# 7. OPERATIONAL RISK MODELLING AND CAPITAL ADEQUACY – ARE THERE ANY REWARDS IN GREATER COMPLEXITY[1]?

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## Abstract

*The paper applies the methodologies proposed by Basel Committee on Banking Supervision for assessing the capital requirements in the context of operational risk to a Romanian commercial bank. The basic indicator, standard and internal measurement approaches (IMA) have been used to asses the capital requirement levels needed to cover the operational risk. The IMA is implemented using the loss distribution methodology (LDA). The capital at risk is computed from the loss distribution that aggregates, using Monte-Carlo simulations, the frequency and loss size distributions, fitted to the empirical data, for each business line and event type pair. Even though IMA is more costly and difficult to implement, it has, in some circumstances, considerable rewards in terms of capital requirements.*

**Keywords:** operational risk, basic indicator approach, standardized approach, internal measurement approach, loss distribution methodology, Monte-Carlo simulation

**JEL Classification**: G21, E58, C15, C16

## 1. Introduction

The Basel Committee on Banking Supervision has set up in the New Capital Accord (Basel II) three methodologies for determining the necessary capital requirements that cover the operational risk. In Romania (National Bank of Romania assessment on

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November 10, 2010) the methodologies applied for operational risk computation and reporting in the banking system (33 banks) are:

- basic indicator approach (BIA) – used by 27 institutions;
- standardized approach (SA) – used by 4 institutions;
- internal measurement approach (IMA) – used by 2 institutions.

## 2. Basic Indicator Approach

The Basic Indicator Approach (BIA hereafter) is the simplest of the three methods; it implies the computation of a single indicator, such as gross income, that is multiplied by a constant ratio, in order to determine the capital requirements that should cover the operational risk events. The bank that employs this methodology should set aside a capital level consistent with the three year average gross operational income. The ratio used to translate this average into capital requirements has been set by the Basel Committee at 15% (alpha). The formula used is:

$$K_{BIA} = \alpha \frac{\sum_{i=1}^{3} \max(OR_i;0)}{3-n}$$

where: $K_{BIA}$ = the capital requirement determined according to BIA

$OR_i$ = gross revenue for operational activities, for each bank, in the last three years

$\alpha$ = the ratios set by the Basel Committee at 15%

$n$ = the number of years in the last three when the operational revenue had been negative.

The advantages of the BIA are: very easy to implement, it doesn't require special conditions – e.g. for data reporting and compiling; it's recommended for small banking institutions that have a relatively simple activity portfolio. BIA is just a method for determining the capital requirement for operational risk and not a methodology for determining the operational risk.

For the banking institution, for which data are available in this paper, the above-mentioned method produces the following results:

**Table 1**

**Capital requirements for operational risk determination in the BIA approach (mil. RON)**

| | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|
| Operational revenue | 231 | 327 | 537 | |
| Average over the last three years | | | | 365 |
| **Capital requirement according to BIA (15%)** | | | | 54.75 |

*Source: Authors' calculations.*

With total assets at a level of around RON 10 billion at the end of 2009 and total capital close to a level of a quarter of billion RON, the banking institution analyzed in this paper offers diversified financial services. The BIA capital requirement of RON 54.75 million, roughly equivalent to EUR 12.92 million, seems to underestimate the requirement and the characteristics of the bank and its real risk profile.

## 3. The Standardized Approach

The Standardized Approach (SA hereafter) is a refinement of the BIA, the method being basically the same, with the sole difference that the operational gross revenue is split among eight business lines: corporate finance, payment and settlement, trading and sales, agency services, commercial banking, asset management, retail banking and retail brokerage. The gross income from this business lines is considered to proxy the risk exposure to operational risk. The capital requirement is computed applying specific coefficients (beta – between 12% and 18%), that are deemed to estimate the relationship between the volume of activity for that specific business line and the losses implied by the occurrence of operational risk in the same business line. The first three business lines (corporate finance, payment & settlement and trading & sales) are considered to induce larger losses to the bank from the operational risk perspective, hence the coefficient used to translate revenue volume into capital requirements is larger – 18%. The next two business lines – agency services and commercial banking – have a lower coefficient of 15% and the last three (asset management, retail banking and retail brokerage) are considered the least risky, with a coefficient of 12%. The formula used for capital requirements computation in SA is:

$$K_{SA} = \frac{\sum_{i=1}^{3} \max(\sum_{j=1}^{8} (\beta_j \times OR_{ij});0)}{3}$$

where: $K_{SA}$ = the capital requirement under the SA

$OR_{j,I}$ = the gross operational revenue for each of the three years and business lines

$\beta_I$ = Basel II coefficient for capital requirement determination for each business line.

The SA, compared with BIA, seems to better capture the diversity in the bank's risk profiles and is an evolutionary step toward the internal measurement approach. Using data for the same bank and applying the SA the capital requirement is:

**Table 2**

**Capital requirement for operational risks according to SA (mil. RON)**

| Business line | Beta | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|
| Corporate finance | 18% | 5.65 | 7.73 | 11.00 | |
| Trading and sales | 18% | 33.54 | 55.90 | 124.17 | |
| Payment and settlement | 18% | 129.51 | 167.36 | 193.06 | |
| Commercial banking | 15% | 24.89 | 34.08 | 48.42 | |
| Agency services | 15% | 15.32 | 20.98 | 29.81 | |
| Retail banking | 12% | 18.11 | 34.89 | 119.80 | |
| Retail brokerage | 12% | 0.37 | 1.08 | 3.71 | |

| Business line | Beta | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|
| Asset management | 12% | 3.61 | 4.98 | 7.03 | |
| Total | - | 231.00 | 327.00 | 537.00 | |
| Annual operational revenue multiplied by β | | 39.05 | 54,75 | 86,48 | |
| **Capital requirement according to SA** | | | | | 60.09 |

*Source: Authors' calculations.*

The capital requirement applying the SA is RON 60.09 million (around EUR 14.18 million), higher by RON 5.34 million (EUR 1.26 million) than the amount determined by the BIA, indicative of a better assessment of the bank's requirements from the capital adequacy point of view.

## 4. The internal measurement approach

The third method, the internal measurement approach (IMA hereafter) enables the banks to develop their own capital adequacy determination model based on internal estimates. In order to use this approach, the banks must receive the approval of the regulatory and supervising institution and to meet certain requirements – to have their internal model(s) certified as being sophisticated enough to capture events with a significance coefficient of 0.1%.

Unlike credit and market risk, where the internal measurement approach captures only unexpected risks, for the operational risk the expected losses should be captured alongside unexpected ones, also. The data collected by the banking institutions using IMA should be structured along business lines and type of operational risk events. Although, only few Romanian credit institutions have adopted the IMA, most of the banks stride to implement the SA, thus laying the foundation for using, sometime in the future, the IMA, considered the most efficient method to monitor operational risk.

The most frequent internal measurement approaches used in the literature are the loss distribution approach and scorecard method.

The scorecard method is an instrument used by the bank to identify the vulnerable elements that could induce operational risks. The variables used by the scorecard method are financial and non-financial indicators. A representative financial indicator used by the above mentioned method is the cost to revenue ratio. A reduction in this indicator signals usually an efficiency gain, but from a certain point onwards the link between revenue and cost cannot be sustained in the same risk envelope. An example could be a higher cost-revenue ratio achieved by reducing audit and control expenses, or by cutting the monitoring systems expenses or slashing IT development costs, all implying higher operational risks.

Nonfinancial indicators help banks to develop their risk management – an example could be the ratio between back-office and front-office personnel. On one hand, a low ratio could indicate a higher probability of an operational risk occurrence for processing transactions (erroneous or delayed processing) and, on the other hand, a high ratio correlated with an inadequate distribution of responsibilities favors different occurrences of operational risk (the employees could consider that somebody else has processed the transaction). Another non-financial indicator is the training expenses per employee. A good bank employee is a knowledgeable one, trained to efficiently accomplish his/hers activity and with a good understanding of the procedures and risks implied by the job. A good assessment of the initial knowledge endowment of the workforce and constant training are an efficient investment by the bank that could potentially reduce operational risk and increase efficiency. Other key nonfinancial indicators that should be monitored by banks are personnel turnover, the volume of transaction, the number of employees that don't have ten successive days of vacation in a certain amount of time, customer complaints, etc.

A constant monitoring of this (and other) indicators could help the banks to properly analyze their internal processes and to manage correctly the risks, in order to reduce operational risk losses and even the capital requirement necessary to be set aside for this purpose.

The second approach to implement IMA is the loss distribution approach (LDA hereafter) applied to each business line and type of event in order to asses the severity of the losses and their frequency of occurrence. Estimating these two distributions implies the use of the historical records on operational risk events spanning at least over the previous year.

The frequency distribution models the occurrences of operational risk within the bank and the specific business line/event type and being a discrete distribution, a Poisson or binomial distribution is typically used (Frachot *et al.,* 2001).

The loss distribution is more difficult to model as a classical distribution and hence is sometimes modeled in a split fashion, part of it as an ordinary distribution – for small losses with high frequency - and an extreme event part - for big losses with low frequency. The first distribution collects all the losses from the threshold that deems them relevant to the bank to the level that is considered exceptional, and the extreme event distribution will collect all the events that surpass the latter level. The ordinary distribution could be modeled as a positive and continuous distribution such as exponential, Weibull, Pareto or Gamma.

The capital requirement computed by this method is similar to the value at risk methodology. A level of the capital requirement will be determined for each business line and event type (each cell in the risk matrix) and then the total capital is just the sum of the subcomponents.

For a business line and operational risk event type the expected loss (EL) and the unexpected loss (UL) are defined as in Frachot *et al.* (2001):

$$EL(i,j) = E[v(i,j)] = \int_0^\infty x dG_{i,j}(x)$$

and

$$UL(i,j;\alpha) = G_{i,j}^{-1}(\alpha) - E[v(i,j)] = \inf\{x \mid G_{i,j}(x) \geq \alpha\} - \int_0^\infty x dG_{i,j}(x)$$

where: i,j - a business line and an event type

v(i,j) - a random variable which represents the loss of an operation risk event on the business line i and type of event j α - the confidence level

$G_{i,j}$ - the compounded distribution of losses and frequencies

The number of events between time t and t+r is random; the corresponding variable N(i,j) has a probability function $p_{i,j}$. The loss frequency distribution is:

$$P(i,j) = \sum_{k=0}^{n} p_{i,j}(k)$$

The loss for the business line i event type j between times t and t+r is:

$$v(i,j) = \sum_{n=o}^{N(i,j)} \zeta_n(i,j)$$

The expected loss corresponds to the expected value of the random variable v(i,j) and the unexpected loss is the quintile for the level minus the mean. Although the Basel Committee proposes that the amount of unexpected loss to determine the capital requirement, most credit institutions compute the total losses – as a sum of expected and unexpected losses – for determining capital requirements for operational risk. The Capital-at-Risk is defined as (Frachot *et al.*, 2001):

$$CaR(i,j;\alpha) = EL(i,j) + UL(i,j;\alpha) = G_{i,j}^{-1}(\alpha)$$

and the expected loss can be computed as:

$$E[v(i,j)] = E[E[v(i,j) \mid N(i,j)]] = E[N(i,j)] \times E[\zeta(i,j)]$$

A precise modeling of the distributions implied by the method is required in order to produce an accurate estimate of the reality. Moreover, if the distributions are not estimated correctly, their aggregation could lead to results very far from the reality – especially when the distributions have fat tails.

The main problem faced by financial institutions in using this approach is the lack of complete and coherent historical records. The data should have been collected at least over the previous year, but the recommended time span is longer – between 3 and 5 years. The data should include all the business lines and the exposures from all locations and branches. As well as the gross value of the loss, there should be a record on the date of the event, a short description and the amount of the loss recovered if any. Data problems are not uncommon, ranging from records being biased towards small/large events (depending on the costs implied by recording an event), to reporting only for some business lines/event types.

Also, the LDA should consider external databases, but harmonizing these two types of data sources (internal and external) is even more problematic, as the circumstances could be very different (for the internal and external banking institutions) and the biases exhibited by the databases could be also different. An institution's data are considered fully comprehensive if the institution indicated that the loss data above its internal threshold were complete for all business lines of recent years. (Dutta, Perry, 2007).

As the data problems are solved (to some extent) the next step is to choose the loss distribution that depicts the data better. Several distributions can be used (exponential, gamma, chi-squared, Pareto, loglogistic, Weibull, etc.) and the usual tests for comparing the empirical distribution and the theoretical one can be employed (Kolmogorov-Smirnov, Anderson-Darling, Cramer-von Mises, Watson, etc.) along with quantile – quantile plots. The Kolmogorov-Smirnov test compares the two distributions and reports the maximum discrepancy, in absolute value, between the cumulative distribution functions of the empirical and theoretical distributions. The Anderson-Darling test is an extension of the previous test that puts a higher weight on the tails of the distributions.

The database used for applying the LDA contains 2.654 operational loss events (spanning from January 1st, 2007 to December 31, 2009; data is collected in euro) for the same bank that was previously analyzed in the BIA and SA methodologies. After grouping the events along business lines (BL hereafter) and event types (OLE thereafter) in a risk matrix (presented in Table 3 and Table 4 in Appendix) the frequency and the size of the loses for each matrix cell have been modeled separately, the frequency being modeled as Poisson distributions.

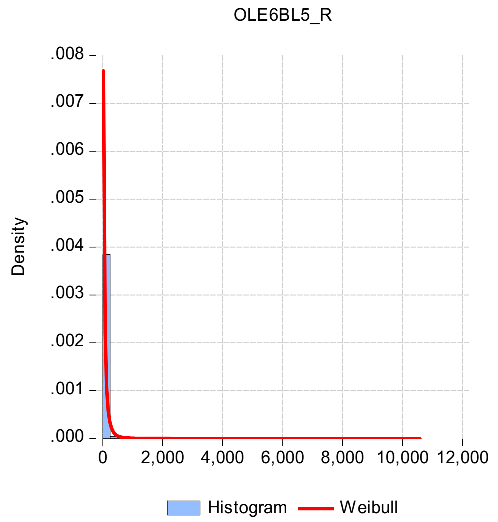
As an example three of the groups are presented below - OL6BL5 (1.653 observations), OLE2BL5 (324 observations) and OLE2BL8 (140 observations) – the empirical series histogram and the theoretical series histogram (corresponding to the theoretical distribution determined to be the closest to the empirical one by the tests - Weibull distribution with parameters s=33.0978 and a=0.5579 for OLE6BL5; Weibull distribution with parameters s=29.0604 and a=0.6579 for OLE2BL5 and also a Weibull distribution with parameters s=535.2750 and a=0.5515 for OLE2BL8).

**Figure 1**

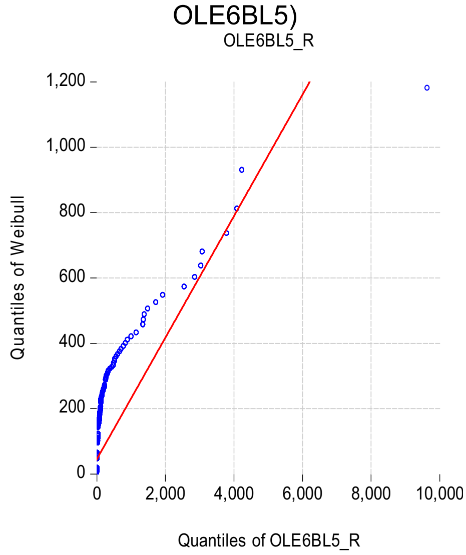
**Histograms and QQ plots for the empirical and theoretical distribution**

OLE6BL5

Histogram of the two series (OLE6BL5 and the theoretical distribution)




QQ plot for the two distributions (empirical and theoretical distribution - OLE6BL5)

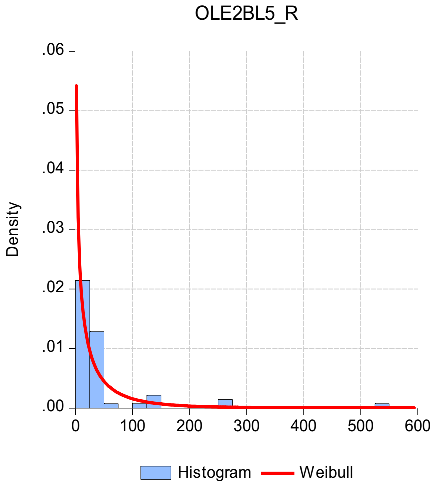
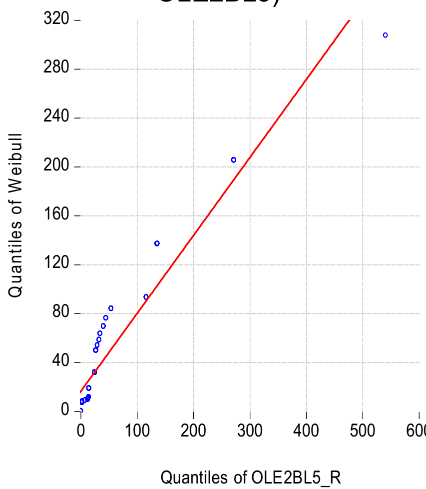



*Source: Authors' calculations.*

There are also QQ plots depicted below for the empirical and theoretical distributions for these three groups.

Each operational risk event category has been modeled separately (except a few that had very few observations and have been modeled together), several distributions being tested – the tests assessing the distance between the empirical and different theoretical distributions being reported in Table 5 (Appendix). In Table 6 (Appendix) the parameters of each distribution fitted to the empirical data is reported. In almost all cases the loss distribution selected by the tests has been the Weibull distribution (except for the event group OLE2BL7 that seems to be better modeled by the gamma or normal distribution).

OLE2BL5

| Histogram of the two series (OLE2BL5 and the theoretical distribution) | QQ plot for the two distributions (empirical and theoretical distribution - OLE2BL5) |
|---|---|
|  |  |





*Source: Authors' calculations.*

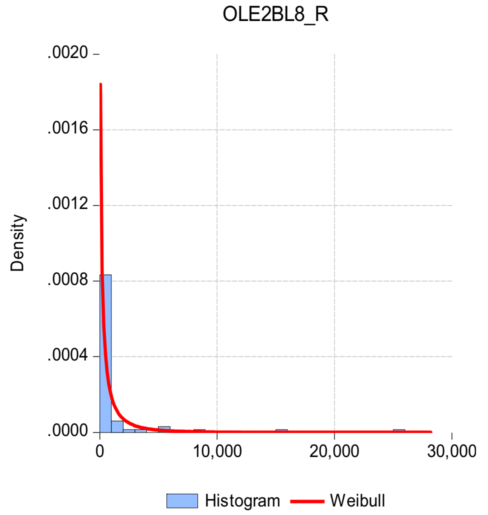
Using the above mentioned distributions for frequency and severity of the losses, 10,000 draws are generated for frequency and loss size and subsequently aggregated in a loss value distribution. The latter is used to compute the capital at risk – the loss value corresponding to a significance level of 0.1%. The process depicted above is repeated 100,000 times, the average of this Monte-Carlo simulations determining the capital at risk values, reported in Table 6 (euro) and Table 7 (RON) for each business line and event type pair, are also at the aggregate level. The total capital at risk value is EUR 8.75 million, around RON 37.1 million. The value is smaller than the level previously determined using BIA and SA (by 32.23% and 38.25%, respectively) which seems to validate the higher accuracy implied by the LDA.

An illustration of the Monte-Carlo simulation process is presented in Figure 2 for the group OLE6BL5 – the loss frequency multiplied by the loss size determines the loss value distribution.

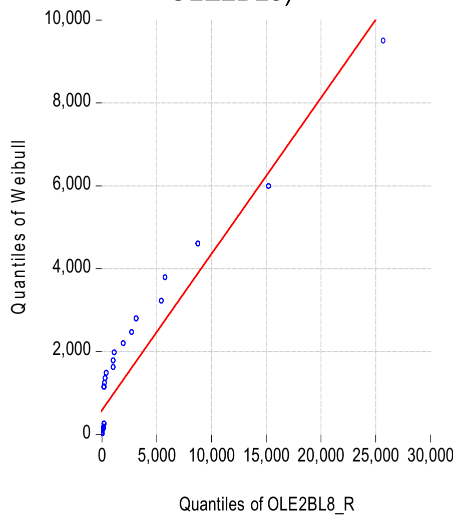
OLE2BL8

| Histogram of the two series | QQ plot for the two distributions |
|---|---|

(OLE2BL8 and the theoretical distribution)




(empirical and theoretical distribution - OLE2BL8)

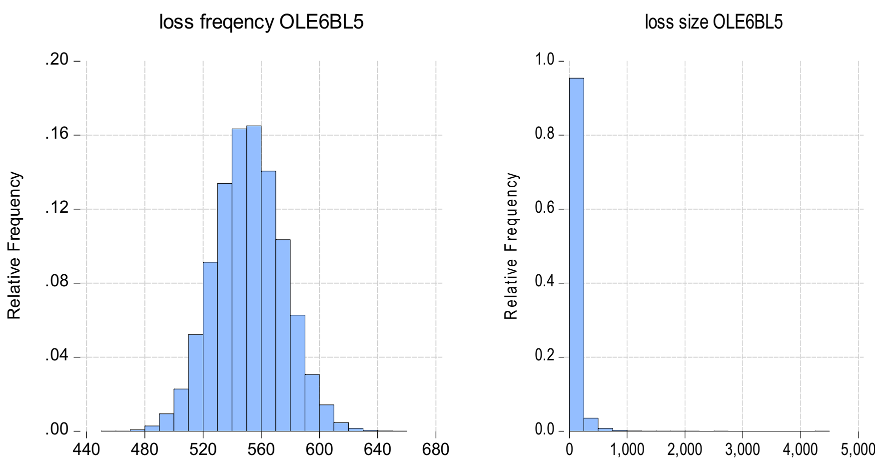


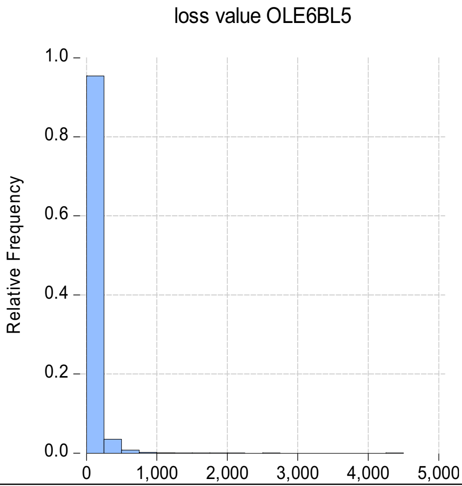

*Source: Authors' calculations.*

For robustness check we have decomposed the composite group (formed by combining the series with very few observations – named OLEcBLc_ext) into two subgroups that have been modeled this time separately (one group named OLE2BL7 and the other group composed by business line/event types: OLE1BL8, OLE3BL6, OLE6BL2, OLE6BL3, OLE6BL6, OLE6BL7 and OLE7BL7 – named OLEcBLc).

**Figure 2**

**Determining the aggregated loss value distribution for OLE6BL5**






*Source: Authors' calculations.*

## 5. Conclusions

In the paper we applied the methodologies proposed by Basel Committee on Banking Supervision for assessing the capital requirements in the context of operational risk to a Romanian commercial bank. Therefore, we tested all the approaches for a credit institution in Romania. Even considering the worst case scenario by using the distributions corresponding to the highest capital requirements, the total capital at risk indicated by the Monte Carlo process described above is EUR 10.26 million (RON 43.5 million) – determining a capital economy of 20.5% and 27.6% versus BIA and SA respectively.

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Table 3

## Matrix of operational risk events grouped by business lines and event types

*(euro)*

| | | | Business lines | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Corporate finance [BL1] | Agency services [BL2] | Asset management [BL3] | Commercial banking [BL4] | Payment and settlement [BL5] | Private banking [BL6] | Retail banking [BL7] | Trading and sales [BL8] | Event type total |
| Event type | Business disruption [OLE1] | number | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| | | total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 338,819.4 | 338,819.4 |
| | | max | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 338,819.4 | 338,819.4 |
| | Clients, products and business malpractice [OLE2] | number | 0 | 1 | 0 | 145 | 324 | 0 | 5 | 140 | 615 |
| | | total | 0.0 | 0.0 | 0.0 | 6,861.8 | 2,378.6 | 0.0 | 589.7 | 81,230.2 | 91,060.3 |
| | | max | 0.0 | 0.0 | 0.0 | 2,673.5 | 541.0 | 0.0 | 402.5 | 25,720.6 | 25,720.6 |
| | Control failure [OLE3] | number | 0 | 0 | 0 | 31 | 16 | 1 | 0 | 30 | 78 |
| | | total | 0.0 | 0.0 | 0.0 | 37,819.0 | 15,533.0 | 55.0 | 0.0 | 79,867.9 | 133,275.0 |
| | | max | 0.0 | 0.0 | 0.0 | 26,456.2 | 14,902.8 | 55.0 | 0.0 | 57,319.8 | 57,319.8 |
| | Inadequate hiring practice and safety procedure failure [OLE4] | number | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| | | total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | max | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | External crime & fraud [OLE5] | number | 0 | 0 | 0 | 0 | 36 | 0 | 0 | 0 | 36 |
| | | total | 0.0 | 0.0 | 0.0 | 0.0 | 7,962.5 | 0.0 | 0.0 | 0.0 | 7,962.5 |
| | | max | 0.0 | 0.0 | 0.0 | 0.0 | 1,360.2 | 0.0 | 0.0 | 0.0 | 1,360.2 |
| | Processing failure [OLE6] | number | 0 | 2 | 2 | 73 | 1,653 | 1 | 3 | 53 | 1,787 |
| | | total | 0.0 | 382.2 | 16.0 | 39,956.9 | 82,381.4 | 75.0 | 6.9 | 59,179.7 | 181,998.1 |
| | | max | 0.0 | 235.0 | 12.7 | 13,648.9 | 9,648.1 | 75.0 | 6.9 | 36,754.8 | 36,754.8 |
| | System failure [OLE7] | number | 0 | 0 | 0 | 88 | 45 | 0 | 3 | 0 | 136 |
| | | total | 0.0 | 0.0 | 0.0 | 13,761.5 | 13,739.0 | 0.0 | 11.6 | 0.0 | 27,512.2 |
| | | max | 0.0 | 0.0 | 0.0 | 5,629.3 | 11,373.4 | 0.0 | 10.9 | 0.0 | 11,373.4 |
| | Unauthorized activity | number | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| | | | Business lines | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Corporate finance [BL1] | Agency services [BL2] | Asset management [BL3] | Commercial banking [BL4] | Payment and settlement [BL5] | Private banking [BL6] | Retail banking [BL7] | Trading and sales [BL8] | Event type total |
| | [OLE8] | max | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Internal fraud [OLE9] | number | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | max | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | IT system failure [OLE10] | number | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | total | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | max | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Business line total | | number | 0 | 3 | 2 | 337 | 2,075 | 2 | 11 | 224 | 2,654 |
| | | total | 0.0 | 382.2 | 16.0 | 98,399.3 | 121,994.6 | 130.0 | 608.1 | 559,097.2 | 780,627.4 |
| | | max | 0.0 | 235.0 | 12.7 | 26,456.2 | 14,902.8 | 75.0 | 402.5 | 338,819.4 | 338,819.4 |

**Table 4**

## Matrix of operational risk events grouped by business lines and event types

*(percent)*

| | | | Business lines | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Corporate finance [BL1] | Agency services [BL2] | Asset management [BL3] | Commercial banking [BL4] | Payment and settlement [BL5] | Private banking [BL6] | Retail banking [BL7] | Trading and sales [BL8] | Event type total |
| Event type | Business disruption [OLE1] | number | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.04 |
| | | total | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 43.40 | 43.40 |
| | | max | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 100.00 | 100.00 |
| | Clients. products and business malpractice [OLE2] | number | 0.00 | 0.04 | 0.00 | 5.46 | 12.21 | 0.00 | 0.19 | 5.28 | 23.17 |
| | | total | 0.00 | 0.00 | 0.00 | 0.88 | 0.30 | 0.00 | 0.08 | 10.41 | 11.67 |
| | | max | 0.00 | 0.00 | 0.00 | 0.79 | 0.16 | 0.00 | 0.12 | 7.59 | 7.59 |
| | Control failure [OLE3] | number | 0.00 | 0.00 | 0.00 | 1.17 | 0.60 | 0.04 | 0.00 | 1.13 | 2.94 |
| | | total | 0.00 | 0.00 | 0.00 | 4.84 | 1.99 | 0.01 | 0.00 | 10.23 | 17.07 |
| | | max | 0.00 | 0.00 | 0.00 | 7.81 | 4.40 | 0.02 | 0.00 | 16.92 | 16.92 |
| | Inadequate hiring practice and safety procedure failure [OLE4] | number | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.04 |
| | | total | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | max | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | External crime & fraud [OLE5] | number | 0.00 | 0.00 | 0.00 | 0.00 | 1.36 | 0.00 | 0.00 | 0.00 | 1.36 |
| | | total | 0.00 | 0.00 | 0.00 | 0.00 | 1.02 | 0.00 | 0.00 | 0.00 | 1.02 |
| | | max | 0.00 | 0.00 | 0.00 | 0.00 | 0.40 | 0.00 | 0.00 | 0.00 | 0.40 |
| | Processing failure [OLE6] | number | 0.00 | 0.08 | 0.08 | 2.75 | 62.28 | 0.04 | 0.11 | 2.00 | 67.33 |
| | | total | 0.00 | 0.05 | 0.00 | 5.12 | 10.55 | 0.01 | 0.00 | 7.58 | 23.31 |
| | | max | 0.00 | 0.07 | 0.00 | 4.03 | 2.85 | 0.02 | 0.00 | 10.85 | 10.85 |
| | System failure [OLE7] | number | 0.00 | 0.00 | 0.00 | 3.32 | 1.70 | 0.00 | 0.11 | 0.00 | 5.12 |
| | | total | 0.00 | 0.00 | 0.00 | 1.76 | 1.76 | 0.00 | 0.00 | 0.00 | 3.52 |
| | | max | 0.00 | 0.00 | 0.00 | 1.66 | 3.36 | 0.00 | 0.00 | 0.00 | 3.36 |
| | Unauthorized activity [OLE8] | number | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | total | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | max | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Internal fraud [OLE9] | number | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | total | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

| | | | Business lines | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Corporate finance [BL1] | Agency services [BL2] | Asset management [BL3] | Commercial banking [BL4] | Payment and settlement [BL5] | Private banking [BL6] | Retail banking [BL7] | Trading and sales [BL8] | Event type total |
| | | max | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | IT system failure [OLE10] | number | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | total | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | max | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Business line total | | number | 0.00 | 0.11 | 0.08 | 12.70 | 78.18 | 0.08 | 0.41 | 8.44 | 100.00 |
| | | total | 0.00 | 0.05 | 0.00 | 12.61 | 15.63 | 0.02 | 0.08 | 71.62 | 100.00 |
| | | max | 0.00 | 0.07 | 0.00 | 7.81 | 4.40 | 0.02 | 0.12 | 100.00 | 100.00 |

**Table 5**

## Test results for the fitted theoretical probability distributions[1]

| No. obs. adj[2]. | Distributions | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exponential | | | Gamma | | | Pareto | | | Weibull | | | Normal | | |
| | Test | Value | Adjusted value | Test | Value | Adjusted value | Test | Value | Adjusted value | Test | Value | Adjusted value | Test | Value | Adjusted value |
| | OLE2BL4 | | | | | | | | | | | | | | |
| 145 | Cramer-von Mises (W2) | 8.1225 | 8.1326 | Cramer-von Mises (W2) | 0.6279 | 0.6296 | Cramer-von Mises (W2) | 4.3183 | 4.3236 | Cramer-von Mises (W2) | 0.0873 | 0.0889 | Cramer-von Mises (W2) | 7.5760 | 7.6054 |
| | Watson (U2) | 1.5635 | 1.5654 | Watson (U2) | 0.3531 | 0.3545 | Watson (U2) | 2.9589 | 2.9626 | Watson (U2) | 0.0870 | 0.0885 | Watson (U2) | 7.4053 | 7.4340 |
| | Anderson-Darling (A2) | 92.3211 | 92.7505 | Anderson-Darling (A2) | 4.0519 | 4.0519 | Anderson-Darling (A2) | 42.8606 | 43.0599 | Anderson-Darling (A2) | 0.8103 | 0.8246 | Anderson-Darling (A2) | 41.5552 | 41.8024 |
| | OLE2BL5 | | | | | | | | | | | | | | |
| 324 | Cramer-von Mises (W2) | 1.7082 | 1.7131 | Cramer-von Mises (W2) | 0.5625 | 0.5625 | Cramer-von Mises (W2) | 1.5632 | 1.5676 | Cramer-von Mises (W2) | 0.3621 | 0.3718 | Cramer-von Mises (W2) | 2.1236 | 2.1426 |
| | Watson (U2) | 0.5742 | 0.5758 | Watson (U2) | 0.4346 | 0.4346 | Watson (U2) | 1.0795 | 1.0826 | Watson (U2) | 0.3461 | 0.3554 | Watson (U2) | 1.9710 | 1.9886 |
| | Anderson-Darling (A2) | 23.6526 | 23.9060 | Anderson-Darling (A2) | 3.2587 | 3.2587 | Anderson-Darling (A2) | 20.2188 | 20.4354 | Anderson-Darling (A2) | 2.3416 | 2.4042 | Anderson-Darling (A2) | 10.5286 | 10.6772 |
| | OLE2BL7 | | | | | | | | | | | | | | |
| 5 | Cramer-von Mises (W2) | 0.0526 | 0.0547 | Cramer-von Mises (W2) | 0.0765 | 0.0765 | Cramer-von Mises (W2) | 0.5833 | 0.6510 | Cramer-von Mises (W2) | 0.0825 | 0.0908 | Cramer-von Mises (W2) | 0.0754 | 0.0848 |
| | Watson (U2) | 0.0483 | 0.0502 | Watson (U2) | 0.0670 | 0.0670 | Watson (U2) | 0.3333 | 0.3775 | Watson (U2) | 0.0767 | 0.0844 | Watson (U2) | 0.0722 | 0.0813 |
| | Anderson-Darling (A2) | 172.1918 | 198.0206 | Anderson-Darling (A2) | 0.4399 | 0.4399 | Anderson-Darling (A2) | 1722.9390 | 1722.9390 | Anderson-Darling (A2) | 0.5352 | 0.5888 | Anderson-Darling (A2) | 0.4129 | 0.5483 |
| 140 | OLE2BL8 | | | | | | | | | | | | | | |
| | Cramer-von Mises (W2) | 7.4367 | 7.4547 | Cramer-von Mises (W2) | 2.2321 | 2.2599 | Cramer-von Mises (W2) | 1.4929 | 1.4965 | Cramer-von Mises (W2) | 1.4389 | 1.4744 | Cramer-von Mises (W2) | 3.6487 | 3.6764 |

[1] *Shaded cells indicate the most appropriate distribution for modeling the specific loss series; the denotations are the same as in the previous tables (business line, event type).*

[2] *Total number of observations; distributions were fitted to an adjusted number of observations by removing zero values; OLE2BL2 is not modeled, the only observation in the series is zero.*

| No. obs. adj$^2$. | Distributions | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exponential | | | Gamma | | | Pareto | | | Weibull | | | Normal | | |
| | Test | Value | Adjusted value | Test | Value | Adjusted value | Test | Value | Adjusted value | Test | Value | Adjusted value | Test | Value | Adjusted value |
| | Watson (U2) | 2.6419 | 2.6483 | Watson (U2) | 1.7794 | 1.7995 | Watson (U2) | 1.1408 | 1.1436 | Watson (U2) | 1.3922 | 1.4265 | Watson (U2) | 3.4733 | 3.4996 |
| | Anderson -Darling (A2) | 53.2437 | 53.7277 | Anderson -Darling (A2) | 10.5209 | 10.5209 | Anderson -Darling (A2) | 17.6759 | 17.8366 | Anderson -Darling (A2) | 7.3118 | 7.4918 | Anderson -Darling (A2) | 17.4157 | 17.6226 |
| | OLE3BL4 | | | | | | | | | | | | | | |
| 31 | Cramer-von Mises (W2) | 3.4286 | 3.4561 | Cramer-von Mises (W2) | 0.3560 | 0.3544 | Cramer-von Mises (W2) | 0.4052 | 0.4085 | Cramer-von Mises (W2) | 0.1118 | 0.1168 | Cramer-von Mises (W2) | 1.1600 | 1.1890 |
| | Watson (U2) | 1.0941 | 1.1028 | Watson (U2) | 0.2589 | 0.2644 | Watson (U2) | 0.3015 | 0.3039 | Watson (U2) | 0.1058 | 0.1106 | Watson (U2) | 1.0937 | 1.1211 |
| | Anderson -Darling (A2) | 76.2961 | 78.5850 | Anderson -Darling (A2) | 1.6891 | 1.6891 | Anderson -Darling (A2) | 36.1621 | 37.2470 | Anderson -Darling (A2) | 0.6130 | 0.6404 | Anderson -Darling (A2) | 5.6280 | 5.8707 |
| | OLE3BL5 | | | | | | | | | | | | | | |
| 16 | Cramer-von Mises (W2) | 1.4079 | 1.4361 | Cramer-von Mises (W2) | 0.2203 | 0.2022 | Cramer-von Mises (W2) | 0.1085 | 0.1107 | Cramer-von Mises (W2) | 0.1066 | 0.1142 | Cramer-von Mises (W2) | 0.4630 | 0.4919 |
| | Watson (U2) | 0.4896 | 0.4994 | Watson (U2) | 0.1711 | 0.1762 | Watson (U2) | 0.0913 | 0.0932 | Watson (U2) | 0.1004 | 0.1075 | Watson (U2) | 0.4350 | 0.4622 |
| | Anderson -Darling (A2) | 101.0850 | 108.6664 | Anderson -Darling (A2) | 1.0756 | 1.0756 | Anderson -Darling (A2) | 86.3736 | 92.8516 | Anderson -Darling (A2) | 0.6047 | 0.6475 | Anderson -Darling (A2) | 2.2820 | 2.5762 |
| | OLE3BL8 | | | | | | | | | | | | | | |
| 30 | Cramer-von Mises (W2) | 3.8313 | 3.8517 | Cramer-von Mises (W2) | 2.23211 | 2.259918 | Cramer-von Mises (W2) | 0.2297 | 0.2309 | Cramer-von Mises (W2) | 0.1458 | 0.1512 | Cramer-von Mises (W2) | 1.8317 | 1.8623 |
| | Watson (U2) | 0.9413 | 0.9463 | Watson (U2) | 1.779426 | 1.799485 | Watson (U2) | 0.1436 | 0.1444 | Watson (U2) | 0.1348 | 0.1397 | Watson (U2) | 1.7491 | 1.7782 |
| | Anderson -Darling (A2) | 55.8208 | 56.9372 | Anderson -Darling (A2) | 10.52092 | 10.52092 | Anderson -Darling (A2) | 24.0142 | 24.4945 | Anderson -Darling (A2) | 0.9805 | 1.0163 | Anderson -Darling (A2) | 8.9495 | 9.1956 |
| | OLE5BL5 | | | | | | | | | | | | | | |
| 36 | Cramer-von Mises (W2) | 4.2532 | 4.2732 | Cramer-von Mises (W2) | 1.3126 | 1.3126 | Cramer-von Mises (W2) | 1.7582 | 1.7665 | Cramer-von Mises (W2) | 1.0593 | 1.0957 | Cramer-von Mises (W2) | 1.6904 | 1.7153 |
| | Watson (U2) | 1.6382 | 1.6459 | Watson (U2) | 1.1186 | 1.1186 | Watson (U2) | 1.2627 | 1.2687 | Watson (U2) | 1.0165 | 1.0514 | Watson (U2) | 1.5590 | 1.5819 |
| | Anderson -Darling (A2) | 64.2884 | 65.4229 | Anderson -Darling (A2) | 6.7580 | 6.7580 | Anderson -Darling (A2) | 30.4892 | 31.0273 | Anderson -Darling (A2) | 5.6445 | 5.8381 | Anderson -Darling (A2) | 8.6004 | 8.8069 |

| No. obs. adj$^2$. | Distributions | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exponential | | | Gamma | | | Pareto | | | Weibull | | | Normal | | |
| | Test | Value | Adjusted value | Test | Value | Adjusted value | Test | Value | Adjusted value | Test | Value | Adjusted value | Test | Value | Adjusted value |
| | OLE6BL4 | | | | | | | | | | | | | | |
| 73 | Cramer-von Mises (W2) | 4.4077 | 4.4267 | Cramer-von Mises (W2) | 0.464396 | 0.466294 | Cramer-von Mises (W2) | 1.4282 | 1.4344 | Cramer-von Mises (W2) | 0.1296 | 0.1338 | Cramer-von Mises (W2) | 1.9897 | 2.0166 |
| | Watson (U2) | 1.3225 | 1.3282 | Watson (U2) | 0.335864 | 0.340439 | Watson (U2) | 1.0384 | 1.0429 | Watson (U2) | 0.1240 | 0.1281 | Watson (U2) | 1.8564 | 1.8815 |
| | Anderson -Darling (A2) | 53.6454 | 54.5153 | Anderson -Darling (A2) | 2.29212 | 2.29212 | Anderson -Darling (A2) | 25.2369 | 25.6462 | Anderson -Darling (A2) | 0.7477 | 0.7723 | Anderson -Darling (A2) | 9.7889 | 10.0034 |
| | OLE6BL5 | | | | | | | | | | | | | | |
| 1653 | Cramer-von Mises (W2) | 79.0993 | 79.1116 | Cramer-von Mises (W2) | 19.4399 | 19.4583 | Cramer-von Mises (W2) | 38.0980 | 38.1039 | Cramer-von Mises (W2) | 9.0833 | 9.1399 | Cramer-von Mises (W2) | 67.5094 | 67.5421 |
| | Watson (U2) | 19.7664 | 19.7695 | Watson (U2) | 15.0695 | 15.0811 | Watson (U2) | 28.0962 | 28.1006 | Watson (U2) | 9.0785 | 9.1350 | Watson (U2) | 66.3922 | 66.4245 |
| | Anderson -Darling (A2) | 442.1479 | 442.4055 | Anderson -Darling (A2) | 96.7295 | 96.7295 | Anderson -Darling (A2) | 180.3329 | 180.4380 | Anderson -Darling (A2) | 48.2576 | 48.5583 | Anderson -Darling (A2) | 327.9054 | 328.1449 |
| | OLE6BL8 | | | | | | | | | | | | | | |
| 53 | Cramer-von Mises (W2) | 2.7457 | 2.7620 | Cramer-von Mises (W2) | 0.4711 | 0.4740 | Cramer-von Mises (W2) | 0.1149 | 0.1156 | Cramer-von Mises (W2) | 0.1793 | 0.1862 | Cramer-von Mises (W2) | 1.4379 | 1.4646 |
| | Watson (U2) | 0.7666 | 0.7711 | Watson (U2) | 0.3292 | 0.3352 | Watson (U2) | 0.0940 | 0.0946 | Watson (U2) | 0.1664 | 0.1728 | Watson (U2) | 1.3611 | 1.3864 |
| | Anderson -Darling (A2) | 47.1585 | 48.2064 | Anderson -Darling (A2) | 2.4705 | 2.4705 | Anderson -Darling (A2) | 26.0072 | 26.5851 | Anderson -Darling (A2) | 1.1607 | 1.2054 | Anderson -Darling (A2) | 7.1504 | 7.3711 |
| | OLE7BL4 | | | | | | | | | | | | | | |
| 88 | Cramer-von Mises (W2) | 6.7060 | 6.7270 | Cramer-von Mises (W2) | 0.6950 | 0.7008 | Cramer-von Mises (W2) | 1.7911 | 1.7967 | Cramer-von Mises (W2) | 0.2368 | 0.2434 | Cramer-von Mises (W2) | 2.7469 | 2.7738 |
| | Watson (U2) | 2.1619 | 2.1687 | Watson (U2) | 0.5221 | 0.5284 | Watson (U2) | 1.3075 | 1.3116 | Watson (U2) | 0.2319 | 0.2384 | Watson (U2) | 2.6168 | 2.6425 |
| | Anderson -Darling (A2) | 106.3318 | 107.5828 | Anderson -Darling (A2) | 3.2127 | 3.2127 | Anderson -Darling (A2) | 62.2233 | 62.9554 | Anderson -Darling (A2) | 1.1805 | 1.2135 | Anderson -Darling (A2) | 13.0983 | 13.3022 |
| 45 | OLE7BL5 | | | | | | | | | | | | | | |
| | Cramer-von Mises (W2) | 1.7075 | 1.7285 | Cramer-von Mises (W2) | 2.6404 | 2.6404 | Cramer-von Mises (W2) | 0.2730 | 0.2764 | Cramer-von Mises (W2) | 0.1497 | 0.1580 | Cramer-von Mises (W2) | 0.7515 | 0.7804 |

| No. obs. adj$^2$. | Distributions | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exponential | | | Gamma | | | Pareto | | | Weibull | | | Normal | | |
| | Test | Value | Adjusted value | Test | Value | Adjusted value | Test | Value | Adjusted value | Test | Value | Adjusted value | Test | Value | Adjusted value |
| | Watson (U2) | 0.5200 | 0.5264 | Watson (U2) | 1.0807 | 1.0807 | Watson (U2) | 0.2021 | 0.2046 | Watson (U2) | 0.1413 | 0.1491 | Watson (U2) | 0.7026 | 0.7296 |
| | Anderson -Darling (A2) | 64.7668 | 67.7561 | Anderson -Darling (A2) | 1276.0100 | 1276.0100 | Anderson -Darling (A2) | 54.1009 | 56.5979 | Anderson -Darling (A2) | 0.8824 | 0.9313 | Anderson -Darling (A2) | 3.7359 | 4.0012 |
| 10 | OLEcBLc = OLE1BL8 + OLE3BL6 + OLE6BL2 + OLE6BL3 + OLE6BL6 + OLE6BL7 + OLE7BL7 | | | | | | | | | | | | | | |
| | Cramer-von Mises (W2) | 2.4100 | 2.4486 | Cramer-von Mises (W2) | 0.4398 | 0.4463 | Cramer-von Mises (W2) | 0.0982 | 0.0998 | Cramer-von Mises (W2) | 0.1920 | 0.2042 | Cramer-von Mises (W2) | 0.6589 | 0.6919 |
| | Watson (U2) | 0.8226 | 0.8358 | Watson (U2) | 0.3437 | 0.3614 | Watson (U2) | 0.0827 | 0.0840 | Watson (U2) | 0.1829 | 0.1945 | Watson (U2) | 0.6206 | 0.6516 |
| | Anderson -Darling (A2) | 111.7516 | 118.4566 | Anderson -Darling (A2) | 2.0449 | 2.0449 | Anderson -Darling (A2) | 69.1755 | 73.3260 | Anderson -Darling (A2) | 1.1217 | 1.1926 | Anderson -Darling (A2) | 3.2034 | 3.5157 |
| 15 | OLEcBLc_ext = OLE1BL8 + OLE3BL6 + OLE6BL2 + OLE6BL3 + OLE6BL6 + OLE6BL7 + OLE7BL7 + OLE2BL7 | | | | | | | | | | | | | | |
| | Cramer-von Mises (W2) | 3.6681 | 3.7100 | Cramer-von Mises (W2) | 0.569723 | 0.583085 | Cramer-von Mises (W2) | 0.3782 | 0.3825 | Cramer-von Mises (W2) | 0.1817 | 0.1914 | Cramer-von Mises (W2) | 0.9960 | 1.0316 |
| | Watson (U2) | 1.1364 | 1.1493 | Watson (U2) | 0.431868 | 0.449534 | Watson (U2) | 0.2833 | 0.2865 | Watson (U2) | 0.1758 | 0.1852 | Watson (U2) | 0.9420 | 0.9756 |
| | Anderson -Darling (A2) | 105.5861 | 110.1112 | Anderson -Darling (A2) | 2.652108 | 2.652108 | Anderson -Darling (A2) | 50.8101 | 52.9877 | Anderson -Darling (A2) | 1.1099 | 1.1692 | Anderson -Darling (A2) | 4.7944 | 5.1063 |

Table 6

## The estimated parameters of the theoretical distributions[3]

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| OLE2BL4 | | | | | | | | | |
| Exponential | | Gamma | | Pareto | | Weibull | | Normal | |
| Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value |
| μ | 0.0100 | m | 0.0000 | k | 0.0100 | m | 0.0000 | μ | 53.1922 |
| 1/λ | 53.1822 | θ | 175.4265 | a | 0.1585 | s | 17.4459 | Σ | 250.5588 |
| | | k | 0.3032 | | | a | 0.4632 | | |
| OLE2BL5 | | | | | | | | | |
| Exponential | | Gamma | | Pareto | | Weibull | | Normal | |
| Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value |
| μ | 0.5400 | m | 0.0000 | k | 0.5400 | m | 0.0000 | μ | 42.4750 |
| 1/λ | 41.9350 | θ | 77.3741 | a | 0.3101 | s | 29.0604 | σ | 88.3809 |
| | | k | 0.5490 | | | a | 0.6579 | | |
| OLE2BL7 | | | | | | | | | |
| Exponential | | Gamma | | Pareto | | Weibull | | Normal | |
| Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value |
| μ | 0.0600 | m | 0.0000 | k | 129.2109 | m | 0.0000 | μ | 147.4225 |
| 1/λ | 147.3625 | θ | 423.6329 | a | 0.1296 | s | 202.9819 | σ | 176.0747 |
| | | k | 0.3480 | | | a | 0.4587 | | |
| OLE2BL8 | | | | | | | | | |
| Exponential | | Gamma | | Pareto | | Weibull | | Normal | |
| Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value |
| μ | 25.0000 | m | 0.0000 | k | 25.0000 | m | 0.0000 | μ | 1,230.7610 |
| 1/λ | 1,205.7610 | θ | 3,054.9640 | a | 0.4415 | s | 535.2750 | σ | 3,847.2950 |
| | | k | 0.4029 | | | a | 0.5515 | | |
| OLE3BL4 | | | | | | | | | |
| Exponential | | Gamma | | Pareto | | Weibull | | Normal | |
| Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value |
| μ | 0.0300 | m | 0.0000 | k | 0.0300 | m | 0.0000 | μ | 1,890.9520 |
| 1/λ | 1,890.9220 | θ | 11,357.1800 | a | 0.1537 | s | 122.0973 | σ | 6,081.8970 |
| | | k | 0.1665 | | | a | 0.2864 | | |

[3] Shaded cells indicate the closest theoretical distribution to their empirical counterpart, using the tests presented in the previous table; these distributions are the ones used in the Monte-Carlo simulations.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| OLE3BL5 | | | | | | | | | |
| Exponential | | Gamma | | Pareto | | Weibull | | Normal | |
| Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value |
| μ | 0.8000 | m | 0.0000 | k | 0.8000 | m | 0.0000 | μ | 1,941.6250 |
| 1/λ | 1,940.8250 | θ | 9,979.8050 | a | 0.2503 | s | 195.8870 | σ | 5,239.9060 |
| | | k | 0.1946 | | | a | 0.3230 | | |
| OLE3BL8 | | | | | | | | | |
| Exponential | | Gamma | | Pareto | | Weibull | | Normal | |
| Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value |
| μ | 6.3200 | m | 0.0000 | k | 6.3200 | m | 0.0000 | μ | 2,662.2650 |
| 1/λ | 2,655.9450 | θ | 10,383.8400 | a | 0.3045 | s | 534.4489 | σ | 10,467.7000 |
| | | k | 0.2564 | | | a | 0.4151 | | |
| OLE5BL5 | | | | | | | | | |
| Exponential | | Gamma | | Pareto | | Weibull | | Normal | |
| Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value |
| μ | 23.3600 | m | 0.0000 | k | 23.3600 | m | 0.0000 | μ | 234.1906 |
| 1/λ | 210.8306 | θ | 487.0678 | a | 1.0246 | s | 134.9604 | σ | 461.0428 |
| | | k | 0.4808 | | | a | 0.5999 | | |
| OLE6BL4 | | | | | | | | | |
| Exponential | | Gamma | | Pareto | | Weibull | | Normal | |
| Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value |
| μ | 0.0400 | m | 0.0000 | k | 0.0400 | m | 0.0000 | μ | 1,079.9170 |
| 1/λ | 1,079.8770 | θ | 4,326.8350 | a | 0.1359 | s | 240.3130 | σ | 3,104.9940 |
| | | k | 0.2496 | | | a | 0.3919 | | |
| OLE6BL5 | | | | | | | | | |
| Exponential | | Gamma | | Pareto | | Weibull | | Normal | |
| Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value |
| μ | 0.2300 | m | 0.0000 | k | 0.2300 | m | 0.0000 | μ | 79.9820 |
| 1/λ | 79.7520 | θ | 206.8927 | a | 0.2416 | s | 33.0978 | σ | 436.6948 |
| | | k | 0.3866 | | | a | 0.5579 | | |
| OLE6BL8 | | | | | | | | | |
| Exponential | | Gamma | | Pareto | | Weibull | | Normal | |
| Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value |
| μ | 25.6300 | m | 0.0000 | k | 25.6300 | m | 0.0000 | μ | 2,191.8410 |
| 1/λ | 2,166.2110 | θ | 6,716.0250 | a | 0.4229 | s | 731.5248 | σ | 7,113.4220 |
| | | k | 0.3264 | | | a | 0.4813 | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| OLE7BL4 | | | | | | | | | |
| Exponential | | Gamma | | Pareto | | Weibull | | Normal | |
| Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value |
| μ | 0.0100 | m | 0.0000 | k | 0.0100 | m | 0.0000 | μ | 269.8339 |
| 1/λ | 269.8239 | θ | 1,142.0920 | a | 0.1395 | s | 52.9255 | σ | 881.2515 |
| | | k | 0.2363 | | | a | 0.3785 | | |
| OLE7BL5 | | | | | | | | | |
| Exponential | | Gamma | | Pareto | | Weibull | | Normal | |
| Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value |
| μ | 3.9400 | m | 0.0000 | k | 3.9400 | m | 0.0000 | μ | 1,056.8490 |
| 1/λ | 1,052.9090 | θ | 11.4622 | a | 0.3040 | s | 296.2077 | σ | 3,120.5030 |
| | | k | 90.2124 | | | a | 0.4534 | | |
| OLEcBLc | = OLE1BL8 + OLE3BL6 + OLE6BL2 + OLE6BL3 + OLE6BL6 + OLE6BL7 + OLE7BL7 | | | | | | | | |
| Exponential | | Gamma | | Pareto | | Weibull | | Normal | |
| Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value |
| μ | 0.7100 | m | 0.0000 | k | 0.7100 | m | 0.0000 | μ | 33,936.6000 |
| 1/λ | 33,935.8900 | θ | 279,121.5000 | a | 0.2345 | s | 340.4830 | σ | 107,124.9000 |
| | | k | 0.1216 | | | a | 0.2337 | | |
| OLEcBLc_ext | = OLE1BL8 + OLE3BL6 + OLE6BL2 + OLE6BL3 + OLE6BL6 + OLE6BL7 + OLE7BL7 + OLE2BL7 | | | | | | | | |
| Exponential | | Gamma | | Pareto | | Weibull | | Normal | |
| Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value | Parameter | Value |
| μ | 0.0600 | m | 0.0000 | k | 0.0600 | m | 0.0000 | μ | 24,195.1600 |
| 1/λ | 24,282.4900 | θ | 197,330.0000 | a | 0.1541 | s | 247.1639 | σ | 17,754.3900 |
| | | k | 0.1231 | | | a | 0.2464 | | |

**Table 7**

## Total capital at risk and capital at risk per business line and/or event type[4]

*(euro)*

| | | | Business lines | | | | | | | | Event type total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Corporate finance [BL1] | Agency services [BL2] | Asset manage-ment [BL3] | Commercial banking [BL4] | Payment& settlement [BL5] | Private banking [BL6] | Retail banking [BL7] | Trading and sales [BL8] | |
| Event type | Business disruption | value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| | [OLE1] | est. val. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3,288,641.9 | 3,288,641.9 |
| | Clients. products and business malpractice | value | 0 | 0 | 0 | 54,931.5 | 11,004.0 | 0 | 0 | 845,754.4 | 911,689.9 |
| | [OLE2] | est. val. | 0 | 0 | 0 | 54,931.5 | 11,004.0 | 0 | 5,723.7 | 845,754.4 | 917,413.7 |
| | Control failure | value | 0 | 0 | 0 | 726,838.8 | 450,271.6 | 0 | 0 | 603,325.0 | 1,780,435.5 |
| | [OLE3] | est. val. | 0 | 0 | 0 | 726,838.8 | 450,271.6 | 533.8 | 0 | 603,325.0 | 1,780,969.4 |
| | Inadequate hiring practice and safety procedure failure | value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| | [OLE4] | est. val. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| | External crime & fraud | value | 0 | 0 | 0 | 0 | 44,621.6 | 0 | 0 | 0 | 44,621.6 |
| | [OLE5] | est. val. | 0 | 0 | 0 | 0 | 44,621.6 | 0 | 0 | 0 | 44,621.6 |
| | Processing failure | value | | 0 | 0 | 829,967.0 | 583,168.8 | 0 | 0 | 716,231.0 | 2,129,366.8 |
| | [OLE6] | est. val. | | 3,709.7 | 155.3 | 829,967.0 | 583,168.8 | 728.0 | 67.0 | 716,231.0 | 2,134,026.7 |
| | System failure | value | 0 | 0 | 0 | 263,149.1 | 325,162.3 | | 0 | 0 | 588,311.4 |
| | [OLE7] | est. val. | 0 | 0 | 0 | 263,149.1 | 325,162.3 | | 112.6 | 0 | 588,424.0 |

[4] The shaded cells indicate the operational risk events that were not modeled individually (due to an insufficient number of observations) but as a composite group. For this reason the cells corresponding to the value of this categories are equal to zero; the capital at risk for the composite group (EUR 3,299,672) has been distributed among members according to their share in the total composite loss and this is the estimated value reported.

| | | Business lines | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Corporate finance [BL1] | Agency services [BL2] | Asset manage-ment [BL3] | Commercial banking [BL4] | Payment& settlement [BL5] | Private banking [BL6] | Retail banking [BL7] | Trading and sales [BL8] | Event type total |
| Unauthorized activity | value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| [OLE8] | est. val. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| Internal fraud | value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| [OLE9] | est. val. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| IT system failure | value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| [OLE10] | est. val. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| Business line total | value | 0.0 | 0.0 | 0.0 | 1,874,886.4 | 1,414,228.5 | 0.0 | 0.0 | 2,165,310.4 | 5,454,425.3 |
| | est. val. | 0.0 | 3,709.7 | 155.3 | 1,874,886.4 | 1,414,228.5 | 1,261.8 | 5,903.3 | 5,453,952.3 | 8,754,097.3 |

**Table 8**

## Total capital at risk and capital at risk per business line and/or event type[5]

*(RON)*

| | | | Business lines | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Corporate finance [BL1] | Agency services [BL2] | Asset manage-ment [BL3] | Commercial banking [BL4] | Payment& settlement [BL5] | Private banking [BL6] | Retail banking [BL7] | Trading and sales [BL8] | Event type total |
| Event type | Business disruption [OLE1] | value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | est. val. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13,943,841 | 13,943,841 |
| | Clients, products and business malpractice [OLE2] | value | 0 | 0 | 0 | 232,910 | 46,657 | 0 | 0 | 3,585,999 | 3,865,565 |
| | | est. val. | 0 | 0 | 0 | 232,910 | 46,657 | 0 | 24,269 | 3,585,999 | 3,889,834 |
| | Control failure [OLE3] | value | 0 | 0 | 0 | 3,081,797 | 1,909,152 | 0 | 0 | 2,558,098 | 7,549,047 |
| | | est. val. | 0 | 0 | 0 | 3,081,797 | 1,909,152 | 2,263 | 0 | 2,558,098 | 7,551,310 |
| | Inadequate hiring practice and safety procedure failure [OLE4] | value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | est. val. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | External crime & fraud [OLE5] | value | 0 | 0 | 0 | 0 | 189,196 | 0 | 0 | 0 | 189,196 |
| | | est. val. | 0 | 0 | 0 | 0 | 189,196 | 0 | 0 | 0 | 189,196 |
| | Processing failure [OLE6] | value | 0 | 0 | 0 | 3,519,060 | 2,472,636 | 0 | 0 | 3,036,819 | 9,028,515 |
| | | est. val. | 0 | 15,729 | 658 | 3,519,060 | 2,472,636 | 3,087 | 284 | 3,036,819 | 9,048,273 |
| | System failure [OLE7] | value | 0 | 0 | 0 | 1,115,752 | 1,378,688 | 0 | 0 | 0 | 2,494,440 |
| | | est. val. | 0 | 0 | 0 | 1,115,752 | 1,378,688 | 0 | 477 | 0 | 2,494,918 |
| | Unauthorized activity [OLE8] | value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | est. val. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Internal fraud [OLE9] | value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | est. val. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | IT system failure [OLE10] | value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | est. val. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Business line total | | value | 0 | 0 | 0 | 7,949,518 | 5,996,329 | 0 | 0 | 9,180,916 | 23,126,763 |
| | | est. val. | 0 | 15,729 | 658 | 7,949,518 | 5,996,329 | 5,350 | 25,030 | 23,124,758 | 37,117,373 |

[5] *The shaded cells indicate the operational risk events that were not modeled individually (due to an insufficient number of observations) but as a composite group. For this reason the cells corresponding to the value of this categories are equal to zero; the capital at risk for the composite group (EUR 3,299,672) has been distributed among members according to their share in the total composite loss and this is the estimated value reported.*