zurich, Working Paper.

Nelsen R.B., 1999, "An Introduction to Copulas", Lecture Notes in Statistics 139, New York, Springer-Verlag

Reshetar A, 2004, "Operational Risk and the effect of the diversification on Capital Charge".

Micocci & Partners Attuariato e Finanza

Main references

- Extreme value theory:

Embrechts P., Kluppelberg C., Mikosch T., 1997, "Modelling Extremal Events for insurance and Finance", Springer-Verlag

Embrechts P., Frey R., McNeil A., 2005, "Quantitative Risk Management", Princeton University Press

Moscadelli M., 2004, "The Modelling of Operational Risk: experience with the analysis of the data collected by the Basel Committee", Working Paper, Banca d'Italia

Main references

- <u>EM algorithm:</u>

Bee M., 2005, “On Maximum Likelihood Estimation of Operational Loss Distributions”, Discussion paper - n.3/2005, Università degli Studi di Trento Dipartimento di Economia

Dempster A.P., Laird N.M., Rubin D.B., 1977, “Maximum likelihood from incomplete data via the EM algorithm”, Journal of the Royal Statistical Society, Series B (Methodological) 39, 1-38

Micocci & Partners
Attuariato e Finanza

Main references

- Loss distribution approach:

De Fontnouvelle P., DeJesus-Rueff V., Jordan J., Rosengren E., 2003, "Using Loss Data to Quantify Operational Risk", Preprint, Federal Reserve Bank of Boston.

De Fontnouvelle P. & Rosengren E., 2004, "Implication of Alternative Operational Risk Modelling Techniques", Working paper, Federal Reserve Bank of Boston

Moscadelli M., 2004, "The Modelling of Operational Risk: experience with the analysis of the data collected by the Basel Committee", Working Paper, Banca d'Italia

Micocci & Partners
Attuariato e Finanza

Agenda

- References
- Definition and Classification
- Model Description
- Model Application

Micocci & Partners
Attuariato e Finanza

Definition of Operational Risk

Operational risk definition given by Basel Committee on Banking Supervision in 2001 is: ***"the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events***".

Up to now this definition has been adopted for the insurance sector as well.

Micocci & Partners
Attuariato e Finanza

Classification of event types

- business disruption and system failures;
- clients, products and business practice;
- damage to physical assets;
- employment practice and workplace safety;
- execution delivery and process;
- external fraud;
- internal fraud.

Micocci & Partners
Attuariato e Finanza

The purpose of the research: Loss Distribution Approach

- Developing a comprehensive model to quantify the capital charge necessary to cover the Operational Risk in a financial institution.

- The proposed model belongs to the class of the "Loss Distribution Approach" (LDA). LDA is a frequency/severity model widely used in many fields of the actuarial practice.

Micocci & Partners
Attuariato e Finanza

Agenda

- References
- Definition and Classification
- Model Description
- Model Application

Micocci & Partners
Attuariato e Finanza

Model description:
Loss Distribution Approach

- Computation of the loss frequency and the loss severity distributions for each event type.
- Computation of the aggregate loss distribution for each event type as the convolution of the frequency and the severity of loss distributions.
- Determination of the aggregate annual loss Y_i , for event type *i*, as sum of the stochastic number N_i of events occurred in one year with severity Y_{ik} :

$$Y_i = \sum_{k=0}^{N_i} Y_{ik}$$

- Hypothesis: losses Y_{ik} are i.i.d. random variables; loss frequencies and loss severities are independent random variables.

→ Monte Carlo simulation in order to generate a high number of simulated aggregated losses

Micocci & Partners
Attuariato e Finanza

Model description: Main issues

- The main issues in measuring the Operational Risk and the solutions that the model provides are:

1. Database truncation (Solution: EM algorithm)
2. Real dependencies among event types (Solution: Copula functions)
3. Extreme events (Solution: EVT theory)

- Previous models consider only some of these points.

Micocci & Partners
Attuariato e Finanza

1. Database truncation (EM algorithm)

- The problem of determining the parameters of the distribution which represents empirical loss frequencies and loss severities is obviously influenced by the presence of "truncated data".

  → it is necessary to apply the so called EM algorithm to evaluate the parameters of the unknown complete distribution.

- At this aim the conditional distributions and maximum likelihood estimation techniques involving truncated data are considered.

- Remark: in the numerical application, we will assume the standard hypothesis that the severity distribution follows a lognormal distribution.

Micocci & Partners
Attuariato e Finanza

1. Database truncation (EM algorithm)

- The two steps of the algorithm are:

1) E-step: estimate the expected conditional value of the *loglikelihood* function $l_c = l_c(\theta)$ for the observed sample *y* and the current value for θ. Let denote θ_0 the initial value of the vector parameters (determined arbitrarily), we must then estimate:

$$Q(\theta;\theta_0) = E_{\theta_0}\left\{l_C(\theta)\middle| y\right\}$$

2) M-step: the previous expression must be maximized with respect to θ:

$$Q(\theta_1;\theta_0) = \max Q(\theta;\theta_0)$$

→ These two steps are then repeated until convergence .

Micocci & Partners
Attuariato e Finanza

2. Real dependencies among event types (copula functions)

- The Student's copula is the copula of the multivariate Student's *t*-distribution:

$$C^{n}_{\nu,R}(u) = t^{n}_{\nu,R}\left(t_{\nu}^{-1}(u_{1}),\ldots,t_{\nu}^{-1}(u_{n})\right)$$

- The *t*-Student copula is more flexible than the Archimedean one to simulate multivariate distributions with more than two marginals (Archimedean family possesses only one parameter).

- *t* has a tail dependence property.

3. Extreme events (EVT theory)

- EVT aims to describe the distributions of rare events focusing on the tail of the distribution.
- EVT is then a powerful tool for managing losses due to rare events and inadequacy of internal controls (Low Frequency High Impact Events).
- Extreme events can be treated considering the value that the random variable assumes over a given threshold ("*Peaks Over Threshold method*", *POT*).

Micocci & Partners
Attuariato e Finanza

3. Extreme events (EVT theory)

- Given a random variable X with distribution function F, the excess distribution function (called excess conditional distribution function) above the fixed threshold k is

$$F_k(z) = \Pr\left\{x - k \le z \,\middle|\, x > k\right\}$$

- Pickand (1975) and Balkema - De Haan (1974) theorems: excess distribution can be approximated (for a certain class of distributions) for a high threshold k, by a generalized Pareto distribution:

$$G_{\xi,\sigma}(z) = \begin{cases} 1 - \left(1 + \dfrac{\xi}{\sigma} \cdot z\right)^{-\frac{1}{\xi}} & \xi \ne 0 \\ 1 - e^{-\frac{z}{\sigma}} & \xi = 0 \end{cases}$$

Micocci & Partners
Attuariato e Finanza

Agenda

- References
- Definition and Classification
- Model Description
- **Model Application**

Micocci & Partners
Attuariato e Finanza

Model application: database description

- The input data are taken from OpData, an operational losses database supplied by OpVantage, a division of Fitch Risk Management.
- The data collected from public sources (1972-2006), are losses whose amounts exceed a truncation threshold.
- We consider the database on the period 1994-2006, because previous data are not statistically significant.
- In the OpData, operational losses are categorized according to the Basel Committee’s event types classification.
- Valuations can be “tailored” on the base of some characteristics like: geografical location, dimension of the bank, total assets/liabilities, … and so on.

Micocci & Partners
Attuariato e Finanza

Model application: steps

→ estimation of the parameters of frequency and severity distributions, for each event type applying the EM algorithm. The frequency of loss arising from each event type is assumed to be a Poisson distribution while the lognormal distribution is used to model the loss severity

→ estimation of the aggregate loss distribution, for each event type, via Monte Carlo simulation;

→ quantification of Operational Risk capital charge, for each event type, through risk measures such as Value at Risk and Expected Shortfall;

→ quantification of the total Operational Risk capital charge in different hypothesis:

- **perfect dependence** (comonotonicity) among event types. The total capital charge is obtained by summing capital charges for each event type → overestimation of the total Operational Risk capital charge
- **independence** among event types → underestimation of the total Operational Risk capital charge;
- **realistic dependence structure through a t-Student copula.**

Micocci & Partners Attuariato e Finanza

Model application: steps

- We repeat the above steps using Extreme Value Theory to efficiently model the right tail of the severity distribution.

- We model the severity distribution using the lognormal distribution (in the left tail and in the centre) and the Generalized Pareto Distribution (GPD) for the right tail.

Micocci & Partners
Attuariato e Finanza

Model application: marginal distributions

- We apply then the EM algorithm to estimate the parameters of frequency and severity distributions:
- We consider a unitary capital (Total Assets = 1€)

Table 1. Parameters Estimation of severity and frequency distributions for each Event Type.

Event Type	Severity (lognormal)	Frequency (Poisson)
1.Clients, Products and Business Practices	$\overline{\mu} = -10.425$; $\overline{\sigma} = 2.286$	$\lambda = 37.130$
2.Employment Practices and Workplace Safety	$\overline{\mu} = -12.139$; $\overline{\sigma} = 2.066$	$\lambda = 6.686$
3.Execution, Delivery and Process Management	$\overline{\mu} = -11.456$; $\overline{\sigma} = 2.039$	$\lambda = 6.678$
4.External Fraud	$\overline{\mu} = -10.824$; $\overline{\sigma} = 1.975$	$\lambda = 13.741$
5.Internal Fraud	$\overline{\mu} = -10.692$; $\overline{\sigma} = 2.143$	$\lambda = 18.971$

Micocci & Partners
Attuariato e Finanza

Model application: risk measures for each event type

- Aggregate loss distribution, for each event type at firm level (Monte Carlo simulation with 100,000 replications):

Table 2. Value at Risk for Event Type.

Event Type	VaR 95%	VaR 99%	VaR 99.9%
1.Clients, Products and Business Practices	0.000564	0.001309	0.004634
2.Employment Practices and Workplace Safety	0.000045	0.000116	0.000411
3.Execution, Delivery and Process Management	0.000051	0.000133	0.000477
4.External Fraud	0.000092	0.000210	0.000637
5.Internal Fraud	0.000178	0.000431	0.001260
TOTAL	0.000929	0.002199	0.007419

Table 3. Expected Shortfall for Event Type.

Event Type	ES 95%	ES 99%	ES 99.9%
1.Clients, Products and Business Practices	0.001209	0.002871	0.009721
2.Employment Practices and Workplace Safety	0.000103	0.000243	0.000735
3.Execution, Delivery and Process Management	0.000121	0.000301	0.001043
4.External Fraud	0.000183	0.000398	0.001127
5.Internal Fraud	0.000366	0.000807	0.002224
TOTAL	0.001982	0.004620	0.014850

Micocci & Partners
Attuariato e Finanza

Model application: Capital charge with real dependence structure + EVT

- MC simulation copula + EVT:

Table 4. Operational Risk Capital Charge with EVT (% of total asset A).

OR Capital Charge	VaR 95%	VaR 99%	VaR 99.9%	ES 95%	ES 99%	ES 99.9%
Comonotonicity	0.000940	0.002368	0.009648	0.002263	0.005923	0.024049
t-Student Copula	0.000849	0.002132	0.008214	0.001972	0.004917	0.017879
Independence	0.000782	0.001749	0.006577	0.001684	0.004133	0.016445

Micocci & Partners
Attuariato e Finanza

Conclusions

- LDA Modeling for Operational Risk is a flexible tool for modeling operational risk; this kind of models come from the actuarial experience of the non life sector (that traditionally faces non gaussian distributions to model uncertainty and nonlinear correlated events); also Monte Carlo simulation was introduced since 1970 in actuarial science.

- Operational Loss Databases can provide all the necessary input data to feed the model and to calibrate the technical bases (assumptions) coherently with the characteristics of the single bank (dimension, geographical location, assets/liabilities, …).

- From the calculation point of view all problems can be managed and solved: database truncation, correlations, tail dependences, tailored valuations.

Micocci & Partners
Attuariato e Finanza

Recapiti

Marco Micocci
marco.micocci@studiomicocci.it

Micocci&Partners
Attuariato e Finanza
Via Cesare Pascarella, 12
00153 Roma

Tel. / Fax 065881055 - 0658365196
www.studiomicocci.it

Micocci & Partners
Attuariato e Finanza