Appendix A

# Derivation of the IMA Formula

## — RPI Calculation —

Sumitomo Mitsui Banking Corporation

# 1. Introduction

The second Consultative Paper of the Basel Committee ("CP2") proposed the Internal Measurement Approach (IMA) and showed its basic structure.

The purpose of this paper is to explicitly formulate the IMA after discussing its characteristics, structure and individual components. It is also intended to propose a method for calibrating the IMA based on such a formulation. The final objective is to derive an explicit formula for the IMA including determination of parameters.

It should be noted that the methodologies and data used in this paper are based on Sumitomo Mitsui Banking Corporation(SMBC)'s practice. We believe, however, that our methods are in a sense universal and can be applied to diverse institutions on a global basis. In other words, it is possible to derive a general formula on the basis of our own approach.

## 1.1. Characteristics of the IMA

We understand that the IMA was introduced by CP2 with the following considerations:

As a method for quantifying required capital based on internal risk, there is a modelling approach which is very powerful in measuring the total risk amount for the bank as a whole.

It is, however, not a very practical tool because it does not explicitly show the contribution that each risk factor makes to the total risk amount.

In this respect, the risk sensitive formula under the IMA is actually of more practical use.

We are going to show you in this paper how to determine the IMA formula that approximates the loss distribution while providing risk sensitivity, comparability, simplicity and risk management incentive.

As it turns out, we at SMBC have been internally developing a formula corresponding to the IMA formula from a similar perspective.

The IMA is to measure the required capital amount for each business line and each event type by using a formula for the indicators of business size and the historical loss data.

The roles of the banks and the regulators under the IMA are described as follows:

- Bank can use its own data on loss and exposure.
- Regulator determines the method for calculating the required capital amount.

In the following sections, we will describe some more details of the IMA formula.

## 1.2. Business line

Before starting the explanation of the IMA formula itself, we would like to discuss the

business lines and event types referred to in this paper.

First of all, the business lines are classified into the four core businesses of SMBC, i.e. commercial banking (retail), commercial banking (wholesale), trading & sales, and processing services subsidiaries. Each business line is further divided into subcategories as shown below.

These represent only a part of those listed in CP2, but actually constitute the major businesses of our bank.

Chart 1.1

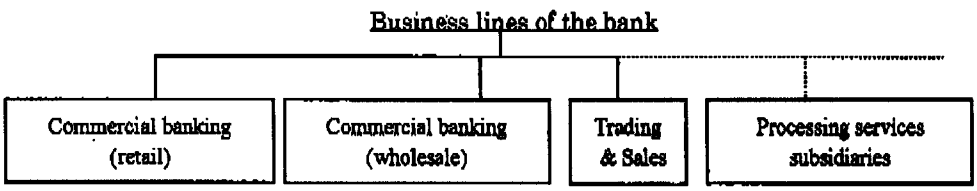



Table 1.1

Table of business lines
Commercial banking (wholesale), market, processing services subsidiaries

| Broad business line | Sub-category |
|---|---|
| Commercial banking (wholesale) | Derivatives |
| | Foreign exchange |
| | Export |
| | Import |
| | Treasury : Settlement |
| | Treasury . Funding /Placement |
| | Forward foreign exchange |
| | Transfer |
| | Loan (repayment) |
| | Loan (disbursement) |
| | Loan (interest) |
| | Deposit |
| | Others |

| Broad business line | Sub-category |
|---|---|
| Market | Foreign exchange |
| | Treasury |
| | Money market |
| | Settlement |

| Broad business line | Sub-category | |
|---|---|---|
| Processing services subsidiaries | Subsidiaries A | Negotiation of export bill |
| | | Collection of bill |
| | | Correspondent deposits |
| | | Outgoing remittance |
| | | Incoming remittance |
| | | Forward contract |
| | Subsidiaries B | Transfer |
| | | payment of cash deposit |
| | Subsidiaries C | Investment trust |

## 1.3. Event Type

As for event type, we assigned two event types to each business line. One is an event related to processing, and the other is an event related to systems. The processing event type includes fraud, theft and unauthorized activity and so on. The systems event type includes infrastructure problem, hardware breakdown, software bug etc.

These are, of course, just a part of all the event types in the industry, but they are the ones that are material to SMBC's operation.

Table 1.2
Event type: the case of Commercial Banking (Retail)

| Broad Business Line | Sub-category | | Event Type: Processing | Event Type: System |
|---|---|---|---|---|
| Commercial banking (retail) | Deposit / money transfer | Payment of cash deposit | | |
| | | Payment for clearing | | |
| | | Receipt of cash deposit | | |
| | | Receipt for clearing (Principal) | | |
| | | Transfer | | |
| | | Payment of "assets building savings" | | |
| | | Time deposit (Interest payment) | | |
| | | Outgoing remittance | | |
| | | Tax and public funds | | |
| | | Automatic transfer | | |
| | | Bonds | | |
| | Credit | Loan guaranteed by CGCs | | |
| | | Agency loan (collection) | | |
| | | Loan with derivatives | | |
| | Loan | Card loan | | |
| | | Agency loan (collection) | | |
| | | Secured loan | | |
| | | Loan by GHLC(collection) | | |
| | Foreign Exchange | Export | | |
| | | Incoming remittance | | |
| | | Collection of bill | | |
| | | Import | | |
| | | Outgoing remittance | | |
| | | Foreign exchange | | |
| | | Forward contract | | |
| | | Foreign currency deposit | | |
| | | Foreign currency loan (collection) | | |
| | Payment services | ATM | | |
| | | Teller | | |

## 2. Structure of the IMA

First of all, we analyze the structure of the IMA.

The fundamental structure of the formula is as follows:

Expected loss
= EI(Exposure indicator)*PE(Probability of loss event)*LGE(Loss given event)

And also;

Required capital for each Business line/Event type
= $\gamma$ * EI * PE * LGE * RPI(Risk profile index)

In other words, required capital has the expected loss as its core factor and is obtained by multiplying EL by $\gamma$ and RPI.

The IMA formula for operational risk can be compared with the formula under the Internal Ratings Based Approach for credit risk as illustrated in the figure shown below.

## 2.1. Comparison with credit risk (i)

| [Credit Risk] | [Operational Risk] |
|---|---|
| Internal Rating Based Approach | Internal Measurement Approach |
| —Exposure at default (EAD) | —Exposure indicator (EI) |
| —Probability of default (PD) | —Probability of event (PE) |
| —Loss given default (LGD) | —Loss given event (LGE) |
| —Granularity index (GI) | —Risk profile index (RPI) |

The IRB formula for credit risk as proposed by CP2 is summarized on the left-hand side, while the components of the IMA for operational risk are shown on the right hand side.

By comparing each component of operational risk IMA with credit risk IRB in this way, we can discuss operational risk by analogy with credit risk.

The following figure would facilitate a more detailed comparison

## 2.2. Comparison with credit risk (ii)

| [Credit Risk] | [Operational Risk] |
|---|---|
| Required capital | Required capital |
| =EAD*PD*LGD*GI | =γ*EI*PE*LGE*RPI |
| =EAD**BRW*(PD)*LGD*GI | =EI*[γ*PE]*LGE*RPI |
| | =EI**f*(PE)*LGE*RPI |
| —*BRW*(PD) | —*f(PE)* |
| A function to convert PD to RW | *A function to convert PE to operational risk ratio* |
| "Risk weight function" | "Operational risk ratio function" |

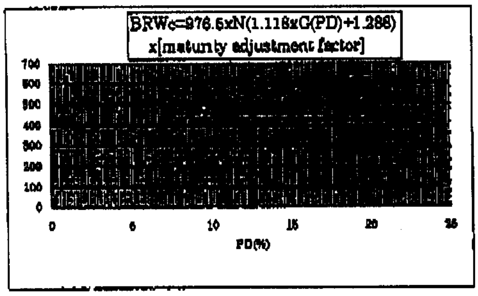
The IRB formula for credit risk is shown on the left-hand side. The characteristic of the IRB formula is that the function for PD is non-linear. This function, whose shape is shown below, is a function to convert PD to risk weight, called the "Risk Weight Function". By applying this idea to operational risk, we can obtain a similar formula as shown on the right hand side of Figure 2.2.

As in the case with credit risk, it is most appropriate for the function for PE to be non-linear. We call this function for PE the "Operational risk ratio function" by analogy with the "Risk weight function". We will elaborate on this later.

**Table 2.1**

| PD(%) | BRWc |
|---|---|
| 0.03 | 14 |
| 0.05 | 19 |
| 0.1 | 29 |
| 0.2 | 45 |
| 0.4 | 70 |
| 0.5 | 81 |
| 0.7 | 100 |
| 1 | 125 |
| 2 | 192 |
| 3 | 246 |
| 5 | 331 |
| 10 | 482 |
| 15 | 588 |
| 20 | 625 |

**Chart 2.1 Benchmark risk weight function**




## 3. Components of the IMA

Required capital = EI*f(PE)*LGE*RPI

### 3.1. Exposure indicator (EI)

We explain in this section each factor in the formula for the required capital.

First of all, Exposure Indicator (EI) represents the size of operational risk exposure. An example would be: the total amount of transactions handled for one year.

The standard EI for each business line and event type will be determined by regulators.

### 3.2. Probability of loss event (PE)

Probability of loss event (PE) measures how frequently a loss event occurs for each business line and event type. The definition would look like:

Loss event rate (per annum) = # of loss events / # of transactions

This rate is measured based on historical data of actual losses held at each financial institution.

### 3.3. Loss given event (LGE)

The Loss Given Event as incorporated into the measurement is described as follows.

LGE is defined as the proportion of the loss finally incurred to the exposure of a loss event which has actually occurred for each Business line and Event type.

Measurement of the Loss Given Event is given by:

Loss given event = Loss amount / Exposure amount for each event.

This is conservatively estimated by each bank based on its own historical data of the distribution of the Loss Given Events. Of course, there could be an alternative approach which would be termed "Foundation Approach". In such a case, LGE would be determined by regulators.

It should be ensured that consistency between the definition of Event and that of reference Event for PE is maintained.

### 3.4. Risk Profile Index (RPI)

Risk Profile Index can be decomposed into the adjustment factor for severity and that for frequency.

The adjustment factor for severity reflects the tail of the distribution of the EI. The adjustment factor for frequency reflects the level of frequency of events. We call these factors RPI1 and RPI2, respectively. These factors reflect the profile of operations at each financial institution and are quite characteristic of operational risk measurement because the RPI is the factor which reflects "low-frequency / high-severity". The RPI is designed so that the RPI becomes greater when the severity becomes higher and the frequency lower.

We will explain the detailed formula later.

Regulators will determine a standardized formula for each business line and event type.

Each bank applies this standardized formula to its own data to measure the RPI.

Of course, the calculation process must be easy for practical use. As described later, we believe that this is feasible.

### 3.5. *f* (a function to convert PE to operational risk ratio)

In this section, the nature of the operational risk ratio function is described. This function is related to the ratio between unexpected loss and expected loss. In other words, by analogy with credit risk, as we explained earlier, this function f non-linearly transforms the PE to unexpected loss. The absolute level of the value of this function is determined by the holding period and the confidence interval.

Regulators will determine this operational risk ratio function for each business line and event type.

In summary, f and RPI transform EL to UL. And the RPI term is the adjustment factor for the difference between banks in frequency and severity. On the other hand, f is determined by the holding period and the confidence interval. Both these factors relate EL vis-a-vis UL.

## 4. Explicit formula

So far, we have described each component of the IMA. Now we are going to propose an explicit formula for each component of the IMA. Eventually, these formulae will be calibrated using actual data.

$$\text{Required capital} = EI * f(PE) * LGE * RPI$$

### 4.1. EI

EI is represented by, for example, the total transaction amount, namely the total number of transaction times the average amount.

- Total transaction amount (annual)

$$= \Sigma_{(\text{All transactions, annual})}[\text{Transaction amount}]$$

$$= \text{Total number of transactions} * \text{Average amount}$$

$$= T\# * \mu$$

### 4.2. f(PE)

In this section, we will explain the operational risk ratio function.

First, we show here three candidates for f(PE).

Example 1 $f(PE) = \lambda PE$

Example 2 $f(PE) = \lambda \sqrt{PE}$

Example 3 $f(PE) = \lambda N(\alpha_0 * G(PE) + \alpha_1)$

- $N(x)$: Cumulative distribution function for a standard normal random variable
- $G(z)$: Inverse cumulative distribution function for a standard normal random variable

Example 1 is a linear function of PE. Examples 2 and 3 are non-linear functions. Of these, Example 3 is an adaptation from the risk weight function in the context of credit risk.

In the case of credit risk, CP2 set the coefficients as follows:

$\alpha_0$=1.118, $\alpha_1$=1.288 under the assumptions of 99.5% confidence interval and asset correlation of 0.20.

### 4.3. LGE

LGE is determined for each business line conservatively based on historical data. For example, they can be set as follows

100% for commercial banking (retail), processing services subsidiaries.

5% for commercial banking (wholesale) and market-related activities.

### 4.4. RPI

As we explained earlier, RPI is decomposed into $RPI_1$ for severity and $RPI_2$ for frequency.

A higher severity gives a higher $RPI_1$ and a lower frequency a higher $RPI_2$, hence a higher total RPI, which means UL is relatively higher for the same EL. In other words, the risk is higher.

On the other hand, when severity is low and the frequency is comparatively high, both $RPI_1$ and $RPI_2$ become smaller and RPI becomes closer to 1.

As a candidate for such a function, we selected

$$RPI=1+RPI_1*RPI_2.$$

We will now discuss $RPI_1$ and $RPI_2$ separately in the following sections.

#### 4.4.1. $RPI_1$(Adjustment factor for severity)

First of all, $RPI_1$ i.e. adjustment factor for severity reflects the shape of the distribution of the EI. Therefore, we considered a function of $\sigma/\mu$.

$$RPI_1=F(\sigma/\mu)$$

We selected $C_1*\sigma/\mu$ as a candidate linear function.

$$F(\sigma/\mu)= C_1\sigma/\mu$$

Here, $C_1$ is a constant, $\mu$ denotes the mean of EI and $\sigma$ the standard deviation of EI. When the tail of the distribution of EI becomes longer, $\sigma/\mu$ becomes larger, hence a higher $RPI_1$.

#### 4.4.2. $RPI_2$(Adjustment factor for frequency)

$RPI_2$ is the adjustment factor for frequency and reflects the level of the number of events. As a function which gives a higher value for a lower frequency, we selected a function which is $n^{C2}$.

$$RPI_2=n^{C2}, \quad \text{n: Number of events}$$

According to our experience, the most appropriate number for $C_2$ is determined based on the shape of the distribution of EI.

When we assume that EI follows a normal distribution, then the best $C_2$ for the IMA formula is -0.5. On the other hand, if we assume that EI follows a lognormal distribution, then the best $C_2$ is -0.3.

We will later verify which $C_2$ is more suitable based on actual data.

4.5. Summary

In summary, we selected the following as a candidate for the explicit formula:

$$\text{Required capital} = EI \times f(PE) \times LGE \times RPI$$

Now RPI can be decomposed into the adjustment factor for severity $RPI_1$ and the adjustment factor for frequency $RPI_2$. Therefore,

$$\text{Required capital} = EI \times f(PE) \times LGE \times (1 + RPI_1 \times RPI_2)$$

Further, $RPI_1$ and $RPI_2$ can be expressed using the distribution of EI and the number of event as we explained earlier. Accordingly,

$$\text{Required capital} = EI \times f(PE) \times LGE \times (1 + C_1 \; n^{C_2} \sigma / \mu)$$

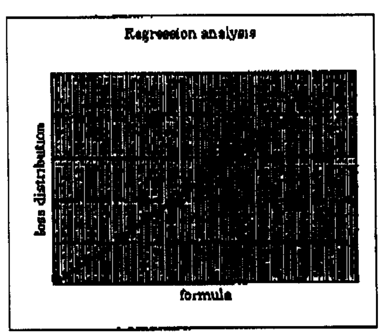
These formulae will be calibrated by using actual data. The rest of this paper is mostly devoted to the explanation of this calibration.

We took an inductive way to determine the IMA formula. In other words, we selected a candidate formula which seemed the most appropriate.

Then, we evaluated by regression analysis how appropriately this formula would fit in with the actual loss distribution.

The plots in the graph shown below represent the required capital measured with this candidate IMA formula on the horizontal axis and the required capital estimated based on actual loss distribution shown on the vertical axis.

Chart 4.1 Regression analysis



If these plots are situated on a straight line, it means that this IMA formula gives a very good approximation of the required capital measured based on real loss distribution.

The slope of this straight line is the coefficient of the formula.

This is how we established the formula.

## 5. Calibration

### 5.1. Generation of loss distribution

We said earlier that the candidate formulae would be calibrated based on the actual loss distribution. However, the actual loss data available to us is too limited to be used for such a calibration. Probably, every bank has the same limitation on its own. Accordingly, we chose the following way:

First, we generated a hypothetical loss distribution with a statistical method. As the second step we calibrated the formula based on this distribution.

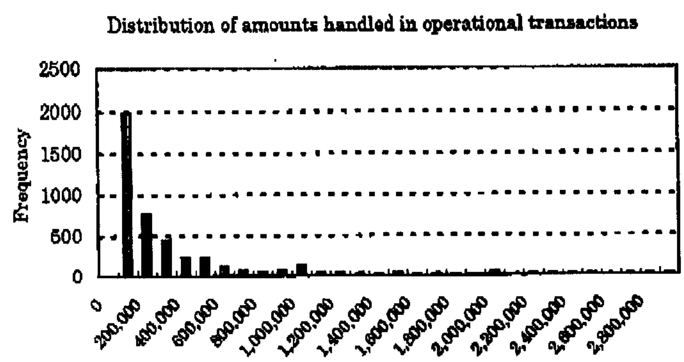
We now briefly describe how to generate a loss distribution with a statistical method.

Loss distributions are generated for each business line and each event type. We assume a 1-year risk horizon and a 99.9% confidence interval.

The factors in the statistical method are PE and EI.

Loss distributions are generated by selecting PE and EI at random. The next graph shows an example of a distribution of amounts actually handled for 1 year in a certain business line.

Chart 5.1 Distribution of EI




As a result, the distribution may take shape as depicted in this figure, for example, which has a fairly long tail.

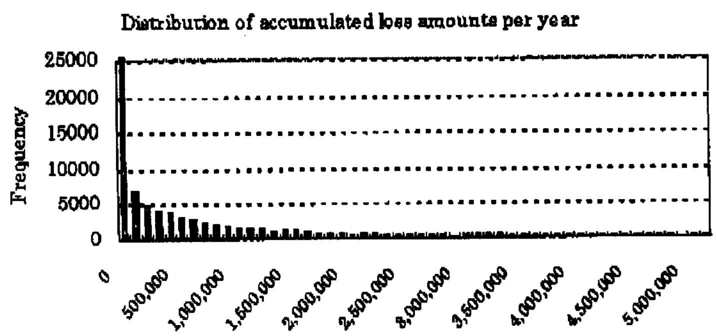
Now we perform a Monte-Carlo simulation with PE and EI as risk factors. The process is as follows:

We pick up at random from the EI distribution mentioned earlier as many exposures as the number of the events generated based on the PE. The total amount of the exposures picked up this way is the accumulated loss amount.

A loss distribution is generated by iterating this process 100,000 times.

The next graph is an example of a loss distribution for a certain business line.

Chart 5.2 Loss distribution




This is how to generate a hypothetical loss distribution.

As you can see in the above graph, the distribution of operational risk has a very long tail. This implies that the hypothetical distribution complements the insufficient part of the distribution based on actual loss.

## 5.2. Candidate formula

Now, after finishing such a preparation, we start to calibrate the candidate formula.

From now on, we assume that the operational risk ratio function is;

$$f(PE)=\lambda N(1.118*G(PE)+1.545).$$

This is an adaptation from the risk weight function in the credit risk IRB approach with 99.9% confidence interval. And we also assume that the coefficients for RPI,

$$C_1=10 \text{ and } C_2=-0.5.$$

This formula is just a candidate, but as we will verify later, it is highly suitable.

The coefficient $\lambda$ for the operational risk ratio function is yet to be determined. This will be derived as the slope of the line by performing a regression analysis on the loss

distribution.

### 5.3. Calibration

The following table shows the value for each component obtained by using the candidate formula based on the assumptions mentioned earlier. This is the case for processing risk in the retail commercial banking, and a similar calculation can be performed for the other business lines and event types.

Table 5.1 Calibration: Commercial banking (retail), Processing risk

| Sub-category | | NO | Example of IMA formula | | | | | | | Loss Distribution Approach |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | EI | f(PE) | LGE | RPI1/C1 | RPI2 c=-0.5 | RPI | Required Capital/ λ | VaR calculated with a model |
| Deposit / money transfer | Payment of cash deposit | 1 | 219,664 | 0.005% | 100% | 16 | 0.4 | 61 | 631 | 13 |
| | Payment for clearing | 2 | 3,068,174 | 0.001% | 100% | 6 | 1.2 | 71 | 1,496 | 25 |
| | Receipt of cash deposit | 3 | 774,050 | 0.001% | 100% | 9 | 1.2 | 109 | 577 | 5 |
| | Receipt for clearing (Principal) | 4 | 774,050 | 0.000% | 100% | 9 | 1.7 | 154 | 407 | 4 |
| | Transfer | 5 | 561,667 | 0.001% | 100% | 12 | 1.7 | 216 | 1,470 | 9 |
| | Payment of "assets building saving | 6 | 2 | 0.047% | 100% | 5 | 1.0 | 54 | 0 | 0 |
| | Time deposit (Interest payment) | 7 | 106,766 | 0.016% | 100% | 8 | 1.2 | 82 | 509 | 8 |
| | Outgoing remittance | 8 | 2,096,506 | 0.008% | 100% | 16 | 0.4 | 72 | 11,219 | 200 |
| | Tax and public funds | 9 | 1,704 | 0.005% | 100% | 2 | 0.4 | 11 | 1 | 0 |
| | Automatic transfer | 10 | 890 | 0.011% | 100% | 2 | 0.6 | 18 | 1 | 0 |
| | Bonds | 11 | 669 | 0.079% | 100% | 1 | 1.7 | 15 | 8 | 0 |
| Credit | Loan guaranteed by CGCs* | 12 | 122,506 | 0.008% | 100% | 1 | 1.2 | 14 | 129 | 2 |
| | Agency loan (collection) | 13 | 5 | 1.796% | 100% | 0 | 0.7 | 8 | 0 | 0 |
| | Loan with derivatives | 14 | 10,255 | 1.014% | 100% | 4 | 1.7 | 67 | 6,920 | 92 |
| Loan | Card loan | 15 | 142 | 0.171% | 100% | 5 | 1.2 | 64 | 16 | 0 |
| | Agency loan (collection) | 16 | 1 | 2.574% | 100% | 0 | 1.2 | 4 | 0 | 0 |
| | Secured loan | 17 | 14,581 | 0.028% | 100% | 1 | 1.7 | 22 | 87 | 2 |
| | Loan by GHLC**(collection) | 18 | 66 | 0.044% | 100% | 0 | 1.7 | 6 | 0 | 0 |
| Foreign Exchange | Export | 19 | 53,408 | 0.057% | 100% | 4 | 1.0 | 36 | 1,105 | 13 |
| | Incoming remittance | 20 | 280,409 | 0.044% | 100% | 4 | 0.7 | 24 | 2,965 | 41 |
| | Collection of bill | 21 | 2,970 | 0.122% | 100% | 4 | 1.0 | 43 | 156 | 3 |
| | Import | 22 | 16,464 | 0.066% | 100% | 4 | 1.7 | 62 | 630 | 11 |
| | Outgoing remittance | 23 | 277,216 | 0.066% | 100% | 5 | 0.5 | 26 | 3,960 | 77 |
| | Foreign exchange | 24 | 544 | 0.015% | 100% | 2 | 1.2 | 31 | 2 | 0 |
| | Forward contract | 25 | 85,769 | 0.079% | 100% | 3 | 0.9 | 29 | 1,958 | 40 |
| | Foreign currency deposit | 26 | 58,886 | 0.044% | 100% | 26 | 1.0 | 257 | 6,065 | 13 |
| | Foreign currency loan (collection) | 27 | 18,626 | 0.250% | 100% | 2 | 1.2 | 25 | 1,094 | 15 |
| Payment services | ATM | 28 | 53,963 | 0.000% | 100% | 2 | 1.7 | 35 | 1 | 0 |
| | Teller | 29 | - | 0.021% | 100% | 3 | 0.1 | 4 | - | 0 |

Starting from the left under the "Example of IMA formula", EI represents total transaction amount for 1 year.

This is the operational risk ratio function without λ. The value of this f(PE) is from 10 to 100 times the original PE. The next column shows the LGE. For retail commercial banking, this is set uniformly at 100% as mentioned earlier. The next item is $RPI_1$ without coefficient $C_1$, i.e. $\sigma / \mu$. This ranges widely from 0 to 30. The next column $RPI_2$ ranges between just 0 and 2. The RPI shown in the next column, which is $1+RPI_1*RPI_2$ incorporating $C_1$, ranges very widely from 3 to 257.

By multiplying these factors we obtain the formula before considering λ which is shown on the second column from the right. The far right column shows the unexpected loss calculated with a statistical method with a 99.9% confidence interval and a 1-year risk horizon.

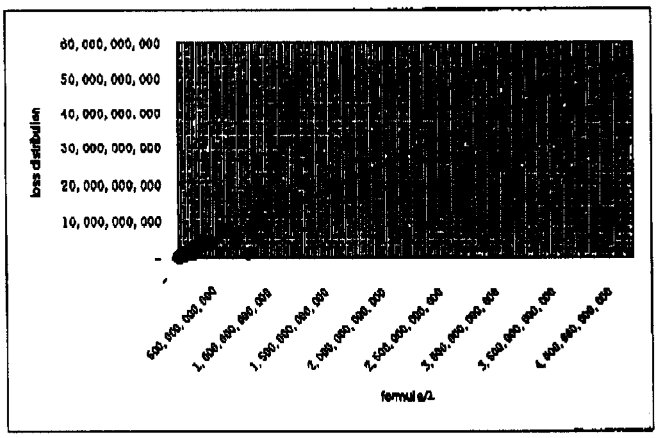
The result of the verification of how this far-right column fits in with the second from the right using regression analysis will be shown in the following paragraph.

Before starting the discussion, however, we would like to say that the analysis we have described so far has been carried out within SMBC. If we apply the same method to the industry as a whole, the sub-category column on the far-left side will be replaced with a list of banks. The next step would be to carry out an analysis to find out whether there is a meaningful proportional relationship between the loss distribution and the value of the formula. If we find such a relationship, then we can establish an LMA formula which can be applied industry-wide.

Now, we come back to SMBC's case.

The following graph shows the result of the regression analysis for processing risk in the bank as a whole.

Chart 5.3 Regression analysis: The bank as a whole, Processing risk



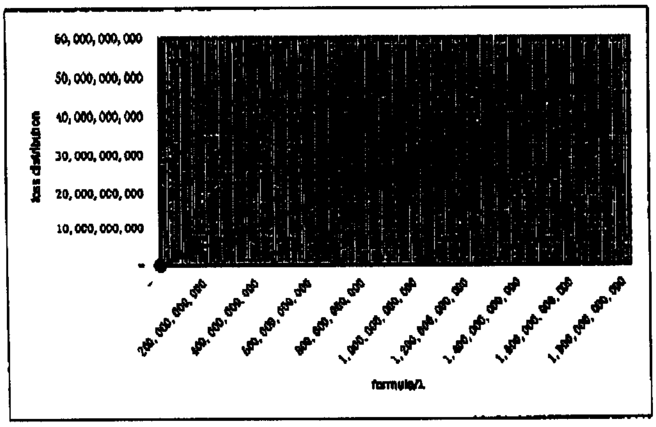

The horizontal axis represents the value of the formula without considering λ, the vertical axis the unexpected loss under the Loss Distribution Approach. Each plot represents the resulting value for each sub-category in each business line.

The slope of the line i.e. λ is 0.014. In this case, R2 is 0.97, which means this formula gives a very good approximation.

Consequently, when the event type is processing risk, then UL can be calculated with the same formula regardless of business line.

The next one is the case for systems risk.

Chart 5.4 Regression analysis: The bank as a whole, Systems risk




The $R^2$ for this case is 0.93, which means that this formula also gives a good approximation.

For systems risk, the same formula can be used regardless of business line.

## 5.4. IMA formula

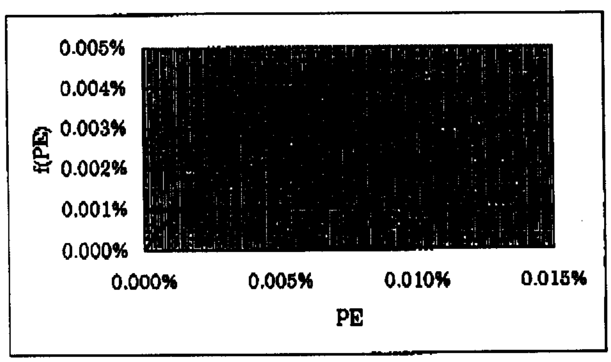
### 5.4.1. Processing risk

$$\text{Required capital} = EI \times f_p(PE) \times LGE \times (1+10\, n^{-0.5}\, \sigma/\mu)$$
$$\text{where} \quad f_p(PE) = 0.014 \times N(1.118 * G(PE)+1.545)$$

In summary, this formula for processing risk can be applied to all business lines. The non-linear operational risk ratio function for PE has a shape as shown in the following graph.

Chart 5.5 Operational risk ratio function: Processing risk

| PE | f(PE) |
|---|---|
| 0.000% | 0.000% |
| 0.001% | 0.000% |
| 0.002% | 0.001% |
| 0.003% | 0.002% |
| 0.004% | 0.002% |
| 0.005% | 0.003% |
| 0.006% | 0.003% |
| 0.007% | 0.003% |
| 0.008% | 0.004% |
| 0.009% | 0.004% |
| 0.010% | 0.004% |
| 0.011% | 0.004% |
| 0.012% | 0.005% |



This formula for operational risk is quite similar to that for the credit risk IRB approach. Furthermore, the RPI which measures the "low-frequency and high-severity" characteristic of operational risk is incorporated through n and sigma.

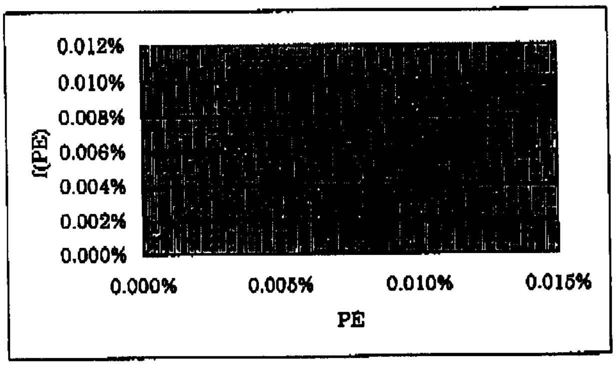
### 5.4.2. Systems risk

Similarly, this is the formula for systems risk.

$$\text{Required capital} = \text{EI} \times f_s(\text{PE}) \times \text{LGE} \times (1+10\, n^{-0.5}\ \sigma / \mu)$$
$$\text{where} \quad f_s(\text{PE}) = 0.029 \times N(1.118 * G(\text{PE})+1.545)$$

Chart 5.6 Operational risk ratio function: Systems risk

| PE | f(PE) |
|---|---|
| 0.000% | 0.000% |
| 0.001% | 0.001% |
| 0.002% | 0.003% |
| 0.003% | 0.004% |
| 0.004% | 0.005% |
| 0.005% | 0.005% |
| 0.006% | 0.006% |
| 0.007% | 0.007% |
| 0.008% | 0.007% |
| 0.009% | 0.008% |
| 0.010% | 0.009% |
| 0.011% | 0.009% |
| 0.012% | 0.010% |




This is also applicable to all the business lines. If you look at this formula, the only difference from the processing risk is the coefficient λ. In other words, the structure of the formula is exactly the same and the difference in event type is represented by the coefficient λ.

In the case of systems risk, λ is 0.029 which is higher than 0.014 for processing risk.

We think that this is due to the fact that systems risk is characterized by the chain-reaction manner of events.

### 5.5. Reference

So far, we have established a formula common to all business lines.

Charts 5.7 – 5.10 graphically show a calibration of the formula for each business line in the case of processing risk.

The resulting λ's are at a similar level but are not completely identical for different business lines. Therefore, a formula can be established for each business line if this difference is meaningful.

Chart 5.7 Commercial banking (retail)
Processing risk $R^2$=0.84, λ=0.014

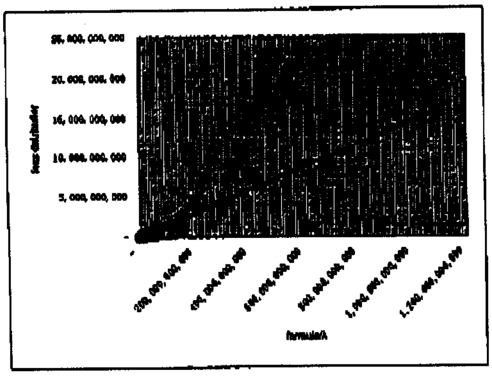


Chart 5.8 Commercial banking (wholesale)
Processing risk $R^2$=0.90, λ=0.01

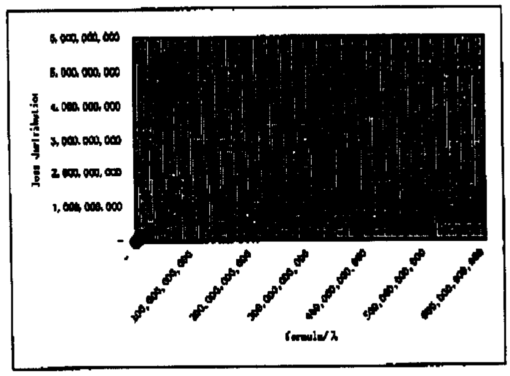


Chart 5.9 Market
Processing risk $R^2$=0.82, λ=0.014

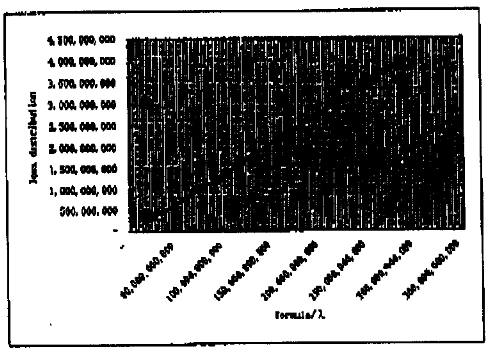
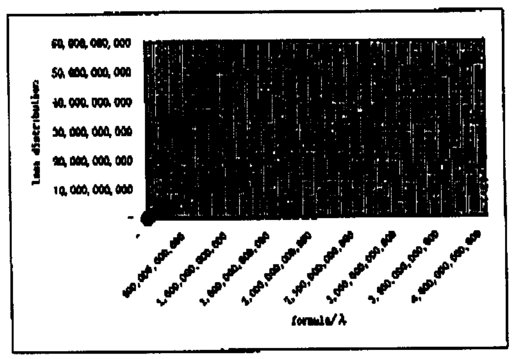


Chart 5.10 Processing services subsidiaries
Processing risk $R^2$=1.0, λ=0.014



## 6. Work yet to be done for global application

So far, we have shown the examples of analysis for SMBC only. If such an analysis is to be carried out on a global basis, we think that the following four steps should be taken.

The first step is;

Collection of the historical loss data on a global basis.

This is data collection from each bank by business line and event type.

The second step is;

Generation of the hypothetical loss distribution to complement the historical loss distribution (statistical method) on a global basis.

This process can be carried out by regulators.

The third step is;

Estimation of coefficients on a global basis.

This is what this paper is all about.

The final step is;

Calibration of the absolute level for regulatory capital purposes.

The IMA formula presented in this paper gives a relative level based on a certain confidence interval and risk horizon. In other words, this is a so-called bottom-up calibration.

For regulatory capital purposes, it is necessary to compare the result with other types of risks and the Basic Indicator Approach, and make necessary adjustments to obtain the absolute level of required capital.

Accordingly, the collection of the historical data, i.e. the first step, should be started urgently. In this regard, we hope that the definition of loss data will be indicated to the entire industry as soon as possible.

## 7. Summary of the IMA

Finally, we would like to point out the three merits of the Internal Measurement Approach.

First of all, this is "risk sensitive" and provides a powerful measure of sensitivity to each risk indicator.

Secondly, comparability with other types of risk and simplicity of calculation are important characteristics.

Thirdly, this approach gives sufficient incentive for risk management because it can explicitly show which area has what level of risk.

Accordingly, we support the IMA not only in light of internal risk management, but also for regulatory capital purposes.

The numbers used in this paper are for illustration purposes only and do not neccssarily reflect the reality.