Measuring Operational Risk Exposures in Islamic Banking: A Proposed Measurement Approach

HYLMUN IZHAR*

Abstract

The aim of the paper is to propose a model, namely Delta-Gamma Sensitivity Analysis-Extreme Value Theory (DGSA-EVT). DGSA-EVT is a model to measure HF-LS and LF-HS type of operational risks. The first leg of the proposed model, namely DGSA, is a methodology that deals with propagation of errors in the value adding activities which works by using measures of fluctuations in the activities.

The sensitivities of the output, hence, are deployed to estimate the performance volatility. Furthermore, the second leg of the proposed model, Extreme Value Theory (EVT), is a technique to cater for an excess operational loss over a defined threshold which is normally characterised by low frequency and high severity (LF-HS) type of loss.

1. Introduction

The complexity of operational risk measurement has been exacerbated by two major dimensions of operational risk data, namely high frequency-low severity (HF-LS) and low frequency-high severity (LF-HS)\(^1\), and the integration of scaling external and internal data\(^2\). Consequently, each type requires a different approach

---

* The author would like to extend his gratitude to IRTI scholars and the participants of IRTI Research Seminar for their helpful suggestions and stimulating discussion. He is also grateful to three anonymous referees whose insightful comments have enabled him to improve the paper. Any shortcoming therein, however, solely rests upon the author. He can be reached at hizhar@isdb.org.

\(^1\) See Moosa, 2007

\(^2\) See Chernobai, Anna S., Rachev, Svetlozar T., and Fabozzi, Frank J., 2007
to cater for operational risk. The current literature on operational risk almost exclusively focuses on two issues: firstly, the estimation of operational risk loss processes using extreme value theory or Cox processes\(^3\), and secondly, the application of these estimates to the determination of economic capital\(^4\). In the estimation of economic capital for operational risk, the estimates appear to be quite large, in fact, at least as large as that necessary to cover market risk\(^5\). As evidenced by the references mentioned earlier that the modelling and estimation of operational risk is treated identically to market and credit risk, i.e., a loss process is modelled and estimated. However, this is where the similarity comes to an end. Unlike market and credit risk, which are external to the bank in their origin, operational risk is internal to the bank.

An intensive use of Value at Risk (VaR) has also taken place in the measurement of risk exposure in financial institutions. For a long time, economists have considered empirical behaviour models of banks where these institutions maximise some utility criteria under a solvency constraint of VaR type\(^6\). Similarly, other researchers have studied optimal portfolio selection under limited downside risk as an alternative to traditional mean-variance efficient frontiers\(^7\). Moreover, internal use of VaR by financial institutions has also been addressed in a delegated risk management framework in order to mitigate agency problems\(^8\).

Despite a growing interest in VaR related to credit risk and market risk; there is, unfortunately, a very limited research in the area of operational risk. Nevertheless, there has not been any research dealing with the theoretical properties of risk measures and their consequences on operational risk measurement in Islamic banking. Islamic Financial Services Board (IFSB) as one of regulatory bodies in Islamic banking industry in its draft No. 2 on Capital Adequacy Standard\(^9\) mentions the definition of operational risk and proposes Basic Indicator Approach

---

\(^3\) See Chavez-Demoulin et al., 2006; Coleman, 2003; de Fontnouvelle et al., 2004; de Fontnouvelle et al., 2005; Ebnother et al., 2001; Jang, 2004; Moscadelli, 2004; Lindskog and MecNeil, 2003; K. Dutta, J. Perry, 2007.

\(^4\) See de Fontnouvelle et al., 2004; de Fontnouvelle et al., 2005, Moscadelli, 2004, and Basel Committee on Banking Supervision, 2009.

\(^5\) See Chernobai, Anna S., Rachev, Svetlozar T., and Fabozzi, Frank J., 2007

\(^6\) This issue is discussed in Gollier et al., 1996; Santomero and Babbel, 1996.

\(^7\) As exemplified in Roy, 1952; Levy and Sarnat, 1972; Arzac and Bawa, 1977.

\(^8\) See Kimball, 1997; Froot and Stein, 1998; Stoughton and Zechner, 1999

(BIA) and the Standardised Approach (TSA) as methods to calculate operational risk capital. The proposed methods are basically meant for the calculation of capital which needs to be kept aside in order to cater for operational risks. There is, however, an essential step which is overlooked, namely a method to measure the magnitude of operational risk exposures. The paper, hence, provides a proposed measurement approach to fill this gap.

The proposed model, namely Delta-Gamma Sensitivity Analysis-Extreme Value Theory (DGSA-EVT), is a model to measure HF-LS and LF-HS type of operational risks. The first leg of the proposed model, namely DGSA, is a methodology that deals with propagation of errors in the value adding activities which works by using measures of fluctuations in the activities. The sensitivities of the output, hence, are deployed to estimate the performance volatility. Through operating loss distribution that is the result of the entire quantification process, DGSA would help in generating the level of operational value at risk (OpVaR) of the analysed Islamic banks. Furthermore, the second leg of the proposed model, Extreme Value Theory (EVT), is a technique to cater for an excess operational loss over a defined threshold which is normally characterised by low frequency and high severity (LF-HS) type of loss.

The second section of the paper reviews in some more detail the existing models in operational risk measurement and its classifications. The third section explains the theoretical background of the proposed model and its features. In the fourth section, attention is focused on the empirical aspect of the proposed model. The paper concludes with a fifth section, which includes practical suggestions and some direction for future research.

2. Review of Operational Risk Modelling

Modelling operational risk ranges from mathematical to statistics-econometrical approach which is designed to measure the regulatory and economic operational risk capital. Different models are also designed to study causes and consequences

---

10 This shortcoming is also reflected in the studies by Khan and Ahmed, 2001; Hassan and Dicle, 2005; Ismail and Sulaiman, 2005; Kahf, 2005; Muljawan, 2005; and Sundararajan, 2005.

11 It is expected that the proposed approach will result in an operational risk capital charge that credibly reflects the operational risk profile of the bank. This is the essence of Operational Risk Management System (ORMS) which consists of the systems and data used to measure operational risk in order to estimate the operational risk capital charge. ORMS is a subset of Operational Risk Management Framework (ORMF). For further discussion, see Basel Committee on Banking Supervision Consultative Document on Operational Risk-Supervisory Guidelines for the Advanced Measurement Approach, 2010.
of operational risk. Surely, a constantly changing financial environment has made modelling of operational risk vital\textsuperscript{12}. Furthermore, operational risk modelling is also needed to provide bank management with a tool to make a better decision in carrying out a desirable level of operational risk management. It is also suggested that the only feasible way to effectively manage operational risk is by identifying and minimising it, which requires the development of adequate quantification techniques\textsuperscript{13}. As a matter of fact, quantification of operational risk is a prerequisite for the formulation of an effective operational risk management and a sound economic capital framework\textsuperscript{14}.

2.1. Taxonomy of Operational Risk Modelling

The paper broadly classifies modelling in operational risk into three classes; (i) process approach, (ii) factor approach, and (iii) actuarial approach. It should also be noted that a selection of which approach to implement may largely depend on operational risk categories (ORC) which may vary across an institution. As clearly mentioned in the Basel Committee Document on the Supervisory Guidelines for the Advanced Measurement Approaches, a bank’s risk measurement is greatly influenced by the number of ORCs used within the model\textsuperscript{15}.

Table 1
Approaches in Operational Risk Modelling

<table>
<thead>
<tr>
<th>Process Approach</th>
<th>Factor Approach</th>
<th>Actuarial Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Causal models</td>
<td>Risk Indicators</td>
<td>Empirical loss distributions</td>
</tr>
<tr>
<td>Bayesian belief networks</td>
<td>Capital Assets Pricing equivalent models</td>
<td>Explicit distributions</td>
</tr>
<tr>
<td>Fuzzy logic</td>
<td>Predictive models</td>
<td>parameterised using historical data</td>
</tr>
<tr>
<td>Reliability analysis</td>
<td></td>
<td>Extreme value theory</td>
</tr>
<tr>
<td>Connectivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Dynamics</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Smithson and Song (2004)


\textsuperscript{15} See Basel Committee on Banking Supervision Consultative Document on Operational Risk-Supervisory Guidelines for the Advanced Measurement Approach, 2010, paragraph 33. A proposed operational risk categories (ORCs) for an Islamic bank is presented in the Appendix.
2.2. Process approach

It is an approach that focuses on the chain of activities that comprise an operation or transaction (in much the same way that an industrial engineer examines a manufacturing process by looking at the individual work stations). Examples of this approach include:

- **Causal models;** it attempts to look at a specific outcome (for example, a settlement payment) in terms of the probabilistic impact of the activities that are in the chain (for example, recognition that a payment date has occurred, calculation of the settlement amount, notification of the counterparty, and paying or receiving). The success of each activity in the chain might be modelled as a function of inputs.

- **Reliability analysis;** it is used in operational research to measure the impact of failure of components in complex mechanical/electronic system. However, it is also widely implemented in operational risk to estimate the hazard rate of arrival of failure (operational risk event)

- **Connectivity;** which requires the modelling process to develop a ‘connectivity matrix’ that can then be used to estimate the likelihood of failure (or potential losses) for the process as a whole.

Three additional techniques that could be considered ‘process’ approaches are:

- **Bayesian belief network**, which extends the ‘causal model’ technique by treating the initial model as the null hypothesis, and so, as data is collected, the model can be tested to provide a more accurate picture of the process.

- **Fuzzy logic** is a branch of mathematics that facilitates decision-making when some of the inputs are vague, or if they are subjective judgements. In a ‘causal model’, fuzzy logic could provide a way to aggregate the subjective drivers of a process.

- **System dynamics**, which extends the ‘connectivity’ approach; it is carried out by making the connections between dynamic activities. This technique requires a development of the model to simulate the cause-effect interactions among activities that make up the processes within the firm.
2.3. Factor Approach

A factor approach was initiated as an attempt to identify the significant determinants of operational risk – either at the institutional level or at the level of an individual business or individual process. The objective is to obtain an equation that relates the level of operational risk for institution \( i \) (or business \( i \) or process \( i \)) to a set of factors:

\[
(\text{Operational Risk }_i) = \alpha + \beta(\text{Factor 1}) + \gamma(\text{Factor 2})
\]

The key element of factor approach is the identification of appropriate factors in order to obtain the measures of the parameters \( \alpha, \beta, \) and \( \gamma \). As a result, an estimation of the level of operational risk that will exist in future periods can be materialised. In the analysis of operational risk quantification, Smith and Song (2004) describe three applications of the factor approach:

- **Risk indicators**, in which regression techniques are utilised to identify the significant operational risk factors.

- **Capital Assets Pricing equivalent model**; a model that relates the volatility in share returns (and earnings and other components of the institution’s valuation) to operational risk factors.

- **Predictive models**, which use discriminated analysis and similar techniques to identify factors that ‘lead’ to operational losses.

2.4. Actuarial Approach

An actuarial approach attempts to identify the loss distribution associated with operational risk – either at the level of an institution or at the level of a business or process.

- **Empirical loss distribution**, is the most straightforward way to estimate the loss distribution, using the institution’s own data on losses or both internal data and (properly scaled) external data. However, empirical loss distributions will probably suffer from limited data points (especially in the tail of the distribution).

- **Explicit distributions parameterized using historical data** is one way to get around the sparse data problem. The analyst specifies a distributional form for the
loss distribution or a distribution for the frequency of occurrence of losses and a different distribution for the severity of the losses.

- **Extreme value theory** provides another way of getting around the data sparseness problem. This theory is an area of statistics concerned with modelling the limiting behaviour of sample extremes, which indicates that, for a large class of distributions, losses in excess of a high enough threshold all follow the same distribution (a generalised Pareto distribution).

### 3. Empirical Research in Islamic Banking

In the IFSB Draft No. 2 on Capital Adequacy Standard, operational risk is defined as the risk of losses resulting from inadequate or failed internal risk and Shan'ah compliance risk (IFSB, 2005: 22)\(^\text{16}\). This definition is rather different from Basel 2 on operational risk\(^\text{17}\). However, IFSB adopts Basel 2’s methodology in the calculation of a minimum capital requirement for operational risk exposure. Four methods have been proposed by the Basel; namely the Basic Indicator approach (BIA), the Standardised approach (TSA), the Alternative Standardised approach (ASA) and the Advanced Measurement approach (AMA). The IFSB standards provide fairly detailed guidance on adaptation of Basel 2 to the specific risk characteristics of Islamic banks. In particular, the IFSB draft proposes an adaptation of standardised approach to operational risk exposure provided the bank satisfies certain qualification criteria to assure the supervisory authority of the existence of efficient and independent operational risk management system and of its ability to fairly estimate operational risk and the capital needed to face it, including the expected losses as well as the unexpected losses.

---

\(^{16}\) Islamic Financial Services Board, op cit. p. 22.

\(^{17}\) In Basel 2, operational risk as the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events. This definition includes legal risk, but excludes strategic and reputational risk. See Basel 2, 2005, paragraph 33.
measurement—based on externally provided rating categories—and within this framework allows supervisory discretion to recognise the extent of risks assumed by the PSIA’s\(^\text{18}\) in computing capital adequacy for Islamic banks. Kahf opposes the use of gross income as a proxy of operational risk exposure as set out by IFSB\(^\text{19}\). In this respect, his argument is in line with Sundararajan who argued that the use of gross income as the basic indicator for operational risk measurement could be misleading in Islamic Banks, as large volume of transactions in commodities, and the use of structure finance raise operational exposures that will not be captured by gross income.\(^\text{20}\) However, Sundararajan (2005) still supports the standardised approach that allows for different business lines to be better suited, but would still need adaptation to the needs of Islamic banks.

Some empirical aspects of the operational soundness in Islamic banks were studied by Ismail and Suleiman (2005), Hassan and Dicle (2005) and Muljawan (2005). Using the Cavello and Majnoni model, Ismail and Suleiman discuss the interaction between the capital requirement as stated in the New Basel Capital Accord and the cyclical pattern of profit\(^\text{21}\). In addition to that, CAMEL\(^\text{22}\) framework is deployed by Muljawan as an alternative tool to assess the operational soundness of Islamic banks.\(^\text{23}\) The analysis of Hassan and Dicle is somewhat broader than other papers in the sense that it also discusses the nature of

\(^{18}\) PSIA refers to profit sharing investment account
\(^{19}\) Monzer Kahf, *Basel II: Implications for Islamic Banking*. Paper presented at the Sixth International Conference on Islamic Economics and Finance: Islamic Economics and Banking in the 21st Century, organized by Bank Indonesia, Islamic Research and Training Institute, The International Association for Islamic Economics, and University of Indonesia, 2005, p. 313
\(^{22}\) C(apital), A(set quality), M(anagement), E(arning), and L(iquidity)
operational risk. However, it does not make any suggestions on how to handle capital requirements with respect to Islamic banks.

There are two things that can be highlighted from the review above; first, it is clear that the empirical research that have been conducted are on the aspect of capital attribution for operational risk; second, there is no unanimous standard of operational risk measurement method. The most recent research on this issue was conducted by Jackson-Moore; nevertheless, the writer could not come up with a conclusive suggestion on the refined measurement method.

The following section attempts to discuss the proposed framework in measuring operational risk exposures in Islamic banks.


The objective of operational risk management is to decide which risks are important to the bank so that it could determine their magnitude and mitigate them accordingly. Therefore a refined measurement method is required to provide a measure that has a defined relationship to a risk factor that can be assigned as controllable or uncontrollable. This would result in the determination of an appropriate intervention for controllable risks by focusing on their causes.

Given the foregoing discussion, the impact on operations can be separated into controllable risk and uncontrollable risk. In this study, a controllable risk is defined as any risk which has assignable causes that can be influenced. Generally, process-related risks will have assignable causes and therefore, they are controllable. For instance, classifying loan customers into the wrong credit categories can result in substantial differences in the default rates and loan provision requirements and is an example of a risk that is controllable because the cause is known.

Uncontrollable risk, on the other hand, is defined as any risk that does not have causal factors that can be influenced. Their impact is determined through loss

models that analyse extreme values (losses), and use classification instead of causes. Ideally, extreme loss models will be used with scenarios that provide stress points for the analysis. Uncontrollable does not mean that there is nothing that can be done about it. There are many mitigation strategies that can be implemented in order to reduce the effects of a loss. Also, uncontrollable risks may become controllable if an assignable cause can be found and which would enable the management to carry out a corrective action.

The proposed DGSA deals with controllable risks; in other words, DGSA is designed to measure the magnitude of operational risk exposures which can be controlled, or HF-LS type of operational risks.

4.1. Building Blocks of DGSA

The analysis of DGSA begins by developing a function for a value adding process and then examining the key factors that contribute to the performance and their associated errors (uncertainties). This can be done by partitioning the business unit into different income generating channels (IGCs). IGCs contain different earnings function as the unit of analysis for measuring operational risk, as shown in Figure 1.

Income generating channels can be defined as the production unit by which a bank creates a product valuable to its customers. An activity in the income generating channels employs purchased inputs, human resources, capital, and some form of technology to perform its function. Since a business unit has profit and loss reporting (by definition), its income generating processes are the key components that make up the profit and loss for the business unit. In our model, Islamic banks business model can be partitioned into three income generating channels, namely; (a) investment channel, (b) financing channel, and (c) service channel.

a) Investment channel, which comprises any investment in the form of a partnership. There are two types of investing instruments: fund management (muḍārabah) and equity partnership (mushārakah). Muḍārabah, which can be short, medium, or long term, is a trust-based financing agreement whereby an investor entrusts capital to an agent to undertake a project. Profits are based on a pre-agreed ratio. Mushārakah, which can be either

---

26 Jack L. King, Operational Risk: Measurement and Modelling, 2001, p. 74, Chichester: John Wiley & Sons, Ltd.
medium or long term, is a hybrid of *shirka* (partnership) and *mudarabah*, combining the act of investment and management. In the absence of debt security, the Sharī‘ah encourages this form of financing.

b) Financing channel, which contains any financing instruments that are used primarily to finance obligations arising from the trade and sale of commodities or property. Financing instruments also include instruments generating rental cash flows against exchange of rights to use the assets such as *ijārah* and *istiṣnā‘*. Financing instruments are closely linked to a sale contract and therefore are collateralised by the product being financed. These instruments are the basis of short-term assets for the Islamic banks. *Murābahah*, a cost-plus sales contract, is one of the most popular contracts for purchasing commodities and other products on credit.

c) Service channel; consists of any financial transactions that create earnings by charging fees, an example of which is *ju‘ālah*.

For each income generating channel, an earning figure can be located and linked up with causal factors for the business. Causal factors can be defined as factors that have impacts on earnings. In other words, *DGSA* uses risk factors resulting from causal factors that create losses with a random uncertainty to measure the variability of earnings.

In contrast, un-assignable loss cannot be tied to a risk factor since the cause is normally unknown or is due to an external event. Based on the causality between risk factors contributing to assignable losses, an earning function can be produced in each income generating channel. The *DGSA* methods use factors which lead to loss and their sensitivities to generate loss distributions in different business units.
Figure-1
How Does the DGSA Work?

I. High Frequency-Low Severity (HF-LS): predictable, assignable, and controllable

Identification of Risk Factors in Three Income Generating Channels (IGC)

Investment  Financing  Services

II. Establish earnings functions related to risk factors in each IGC. How?

Delta-Gamma based on Error Propagation

1st step (static process): Given E=f(x); sensitivity of causality factors is defined as
\[ \frac{\Delta E}{\Delta x} = \frac{\partial f}{\partial x} \] ... The Delta

2nd step (dynamic process): the sensitivity of delta is defined as
\[ \frac{\Delta E}{\Delta x} = \frac{\partial^2 f}{\partial x^2} \] ... The Gamma

Output:

Operating Loss Distribution (OLD)

Value at Risk for Operational Losses

Decide maximum OLD as a threshold (µ)
In it worth noting here that losses within business units are not normally accounted for in a systematic way that would allow their direct assignment to risk factors. Since there are a large number of small losses, many banks simply aggregate operational losses in general accounts along with other entries. They may be included as a cost of doing business or simply mixed up in the profit and loss accounting. Without having a loss figure that can be linked to risk factors, therefore, it is almost impossible to produce a direct measurement of operational risk caused by assignable loss. Hence the DGSA method can overcome this problem.

In summary, the steps of building DGSA frameworks are as follows:

1) Establish the business model with income generating channel
2) Determine the risk factors for the major activities in the income generating channel
3) Determine the relations between risk factors and earning through setting up earnings function in different income generating channel
4) Estimate operational losses using uncertainty of the risk factors propagated to the risk in earnings (Delta-Gamma method)
5) Set the threshold of operating losses from the processes using the risk factor uncertainties and operating losses from Delta-Gamma method
6) Filter the large losses using the threshold.

4.2. Key Features of DGSA

The DGSA methodology is the calculation technique to determine the value of the assignable losses based on the sensitivity causality between the risk factors. DGSA is produced through error propagation of the risk factors to measure operational risk. The uncertainty of the risk factors is utilised to calculate the uncertainty in earnings using sensitivities from which the relation of the change in earnings to a change in the risk factors can be located.

In DGSA, operational risk is measured as the uncertainty in earnings due to two parts. First, using the uncertainty in causal factors for losses up to a threshold and second, using a large loss model for un-assignable loss above a threshold. Causality model, hence, plays a critical role in determining the risk factors establishing the model. Hence, the combination of the two constitutes DGSA and is described by the operational risk formula as follows:
Uncertainty in earnings due to operational risk is a function of the uncertainties in a set of risk factors plus a function of the distribution of un-assignable losses larger than a given threshold ($\mu$). DGSA method is used to calculate the first term in the model. This model expresses the uncertainty in earnings as a function of the uncertainty in a set of risk factors:

$$u( E ) = f(\Delta X_1 )...u(\Delta X_n ) + \Phi( L_{\text{unassignable}} \mid L_{\text{unassignable}} > \mu)$$  \hspace{1cm} (1)

DGSA method for measuring operational risk is based on the five following key concepts:

1. Earnings as a function of causal factors.
   In DGSA method, it is assumed that earnings are described by a series of causal factors. For a given earnings level, there is a set of causal factors whose values are used to estimate earnings:

   $$earnings = f(\text{causal factors})$$  \hspace{1cm} (3)

   Earnings are described as a function of a set of causal factors. For example, earnings may be calculated as 20% of sales revenue minus an adjustment for rejects. By separating the causal factors into constants and volatilities, earnings can be described by a set of performance drivers that create the expected level of earnings and a set of risk factors that create volatility in the level of earnings (risk):

   $$earnings = f(\text{performance drivers}) \pm f(\text{risk factors})$$  \hspace{1cm} (4)

   Earnings are described as a function of performance drivers for level and risk factors for volatility. Therefore, in the model, earnings are calculated as 20% of sales revenue minus the variance to target cost for rejects. ‘Sales revenue’ is the performance driver and ‘rejects’ is the risk.

2. The risk in earnings is a random fluctuation in value caused by uncertainty in the risk factors. Given

   $$E = f(x)$$  \hspace{1cm} (5)

   Therefore

   $$u( E ) \approx f(\mu(x))$$  \hspace{1cm} (6)
3. The basic measure of uncertainty for operational risk is the standard deviation of the mean, or standard error.

In general, the standard deviation of the mean of the measured values is referred to as the standard error or simply the error. It is calculated from a sample of \( n \) measures using the following formula:

\[
\sigma_x = \sqrt{\frac{1}{n(n-1)} \sum_{k=1}^{n} (x_k - \bar{x})^2}
\]  
(7)

Whereby \( \bar{x} \) is the mean of the analysed operational risk variable.

4. Uncertainties are combined using the formula for the expected value of the sum of variances.

This formula is given for the simple case of correlation values of only 0 or 1, corresponding to independent analysed operational risk variables and others that are perfectly correlated. Normally this should be sufficient for operational risk measures.

\[
\sigma_z^2 = \sum_i \sigma_i^2 + \left( \sum_j \sigma_j \right)^2
\]  
(8)

Formula for combining uncertainties using standard errors where the \( i \)'s are uncorrelated and the \( j \)'s are correlated (perfectly) measures.

5. Uncertainties for functions of uncertainty measures are calculated using the law of error propagation. For each risk factor, the sensitivity of the earnings with respect to the factor is needed. The sensitivity is the amount of change in earnings given a single unit change in the factor with everything else remaining unchanged, or the partial derivative of the earnings function with respect to the factor. Given the earnings function that expresses earnings as a function of a factor

\[
E = f(x)
\]

Then sensitivity is defined as
\[
\frac{\Delta E}{\Delta x} = \frac{\partial f}{\partial x} \tag{9}
\]

The method of combining measurement uncertainties from various factors and accounting for their correlation is known as the *propagation of uncertainty*. The basic formula uses the sensitivities (partial derivatives) of the factors to calculate the standard deviation of the estimate. It is based on a Taylor approximation for the uncertainty in terms of factors such as:

\[
R = f( X_1, X_2, \ldots, X_n ) \tag{10}
\]

Using the Taylor approximation’s first term, the uncertainty for the measure can be figured out using the following technique:

\[
u^2(r) = \sum_{i=1}^{N} \left( \frac{\partial f}{\partial x_i} \right)^2 \nu^2(x_i) + 2 \sum_{i=1}^{N} \sum_{j=i+1}^{N} \frac{\partial f}{\partial w_i} \frac{\partial f}{\partial w_j} \sigma_i \sigma_j \rho_{ij} \tag{11}\]

The formula shown above is the formula for the calculation of combined uncertainty from many factors, also known as the ‘general law of error propagation’. Where \(u(\cdot)\) denotes the uncertainty in the value, \(r\) is the risk measurement, \(x\) is the factor, and \(f\) is the functional relationship between \(x\) and \(r\). The partial derivative term is known as the sensitivity to the factor. This formula also explicitly considers correlation between factors \(\rho_{ij}\).

6. The *gamma* (\(\Gamma\)) of a portfolio on an underlying assets is the rate of change of the portfolio’s delta with respect to the price of the underlying asset. While the *delta* is the first derivative of the model, the *gamma* is the second partial derivative of the portfolio with respect to different risk factors:

\[
Gamma = \frac{\partial^2 \pi}{\partial S^2} \tag{12}
\]

If the value of gamma is small, the delta changes slowly and adjustments to keep a portfolio delta neutral only need to be made relatively infrequently. However, if gamma is large in absolute terms, then delta is highly sensitive to the price of the underlying asset. It is then quite risky to leave a delta neutral portfolio unchanged for any length of time. In this study, gamma is an important factor in determining which risk factors are more influential to income generating channels.
It is expected that partnership type of financing, such as *muḍārabah* and *mushārakah* would give higher value since they are likely to increase the level of operational risk exposures.

7. **Threshold**: it is used to separate losses to be analysed using *DGSA* from those that are not assignable. As highlighted in the earlier paragraph, *DGSA* deals with small losses (*HF*-*LS* type of operational risks); hence, the threshold is the transition point from small loss (*HF*-*LS*) to large loss (*LF*-*HS*). However, to ensure that there will not be any overlap, meticulous calculations must be carried out to set the threshold precisely since losses assigned to risk factors using *DGSA* method are assumed to have random error properties. And *DGSA* is used to estimate the central tendency of this uncertainty.

4.3. **Why Sensitivity Analysis?**

The activity in the field of sensitivity analysis (*SA*) has been steadily growing, due to the increasing complexity of numerical models, whereby *SA* has acquired a key role in testing the correctness and corroborating the robustness of models in several disciplines. This has led to the development and application of several new *SA* techniques. Most of the recent literature in portfolio management has proposed *SA* approaches based on partial derivatives (*PDs*)

Nevertheless, recent studies in the *SA* literature have highlighted that *PDs*-based *SA* suffers from several limitations when used for parameter impact evaluation and risk management purposes. It is shown that a *PDs*-based *SA* to evaluate the impact of parameter changes with respect to the generic model output:

1) is equivalent to neglecting the relative parameter changes, or, equivalently, to impose that all the parameters are varied in the same way;

2) does not allow the appreciation of the model sensitivity to changes in groups of parameters

---

28 Studies by Borgonovo and Apostolakis, 2001a; Saltelli, 1997; Saltelli, 1999; Saltelli, Tarantola and Chan, 1999; Turany and Rabitz, 2000 show the importance of sensitivity analysis approach in financial analysis.

29 As brought forward by Drudi, Generale and Majmoni, 1997; Gourieroux, Laurent and Scaillet, 2000; Manganelli, 2004; McNeal and Frey, 2000.

30 See Borgonovo and Apostolakis, 2001a; Borgonovo and Apostolakis, 2001b; Borgonovo and Peccati, 2004; Borgonovo and Peccati, 2005; Cheok, Parry and Sherry, 1998.

31 As argued by Borgonovo and Apostolakis, 2001a; Borgonovo and Apostolakis, 2001b; Borgonovo and Peccati, 2004.
Therefore, using Elasticity ($E$) is considered to be a better alternative as compared to $PDs^{32}$. In this case limitation 2 would still be in place, as $E$ is not additive; and limitation 1 would be replaced by introducing $E$ to impose on any parameters that are changing by the same proportion.\textsuperscript{33}

This study will show that the use of Differential Importance Measure ($D$) would overcome the two above mentioned limitations. Let us consider the generic model output:

$$Y = f(x)$$

Where $x = \{x_i, i = 1,2,...,n\}$ is the set of the input parameters. Suppose:

$$dx = [dx_1, dx_2,...,dx_n]^T$$

Which denote the vector of change; if $f(x)$ is differentiable, then the differential importance of $x_i$ at $x_0$ is defined as\textsuperscript{34}

$$D_i(x_0, dx) = \frac{df_i(x_0)}{df(x_0)} = \frac{f_i' (x_0) dx_i}{\sum_{j=1}^{n} f_j(x_0) dx_j}$$

(14)

$D$ can be interpreted as the ratio of the (infinitesimal) change in $Y$ caused by a change in $x_i$ and the total change in $Y$ caused by a change in all the parameters. Thus, $D$ is the normalised change in $Y$ provoked by a change in parameter $x_i$. It can be shown that\textsuperscript{35}:

a) $D$ shares the additivity property with respect to the various inputs, for example, the impact of the change in some set of parameters coincides with the sum of the individual parameter impacts. More formally, let $S \subseteq \{1,2,...,n\}$ identify some subset of interest of the input set; hence it would give:

---


\textsuperscript{33} See (Borgonovo and Apostolakis, 2001a; Borgonovo and Apostolakis, 2001b; Borgonovo and Peccati, 2004; Borgonovo and Peccati, 2005).


\textsuperscript{35} As concluded by Borgonovo and Apostolakis, 2001a; Borgonovo and Apostolakis, 2001b; Borgonovo and Peccati, 2004; Borgonovo and Peccati, 2005.
\[ D_i(x^0, dx_x) = \frac{\sum_{s=5} f_i(x^0)dx_s}{\sum_{j=1}^{n} f_j(x^0)dx_j} = \sum_{s=5} D_s(x^0, dx) \] (15)

As a consequence,

\[ \sum_{s=1}^{n} D_s(x^0, dx) = 1 \] (16)

for example, the sum of the \( D_i \) \((i=1,\ldots,n)\) of all parameters is equal to unity.

b) Equation (2) shows that \( D \) accounts for the relative parameters changes through the dependence on \( dx \). In fact, equation (14) can be rewritten as:

\[ D_s(x^0, dx) = \frac{f_i(x^0)}{\sum_{j=1}^{n} f_j(x^0) \frac{dx_j}{dx_j}} \] (17)

In the hypothesis of uniform parameter changes \((H1)\) \((dx_j=dx_s \ \forall \ j,s)\), the following can be produced:

\[ D_{1s}(x^0) = \frac{f_i(x^0)}{\sum_{j=1}^{n} f_j(x^0)} \] (18)

Hypothesis of proportional changes \((H2)\) \(\left( \frac{dx_j}{x^0_j} = \omega \forall j \right)\), would result in:

\[ D_{2s}(x^0) = \frac{f_i(x^0) \cdot x^0_s}{\sum_{j=1}^{n} f_j(x^0) \cdot x^0_j} \] (19)

It can be shown that \( D \) generalises other local SA techniques as the Fussel-Vesely importance measure and Local Importance Measure based on normalised partial derivatives, also known as Criticality Importance or \( E \). More specifically, in case \( H2 \) it holds that\(^{36}\):

\[ D_{2s}(x^0) = \frac{E_s(x^0)}{\sum_{j=1}^{n} E_j(x^0)} \] (20)

where \( E_s(x^0) \) is the elasticity of \( Y \) with respect to \( x_i \) at \( x^0 \). Equation (20) shows that \( E \) produces the importance of parameters for proportional changes.

\(^{36}\) E. Borgonovo and L. Peccatti, op cit., p. 23
5. Determination of Risk Factor Contribution

From the practitioners’ viewpoint, a pertinent issue is how much each of the process contributes to the risk exposure\(^{37}\). If it turns out that only a fraction of all processes significantly contribute to the risk exposure, then the risk manager should only focus on this particular process. It is, therefore, important to analyse how much each single process contributes to the total risk. This study considers operational value at risk (OpVaR) resulting from operating loss distribution as a risk measure. To split up the risk into its process components, this study compares the incremental risk (IR) of the processes.

Let \( IR_\alpha (i) \) be the risk contribution of process \( i \) to OpVaR at the confidence level \( \alpha \).

\[
IR_\alpha (i) = OpVaR_\alpha (P) - OpVaR_\alpha (P \setminus \{i\}), \tag{21}
\]

Where \( P \setminus i \) is the whole set of workflows without process \( i \). Since the sum over all \( IR_\alpha \)’s is generally equal to the OpVaR, the relative incremental risk \( (RIC_\alpha (i)) \) of process \( i \) is defined as the \( IR_\alpha (i) \) normalised by the sum overall \( IR_\alpha \), i.e.

\[
RIC_\alpha (i) = \frac{IR_\alpha (i)}{\sum_j IR_\alpha (j)} = \frac{OpVaR_\alpha (P) - OpVaR_\alpha (P \setminus \{i\})}{\sum_j IR_\alpha (j)} \tag{22}
\]

as a further step, for each \( \alpha \), this paper counts the number of processes that exceed a relative incremental risk of 1\%. The resulting curve is attributed as parameter \( \alpha \) or the Risk Selection Curve (RiSC)

6. Extreme Value Theory (EVT)

Extreme value theory (EVT) is a field of study in statistics that focuses on the properties and behaviour of extreme events. In general, there are two main kinds of model for extreme values. The most traditional models are the block maxima models; these are models for largest observations collected from large samples of identically distributed observations. The second type of model which is more comprehensive is the peak over threshold (POT) model; this is a model for all large observations that exceed some high level, and is generally considered to be the most useful for practical applications, due to their more efficient use of the data (often limited) on extreme outcomes.

---

In our analysis, the application of EVT as the second leg of the proposed model starts after the determination of a transition point resulting from DGSA. It is important to note that the transition point is typically classified as the maximum threshold. EVT offers a parametric statistical approach for the extreme values of data. Its roots are in the physical sciences and it has recently been applied to insurance. Since traditional statistical techniques focus on measures of central tendency (e.g. mean), they are not as accurate when estimating values very far from the centre of the data. EVT, on the other hand, deals only with the extreme values and ignores the majority of the underlying data and its measures in order to provide better estimates of the ‘tails’.

The EVT methodology for operational risk is basically a loss model for large losses using a GPD for the severity. The technique for fitting the GPD to data is the peaks over threshold method (POT), where large values over a specific threshold are fitted to the GPD. Following Chavez-Demoulin et al.\textsuperscript{38}, the POT method deployed in the analysis uses the following basic assumptions:

- The excesses of an independent identically distributed (or stationary) sequence over a high threshold $u$ occur at the times of a Poisson process;
- The corresponding excesses over $u$ are independent and have a GPD;
- Excesses and exceedance times are independent of each other.

6.1. Operating Framework for EVT

As depicted in Figure 2, the steps for operating EVT in our analysis start with the separation of loss amount into its severity and frequency.

Furthermore, excess losses are fit to a GPD to determine the severity of a loss given that it exceeds the threshold. This is a conditional severity distribution for large losses. Since the number of exceedances follows a Poisson distribution, it is fitted and used to estimate the frequency of exceedances. Combining the severity and frequency distributions in a Monte Carlo simulation gives the excess loss distribution. The resulting excess loss distribution is a multi-period loss distribution for only those losses that exceed the threshold.

---

The Application of Extreme Value Theory for Operational Risk Measurement in Islamic Banks

Low Frequency-High Severity (LF-HS): unpredictable, un-assignable, and uncontrollable

Severity [loss amount > threshold (µ)]

Frequency distribution

Maximum likelihood method

Fitted to GPD (Generalised Pareto Distribution)

Fitted to Poisson Distribution

Combined in Monte Carlo Simulation

Output:

Excess Loss Distribution (ELD)

Value at Risk for Operational Losses
6.2. Theoretical Building Blocks of EVT: Fisher-Tippet-Gnedenko Theorem

The Fisher-Tippet-Gnedenko theorem states that given a sample of independent identically distributed loss data \( \{x_1, x_2, ..., x_n\} \), as the number of observations \( n \) becomes increasingly large, the maximum of the sequence of observations, under very general conditions, is approximately distributed as the generalised extreme value (GEV) distribution with cumulative probability distribution function

\[
F(x) = \begin{cases} 
\exp \left\{ - \left[ 1 + \xi \left( \frac{x - \mu}{\sigma} \right) \right]^{-1/\xi} \right\} & \text{for } \xi \neq 0 \\
\exp \left\{ - \exp \left[ - \left( \frac{x - \mu}{\sigma} \right) \right] \right\} & \text{for } \xi = 0 
\end{cases}
\]

(23)

where \( \mu \) is the location parameter, \( \sigma > 0 \) is a scale parameter, \( 1 + \xi \sigma > 0 \), \( -\infty \leq \xi \leq \infty \), \( \sigma > 0 \), and \( \xi \) is the tail index parameter. The GEV has three forms; if \( \xi > 0 \), then the distribution takes the form of a type II (Frechet) heavy-tailed distribution. For \( \xi < 0 \), the distribution is takes the type III (Weibull) distribution. When \( \xi = 0 \), the distribution is the type I (Gumbel) light-tailed distribution. In fact, the larger the tail index parameter, the fatter is the tail.

6.3. Parameter Estimation

The parameter \( \mu \) and \( \sigma \) can be estimated from the sample mean and sample standard deviation, respectively. If we rank the data in order size so that \( x_1 > x_2 > ... > x_n \), the tail index parameter \( \hat{\xi} \) can be estimated using the Hill estimator:

Method I: \( \hat{\xi}_k = \frac{1}{k-1} \sum_{j=1}^{k-1} \ln(x_j) \) \( - \ln(x_k) \)

(24)

Method II: \( \hat{\xi}_k = \frac{1}{k} \sum_{j=1}^{k} \ln(x_j) \) \( - \ln(x_k) \)

(25)

The problem now is how to choose \( k \). Theory gives little advices as to what value to choose. Furthermore, the actual estimate will be sensitive to the value of \( k \) chosen. In practice, the average estimator, using either of the following two formulas, often works well:

Method I: \( \hat{\xi} = \frac{1}{n} \sum_{i=1}^{n} \theta_i \) where \( \theta_k = \frac{1}{k-1} \sum_{j=1}^{k-1} \ln(x_j) \) \( - \ln(x_k) \) for \( k = 1, 2, ..., n \)

(26)
Method 2: \( \hat{\zeta} = \frac{1}{n} \sum_{i=1}^{n} \theta_i \) where \( \theta_k = \left( \frac{1}{k} \sum_{j=1}^{k} \ln(x_j) \right) - \ln(x_k) \) for \( k = 1, 2, n \) \hspace{1cm} (27)

6.4. Severity Model

An alternative EVT approach to calculate OpVaR is to use peaks over threshold (POT) modelling. The underlying principle of the operating framework is to use peaks over threshold. Although the method of block maxima utilises the Fisher-Tippet-Gnedenko theorem to inform us what the distribution of the maximum loss is, POT uses the Picklands-Dalkema-de Hann to inform us what is the probability distribution of all events greater than some large present threshold. The Picklands-Dalkema-de Hann theorem states that if \( F_u \) is the conditional excess distribution function of values of the ordered losses \( X \) above some threshold, \( \mu \) is given by \( F_u = \text{Prob}(X - \mu \leq y | X > \mu)0 \leq y \leq x_f - \mu \). Then for a suitably high threshold the limiting distribution of \( F_u \) is a generalised Pareto distribution (GPD) with cumulative distribution function

\[
GPD_{\xi, \sigma} = \begin{cases} 
1 - \left( 1 + \frac{\xi}{\sigma} \frac{x}{\xi} \right)^{-\frac{1}{\xi}} & \text{if } \xi \neq 0 \\
1 - \exp\left( -\frac{x}{\sigma} \right) & \text{if } \xi = 0 
\end{cases}
\]  \hspace{1cm} (28)

where \( \sigma > 0 \), and \( x \geq 0 \) when \( \xi \geq 0 \) and \( 0 \leq x \leq -\beta/\xi \) when \( \xi < 0 \). The parameters \( \xi \) and \( \beta \) are referred to, respectively, as the shape and scale parameters. In other words, \( y_s \) are called excesses whereas \( x_s \) are called exceedances.

It is possible to determine the conditional distribution function of the excesses (i.e, \( y_s \)) as a function of \( x \):

\[
F_u(y) = P(X - u \leq y | X > u) = \frac{F_x(x) - F_x(u)}{1 - F_x(u)}
\]  \hspace{1cm} (29)

In this representation the parameters \( \xi \) is crucial, when \( \xi = 0 \), we have an exponential distribution; when \( \xi < 0 \), we have a Pareto distribution—II Type and when \( \xi > 0 \), we have Pareto distribution—I Type. Moreover, this parameter has a direct connection with the existence of finite moments of the losses distributions. We have the following equations:

\[
E(x^k) = \infty \text{ if } k \geq 1/\xi
\]  \hspace{1cm} (30)
Hence in the case of a GPD as a Pareto—I Type, when $\xi \geq 1$, we have infinite mean models, as also shown by Moscadelli\textsuperscript{39} and Neslehova et. al\textsuperscript{40}.

Following Di Clemente-Romano\textsuperscript{41}, we suggest to model the loss severity using the lognormal for the body of the distribution and EVT for the tail in the following way:

$$F_i(x) = \begin{cases} 
\Phi\left(\frac{\ln x - \mu(i)}{\sigma(i)}\right) & 0 < x < u(i) \\
1 - \frac{N_u(i)}{N(i)} \left(1 + \xi(i) \frac{x - u(i)}{\beta(i)}\right)^{-\frac{1}{\xi(i)}} & u(i) \leq x
\end{cases}$$

Where

$\Phi$ = standardised normal cumulative distribution functions

$N_u(i)$ = number of losses exceeding the threshold $u(i)$

$N(i)$ = number of loss data observed in the $i$th ET

$\beta(i)$ = scale parameters of a GDP

$\xi(i)$ = shape parameters of a GDP

An important issue to consider is the estimation of the severity distribution parameters. While the estimation maximum likelihood (ML) in the lognormal case is straightforward, in the EVT case, it is extremely important to consider whether ML or the alternative probability weighted moment (PWM) routines are able to capture the dynamics underlying losses severities.

With respect to ML, the log-likelihood function equals

$$l(\xi, \beta; X) = -n \ln \beta - \left(\frac{1}{\xi} + 1\right) \sum_{i=1}^{n} \ln \left(1 + \frac{\xi}{\beta} X_i\right)$$

(32)

This method works well if $\xi > -1/2$. In this case, it is possible to show that


\[ n^{1/2} \left( \xi_n - \xi, \frac{\hat{\beta}_n}{\beta} - 1 \right) \xrightarrow{d} N(0, M^{-1})n \rightarrow \infty \] (33)

where

\[ M^{-1} = \left(1 + \xi \right) \begin{pmatrix} 1 + \xi & -1 \\ -1 & 2 \end{pmatrix} \] (34)

Instead, the PWM consist of equating model moments based on a certain parametric distribution function to the corresponding empirical moments based on the data. Estimated based on PWM are often considered to be superior to standard moment-based estimates. In our case, this approach is based on these quantities:

\[ w_r = E[Z(GPD_{\xi, \beta}(Z))] = \frac{\beta}{(r+1)(r+1-\xi)}, \quad r = 0, 1, \ldots \] (35)

where \( GPD_{\xi, \beta} = 1 - GPD_{\xi, \beta} \). \( Z \) follows a \( GPD_{\xi, \beta} \) (36)

From the above equations, it is possible to show that

\[ \beta = \frac{2w_0w_1}{w_0 - 2w_1} \quad \text{and} \quad \xi = 2 - \frac{w_0}{w_0 - 2w_1} \] (37)

Hosking and Wallis\(^\text{42}\) show that PWM is a viable alternative to ML when \( \xi \geq 0 \). In our analysis, we estimated the GPD parameters using the previous approaches together with the standard Hill estimator.

6.5. Frequency Model

Having fitted a GPD to the amount of loss for a set of excess losses, the next step is to determine the frequency of losses using a Poisson distribution. The Poisson distribution is well known as a single parameter distribution for the number of occurrences of an event with relatively small probabilities given a relatively large sample. The formula for the Poisson distribution is

\[ Pr( x) = \frac{\lambda e^{-\lambda} x^x}{x!} \] (38)

Formula for Poisson distribution of $x$ events with single parameter $\lambda$, the arrival rate. The fitting of the Poisson to a set of occurrences proceeds using the inter-arrival times for the loss events. That is, the average time between events can be used to determine the arrival rate or \textit{lambda} for the Poisson formula. (The arrival rate is simply the inverse of the inter-arrival time). For the Poisson distribution, it can be shown that the maximum likelihood estimator for $\lambda$ is given by the mean arrival rate formula below

$$
\lambda = \frac{\sum kn_k}{n}
$$

(39)

Formula for estimating $\lambda$ for the Poisson distribution; where

$k$ is the number of events in a period,
$n_k$ is the number of periods with $k$ events,
$n$ is the total number of periods.

A goodness of fit statistic for the Poisson distribution can be found using a simple $\chi^2$-squared test. The test statistic is:

$$
\chi^2 = \sum\frac{(n_k - n \Pr(k; \lambda))^2}{n \Pr(k; \lambda)}
$$

(40)

Chi-squared test statistic for the goodness of fit of the Poisson distribution to a set of data; where $Pr(k; \lambda)$ is the probability of $k$ events for the Poisson distribution with parameter $\lambda$. The degrees of freedom are $n-2$.

6.6. Compounding via Monte Carlo Methods

Once severity and frequency distributions have been estimated, it is necessary to compound them via Monte Carlo methods to get a new data series of aggregate losses, so that we can then compute the desired risk measures, such as the VaR and expected shortfall.

The random sum $L=X_1+ ... + X_n$ (where $N$ follows a Poisson distribution) have distribution function:

$$
F_L(x) = Pr(L \leq x) = \sum_{n=0}^{\infty} p_n \cdot Pr(L \leq x|N = n)
$$
\[
= \sum_{n=0}^{\infty} p_n F_{x}^{*n}(x)
\]

where \( F(x) = Pr(X \leq x) \) = distribution function of the severities \( X_i \)

\( F_{x}^{*n} = n \)-fold convolution of the cumulative distribution function of \( X \).

Hence, the aggregation of frequencies and severities is performed as a sum of severities distribution function convolutions, thus determining a compound distribution, whose density function can be obtained by:

\[
f_{L}(x) = \sum_{n=0}^{\infty} p_n F_{x}^{*n}(x)
\]

This aggregation is computed via convolution using Monte Carlo methods. It should also be noted that the convolution is a bit more complex as the severity distribution is split in two parts: the body of the distribution, which follows a lognormal distribution, and the tail, which follows a GPD. As a result, two different severity levels are generated. Hence, the probability associated at each severity (i.e., the number of observations obtained by the Poisson distribution) has to be congruent with the fact that losses may belong to the body or to the tail. Therefore, it is crucial to consider \( F(u) \), where \( u \) is the GPD threshold and \( F \) is the distribution function associated to this point. After having sampled from the two severity distributions, every single loss \( X_i \) whose \( F(X_i) < F(u) \) will be modeled as a lognormal variable, otherwise it will be a GPD random draw.

As shown in Figure 1 and Figure 2, value at risk is generated from both processes, \textit{DGSA} and \textit{EVT}. As a result, an approximation of the magnitude of operational risk is generated by adding the value at risk resulting from \textit{DGSA} and \textit{EVT} processes.

7. Concluding Remarks

Indeed, quantifying operational risk is a very challenging task. One of the main reasons is due to the diverse elements involved in the quantification process. Although the use of Basic Indicator and the Standardised approach in measuring operational risk exposures have been suggested by IFSB, however, both approaches are somewhat inaccurate as the suggested methods are used to calculate operational risk capital. In other words, it is a requirement to set aside a certain amount of capital to cater for operational risk. Consequently, it will not come as a surprise that such an approach will result in a high or low of economic capital number; hence, operational risk capital is over estimated or under estimated.
Nonetheless, a very essential step which is actually overlooked in the process; that is the measurement of operational risks itself. In this respect, this paper proposes an approach for the measurement of operational risk, namely *Delta Gamma Sensitivity Analysis-Extreme Value Theory*. This model is an integrated measurement method which caters for two types of operational risks, namely high frequency-low severity (*HF-LS*) and low frequency-high severity (*LF-HS*) risks. The strength of the model lies in its accuracy in measuring the causality taking place in the value adding process in Islamic banking operations. Moreover, *an elasticity based sensitivity analysis* employed in the first leg of the model would be a better alternative to the common *partial derivatives based sensitivity analysis* since it would not neglect the relative parameter changes that occur in the causality models.

The proposed *DGSA-EVT* model would also give a number advantage to the operational risk managers; first, it is a reflection of potential loss that is not merely based on actual loss figure which is rarely available. This aspect is very crucial since in most cases, operational losses are not recorded, especially in an Islamic bank. To the best of the author’s knowledge, there is not any single Islamic bank which discloses publicly the magnitude of its operational losses. Second, the models reflect the quality of the operations in the banks. Thus, it can be perceived that a bank with a better model is likely to have more effective operational risk management. Third, since the error rates are relative errors based on exposures, the models are related to the size of the firm’s business.

Nevertheless, the paper is theoretical and analytical in nature. Testing the proposed model, therefore, is needed to assess the workability of the model. Indeed, it is a quite daunting task considering that data availability can be a hindrance to such a test.


APPENDIX

The appendix discusses different dimensions of proposed operational risk categories (ORCs) in different types of Islamic financial contracts. As can be seen in the table below, the five dimensions of operational risk categories are Sha'ī ah compliance risk (SR), fiduciary risk (FR), people risk (PR), legal risk (LR), and technology risk (TR). The first three dimensions are, by nature, internally inflicted; while the fourth one is naturally from external source. As for technology risk (TR); it can originate from either internal or external operational failures.

### The Dimensions of Operational Risk Categories (ORCs) in Islamic Financial Contracts

<table>
<thead>
<tr>
<th>Contracts</th>
<th>Internal Risks</th>
<th>External Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sha'ī ah Compliance Risk (SR)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fiduciary Risk (FR)</td>
<td>People Risk (PR)</td>
</tr>
<tr>
<td><strong>Murābaḥah</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Exchange of money and commodity needs to be ensured</td>
<td>Inability to meet the specified product stipulated in the contract</td>
<td>Fail to deliver the product</td>
</tr>
<tr>
<td>• In the event of late payment, penalty must be avoided as it will tantamount to riḥā.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Salam</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Final payment of monetary rewards must be concluded in advance</td>
<td>Inability to meet the specified product stipulated in the contract.</td>
<td>Mismatch in the commodity’s specification due to inability of seller to provide the exact product mentioned in the contract.</td>
</tr>
<tr>
<td>• Penalty clause is illegitimate in the event of seller’s default in delivering the goods</td>
<td>Delivery of inferior goods cannot be accepted</td>
<td></td>
</tr>
<tr>
<td>• In parallel salam, execution of second salam contract is not contingent on the settlement of the first salam contract</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Iṣṭiṣnāf</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Should not be used as a need to ensure the quality</td>
<td>Inability to deliver the</td>
<td>Incompatibility of the new</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

43 This section is heavily drawn from Izhar (2010)
<table>
<thead>
<tr>
<th></th>
<th>Legal device; e.g. the party ordering the product to be produced is the manufacturer himself. In parallel <em>istiqlāb</em>, contracts should be separated to avoid two sales in one deal.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standards of the product on time. Accounting software. Contractor or the customer in the event of remedying the defects. Commodity productions agreed in the contract.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Ijārah</strong></th>
<th>Need to ensure that leased asset is used in a <em>Shari‘ah</em> compliant manner. In <em>ijārah muntahiah bitamleek</em>, an option to purchase cannot be enforced.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Major maintenance of the leased asset is the responsibility of the banks or any party acting as lessor. Lessor needs to understand that in the event of payment delay, rental due cannot be increased as clearly exemplified by AAOIFI.</td>
</tr>
<tr>
<td></td>
<td>Incompatibility of the new accounting software. Enforcement of contractual right to repossess the asset in case of default or misconduct by the lessee. Losses of information on the leased assets specified in the contract due to external security breaches.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Musāḥabah</strong></th>
<th>Profit allocation is based on actual profit, not expected profit. Inadequate monitoring of the financial performance of the venture. Lack of technical expertise in assessing the project. Incompatibility of the new accounting software. A mixture of shares in one entity may lead to legal risk if the regulation does not facilitate such action.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inability to provide regular and transparent financial performance of the project. Incompatibility of the new accounting software. Misinterpretation of civil law upon implementation of <em>Shari‘ah</em> compliant <em>muṣāḥabah</em>. Losses of information on the projects specified in the contract due to external security breaches.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Muṣāḥabah</strong></th>
<th>Profit allocation is based on actual profit, not expected profit. Inadequate monitoring of the business. Inability to provide regular and transparent financial performance of the project. Incompatibility of the new accounting software. Misinterpretation of civil law upon implementation of <em>Shari‘ah</em> compliant <em>muṣāḥabah</em>. Losses of information on the projects specified in the contract due to external security breaches.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inability to provide regular and transparent financial performance of the project. Incompatibility of the new accounting software. Misinterpretation of civil law upon implementation of <em>Shari‘ah</em> compliant <em>muṣāḥabah</em>. Losses of information on the projects specified in the contract due to external security breaches.</td>
</tr>
</tbody>
</table>

---

*Muṣāḥabah* is “selling a commodity as per the purchasing price with a defined and agreed profit mark-up”⁴⁴. This mark-up may be a percentage of the selling price or a lump sum. Moreover, according to AAOIFI standard, this transaction may be concluded either without a prior promise to buy, in which case it is called

---

ordinary *murābaḥah*, or with a prior promise to buy submitted by a person interested in acquiring goods through the institution, in which it is called a “banking *murābaḥah*”, i.e. *murābaḥah* to the purchase orderer. This transaction is one of the trust-based contracts that depends on transparency as to the actual purchasing price or cost price in addition to common expenses.

*Murābaḥah* is the most popular contract in terms of its use, since most of Islamic commercial banks operating worldwide rely on this contract in generating income. Different dimensions of operational risk which can arise in *murābaḥah* transaction are as follows:

- **Sharī‘ah compliance risk (SR)**; may arise if the Islamic banks give money, instead of commodity, which will then result in the exchange of money and money. This is prohibited in Sharī‘ah, since the exchange of money with money, plus additional amount above the principal and paid in different time will tantamount to *riba*. AAOIFI Sharī‘ah standard also requires Islamic banks to own, legally, the commodity before they sell it to the customers. It is important to note that the sequence of the contract is very central in *murābaḥah* transaction. Inability or failure to conform with the sequence and Sharī‘ah requirement will result in the transaction to be deemed illegitimate.

- **Fiduciary risk (FR)**; this risk arises due to the inability to meet the specified commodity stipulated in the contract.

- **People risk (PR)**; the risk can result from two sides, seller as well as buyer. *PR* from the seller side occurs if Islamic banks fail to deliver the specified product agreed in the contract on due date, while *PR* from the buyer side takes place when the buyers does not keep their promise to buy the commodity. This can happen in the binding *murābaḥah* contract.

- **Legal risk (LR)**; profit originated from *murābaḥah* cannot be equated with interest, although it looks similar. The main difference is because the resulting profit is tied with the underlying commodity. This might create legal problem as in certain countries, the regulators only give limitation on interest rate, not profit rate. Hence, the absence of so called ‘profit rate cap’ has the potential to crate legal problems if there is any dispute. Another potential problem can occur at the contract signing stage, since the contract requires the Islamic bank to purchase the asset first before selling it to the customer; the bank needs to ensure that the legal implications of the contract properly match the commercial intent of the transactions.

- **Technology risk (TR)**; may result from an incompatibility of the new accounting software or an external system failure.
Salam and Parallel Salam

AAOIFI Sharī’ah standards define salam as a transaction of the purchase of a commodity for the deferred delivery in exchange for immediate payment. It is a type of sale in which the price, known as the salam capital, is paid at the time of contracting while the delivery of the item to be sold, known as al-muslam fihi (the subject matter of a salam contract), is deferred. The seller and the buyer are known as al-muslam ilaihi and al-muslam or rabb al-salam respectively. Salam is also known as salaf. Parallel salam occurs when the seller enters into another separate salam contract with a third party to acquire goods, the specification of which corresponds to that of the commodity specified in the first salam contract.

- Sharī’ah compliance risk (SR); one of the very central conditions in salam contract is that the payment of salam capital must be paid full in advance. If payment is delayed, the transaction is not called salam. Any delay in payment of the capital and dispersal of the parties renders the transaction a sale of debt for debt, which is prohibited, and the scholars agreed on its prohibition. Another aspect, which might lead to SR may also occur in parallel salam; this will take place if the execution of the second salam contract is contingent on the execution of the first salam contract. Penalty clause is also not allowed, in the event of a seller’s default in delivering the good. The basis for not allowing penalty in salam is because al-muslam fihi (the subject matter of a salam contract) is considered to be a debt; hence it is not permitted to stipulate payment in excess of the principal amounts of debt.

- Fiduciary risk (FR); salam is generally associated with the agricultural sector. The buyer must either rejects goods of an inferior quality to that specified in the contract, or accept them at the original price. In the latter case, the goods would have to be sold at a discount (unless the customer under a parallel salam agreed to accept the goods at the originally agreed price).

- People risk (PR); can arise due to a seller’s default in delivering the commodity or due to the commodity’s specification mismatching. Financial institutions may minimise such type of operational risks by asking from the seller guarantees that they are following a quality management system or following any standard system, or by asking for references on past promises on salam contract or by collateralising their losses via insurance policies.

---

45 AAOIFI, 2005, p. 172
46 AAOIFI, 2005, p. 173
- **Legal risk (LR)**; Islamic banks may face legal risk if the goods cannot be delivered at the specified time (unless the customer under parallel salam agrees to modify the delivery date).

- **Technology risk (TR)**; may result from an incompatibility of the new accounting software or the system fails to specify precisely the commodities agreed in the contract.

**Istiṣnāᶜ and Parallel Istiṣnāᶜ**

*Istiṣnāᶜ* is another type of forward contract, but the role of an Islamic bank as a financial intermediary differs from that in a salam contract. In this case, the bank contracts to supply a constructed asset (such as a building or a ship) for a customer. In turn, the bank enters into a parallel *istiṣnāᶜ* with a sub-contractor in order to have the asset constructed. Its reliance on the parallel *istiṣnāᶜ* counterparty (the sub-contractor) exposes it to various operational risks, which need to be managed by a combination of legal precautions, due diligence in choosing sub-contractors, and technical management by appropriately qualified staff or consultants of the execution of the contract by the sub-contractor. Islamic banks that specialise in *istiṣnāᶜ* financing may have an engineering department. Risks may include the following:

- **Sharīᶜah compliance risk (SR)**; could arise if *Istiṣnāᶜ* is being used as a legal device for mere interest based financing. For instance, an institution buys items from the contractor on a cash payment basis and sells them back to the manufacturer on a deferred payment basis at a higher price; or where the party ordering the subject matter to be produced is the manufacturer himself; or where one third or more of the facility in which the subject matter will be produced belongs to the customer. All the circumstances mentioned above would make the deal an interest based financing deal in which the subject matter never genuinely changes hands, even if the deal won through competitive bidding. This rule is intended to avoid sale and buy back transactions (*bayᶜ al-ʿīnah*). In parallel *istiṣnāᶜ*, the separation of contracts is a must, hence this is not an instance of two sales in one deal, which is prohibited.

- **Fiduciary risk (FR)**; the sub-contractor may fail to meet quality standards or other requirements of the specification, as agreed with the customer under the *istiṣnāᶜ* contract.
- **People Risk (PR);** this may arise if the Islamic bank may be unable to deliver the asset on time, owing to time overruns by the sub-contractor under the parallel *istișnā*, and may thus face penalties for late completion.

- **Legal risk (LR);** Islamic banks may face legal risk if no agreement is reached with the sub-contractor and the customer either for remedying the defects or for reducing the contract price.

- **Technology risk (TR);** may result from an incompatibility of the new accounting software or the system fails to specify precisely the commodities that would be produced in the contract.

**Ijārah and Ijārah Muntahia Bitumleek**

In simple terms, an *ijārah* contract is an operating lease, whereas *ijārah muntahia bitumleek* is a lease to purchase. While operational risk exposures during the purchase and holding of the assets may be similar to those in case of *murābahah*, other operational risk aspects include the following:

- **Sharīʿah compliance risk (SR);** the Islamic banks need to ensure that the asset will be used in a Sharīʿah compliant manner. Otherwise, it is exposed to non-recognition of the lease income as non-permissible.

- **Fiduciary risk (FR);** major maintenance is the responsibility of an Islamic bank as a lessor, as directed by AAOIFI Sharīʿah standards. In addition to that, it is the duty of the lessor to ensure that the usufruct is intact, and this is not possible unless the asset is maintained and kept safe so that the lessor may be entitled to the rentals in consideration for the usufruct. Thus, deficiencies in maintaining such responsibility can be deemed to be sources of *FR* in *ijārah* contract.

- **People risk (PR);** lessee is not allowed to increase the rental due, in case of delay of payment by the lessee, this is what AAOIFI clearly exemplifies. Misunderstanding of this principle by the staff is a source of losses caused by *PR*, because the income generated from this, is not permissible from Sharīʿah point of view.

- **Legal risk (LR);** the Islamic bank may be exposed to legal risk in respect of the enforcement of its contractual right to repossess the asset in case of default or misconduct by the lessee. This may be the case particularly when the asset is a house or apartment that is the lessee’s home, and the lessee enjoys protection as a tenant.

---

47 AAOIFI, 2005, p. 154
Technology risk (TR); may occur due to an incompatibility of the new accounting software or losses of information on the leased assets due to external security breaches.

**Mushārakah**

*Mushārakah* is a profit and loss sharing partnership contract. The Islamic bank may enter into a *mushārakah* with a customer for the purpose of providing a Shari‘ah compliant financing facility to the customer on a profit and loss sharing basis. The customer will normally be the managing partner in the venture, but the bank may participate in the management and thus be able to monitor the use of the funds more closely. Typically, a diminishing *mushārakah* will be used for this purpose, and the customer will progressively purchase the bank’s share of the venture. Operational risks that may be associated with *mushārakah* investments are as follows:

- **Sharī‘ah compliance risk (SR);** the source of SR may arise due to the final allocation of profit taking place based on expected profit. AAOIFI commands that it is necessary that the allocation of profit is done on the basis of actual profit earned through actual or constructive valuation of the sold assets\(^{48}\).
- **Fiduciary risk (FR);** any misconduct or negligence of the partners are the sources of FR. This can happen in the absence of adequate monitoring of the financial performance of the venture.
- **People risk (PR);** lack of appropriate technical expertise can be a cause of failure in a new business activity.
- **Legal risk (LR);** an Islamic bank which enters into *mushārakah* contract needs to acquire some shares from separate legal entity that undertake Shari‘ah compliant activities. A mixture of shares in one entity may lead to legal risk if the regulation does not allow doing such action.
- **Technology risk (TR);** may occur due to an incompatibility of the new accounting software or losses of the precise information on projects undertaken due to external security breaches.

**Muḍārabah**

*Muḍārabah* is a profit sharing and loss bearing contract under which the financier (*rabb al māl*) entrusts his funds to an entrepreneur (*muḍārib*). The

\(^{48}\) AAOIFI, 2005, p. 205
exposure of operational risk in *muḍārabah* is somewhat similar to that of *mushārakah*. However, since this type of contract may be used on the assets side of the balance sheet, as well as being used on the funding side for mobilising investment accounts, the operational risk is first analysed from the assets-side perspective and then from the funding side perspective (which is related to fiduciary risk).

### Asset-side *Muḍārabah*

Contractually, an Islamic bank has no control over the management of the business financed through this mode, the entrepreneur having complete freedom to run the enterprise according to his best judge judgement. The bank is contractually entitled only to share with the entrepreneur the profits generated by the venture according to the contractually agreed profit sharing ratio. The entrepreneur as *muḍārib* does not share in any losses which are borne entirely by the *rābb al māl*. The *muḍārib* has an obligation to act in a fiduciary capacity as the manager of the bank’s funds, but the situation gives rise to moral hazard especially if there is information asymmetry—that is, the bank does not receive regular and reliable financial reports on the performance of the *muḍārib*. Hence, in addition to due diligence before advancing the funds, the bank needs to take precautions against problems of information asymmetry during the period of investment.

### Funding-side *Muḍārabah*

Profit-sharing (and loss bearing) investment accounts are a *Sharīʿah* compliant alternative to conventional interest-bearing deposit account. Since a *muḍārabah* contract is employed between the Islamic bank and its investment account holders, the investment account holders (*IAHs*) share the profits and bear all losses without having any control or rights of governance over the Islamic bank. In return, the Islamic bank has fiduciary responsibilities in managing the *IAHs*’ funds. The *IAHs* typically expect returns on their funds that are comparable to the returns paid by competitors (both other Islamic banks and conventional institutions), but they also expect the Islamic bank to comply with *Sharīʿah* rules and principles at all times. If the Islamic bank is seen to be deficient in its *Sharīʿah* compliance, it is exposed to the risk of *IAHs* withdrawing their funds and, in serious cases, of being accused of misconduct and negligence. In the latter case, the funds of the *IAHs* may be considered to be a liability of the Islamic bank, thus jeopardising its solvency.