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REVIEW

# Measurement models for market risk management in Nigeria

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Market risk is connected with the price fluctuations and other market factor movements on four of the world's most prominent financial markets: Debt securities market, stock market, currency market and commodity market. The high level of unpredictability in the market in which organizations operate is a significant element driving the fast growth of risk measurement and management. Firms are exposed to more market risk in a volatile environment, which offers a motivator for them to develop new and improved risk models. This paper generally analyzes the performance of different models which try to solve, estimate, measure and manage various market risks in order to derive parameters which aid good decision making.

**Keywords:** insurance market risk, volatility, risk management, value at risk (VaR)

## Introduction

### Background the study

According to Ama (1), There's a chance that a goal oriented system's favorable expectations won't be met. Anghelache et al. (2) viewed Market risk is defined as the possibility of losing money on a position due to changes in market pricing and other risk variables. Because each categorization may pertain to distinct aspects of market hazards, there is no one classification for market risks. Equity risk, interest rate risk, currency risk, commodity risk, margin risk, shape risk, holding period risk, basis risk, image/reputational risk, and so on are the most prevalent forms of market hazards. The equity risk is the possibility that stock indices/prices or implied volatility will change, whereas the interest rate risk is the possibility that interest rates or implied volatility will change. The currency risk is the risk of changes in international exchange rates. Margin risks arise from the uncertainty of future cash withdrawals as a consequence of margin calls to cover unfavorable position value changes. Image risk concerns itself with the reputation of an organization. If the image/reputation is dented in one way or the other, businesses in that market will be affected

adversely. An example of this in Nigeria in 2017 was the case between the GTBank versus the chairman of Innoson Vehicle Manufacturing (IVM), Dr Innocent Ifediaso Chukwuma. Another illustration is the harm non-settlement of claims has done to the reputation of insurance industry in Nigeria.

All these market risks pose threats to the attainment of major objective and to maximization of advantages (such as the utility for the consumers and profit for the enterprise). Risks are taken by all enterprises depending on two factors: the business analysts' view of likelihood/probability of loss occurrences and view of money based on wealth (3). Market risk is linked to price changes and other market element movements on four of the most major economic markets: the market for debt securities, the market for equity securities, and the market for commodities. Stock market, currency market, and commodity market.

### Problem analysis

The market's biggest treasure is closely aligned to adequate awareness of movements of prices and other market related factors which help to combat the adverse effects of various market risks. Salient potential in the market is due to a lack

of skills or understanding in recognizing future estimations, the treasure has been kept untapped. Therefore, a framework is needed to measure market risk adequately so that the level of any uncertainty can be reduced to the barest minimum, if not totally eradicated. In Nigeria, a lack of knowledge of the genuine market situation has resulted in unnecessarily high inflation and shortages of goods and services. It must be noted that many risk assessment/management standards have been criticized for providing no quantifiable improvement in market hazards, while trust in estimates and judgments appears to be increasing. Furthermore, the variance, covariance, and history Simulation techniques to calculating VaR all presume that previous correlations are stable and will not alter or break down in the future or under market stress (4). The duration market turmoil and periods of severe volatility make this assumption inappropriate as historical correlations tends to break down, especially during financial crises in contrast to an upward going market, all industrial sections face a large increase in correlations. This phenomena is referred as asymmetry correlation/dependence has great impacts on the market value.

The amount of money that might be lost as a result of market risk can be calculated in a variety of ways. The conventions of value at risk (VaR) models are widely known and recognized in short-term risk management practice. It must be noted that VaR's accuracy is constrained by a variety of limiting assumptions. It is assumed that the portfolio composition of the portfolios being measured does not vary over time. In fact, because we live in a dynamic world, this limiting assumption may be considered inappropriate over longer time horizons, as many of the positions in the portfolio or market values may have changed. The only thing constant is change.

One of the major problems in insurance business is claim settlement. It is of no news that many insurers in Nigeria are or have been involved in litigations as a result of non-settlement of claims. This situation has really affected the image/growth of the industry negatively. This problem arises when a claim or an insurance market risk which has a 100% probability of occurring is ignored due to lack of identification ability or wrong usage of underwriting risk model (such as using individual underwriting risk model for collective underwriting risk model and vice versa). The risk and return of insurance business is directly related. That is, the higher the risk the higher is the likelihood/probability of the returns. It may be too risky to invest insurance funds on securities of higher interest returns because higher returns also go hand-in-hand with high security volatility which can lead to loss of invested funds. Loss of invested funds will in turn affect insurance claim settlement. Therefore, there is a need to balance the discrepancy between the actuarial and the financial methods of assessing and measuring insurance risks, especially when dealing with single and group policies.

## Objective of the study

To manage markets risks effectively, one needs to critically identify, actuarially assess and carefully prioritize the identified and assessed risks through the usage of an appropriate market risk model. The general objective of this study is to analyze the performance of different models which attempt to solve, measure and manage various market risks in order to derive estimates or parameters which appropriately aid decision making process and reduce/predict what the potential risk scenario could be. Therefore, the specific objectives, which must be attained in the course of this research work, are listed below.

- To develop a framework that will make future estimates/forecasts/predictions more reliable and authentic.
- To exhibit how a certain change in interest levels can impact on the market value.
- To modify concepts of VaR Model in order to aid informed decision making over longer period horizons.
- To derive an appropriate market risk model for a single policy and the overall market risk for a group of policies, whose volatility/deviation (of expected claim value and actual claim incurred) will be insignificant.

## Research questions

The following research questions must be answered in a specific manner in this study.

- How can we make our statistical estimates to mea- sure market risks adequately in order to reduce uncertainty levels to the barest minimum?
- How can duration periods of high volatility and market turbulence during financial crises affect market value?
- How do other moments (third and fourth) help to modify VaR Method of risk measurement/modeling?
- How can we strike a balance between the actuarial and the financial methods of assessing insurance market risks in order to combat claim settlement problems?

## Scope and limitation of the area of study

This study generally focuses on the analysis of various models that attempt to proffer solutions to market risk problems. Its scope shall be limited to situations in Nigerian markets (financial and insurance), although references will be made to global situations. The major limitation envisaged in this study is likely to be difficulty in getting appropriate/relevant data and/or unwillingness of market operators to release sensitive data for analysis for the fear of falling into the hands of competitors or leaking their financial operations/information

to wise customers who can use such information against them in making more profit for themselves which leads to no or low profit for the servicing operators.

## Significance of the study

There is need to control various market risks and balance the possibility of gains. The dynamic interdependencies of market risks are determined by the optimal management of each type of market risks earlier mentioned, taking into account the models/systems of risks and potential for transformation of the risks. The great degree of unpredictability in the market in which firms operate is a significant element driving the fast growth of risk measurement and management. The findings of this study will be extremely useful to market participants and stakeholders. It may also serve as an asset to students/lecturers and others in the related field of study. Finally, policymakers, investors, and the general public will greatly benefit from the research.

## Theoretical overview

According to Navarrete (5), the variance covariance and history simulation techniques to computing VaR are effective alternatives to Monte-Carlo simulations for all specified multivariate models. They enhance the variance covariance matrix estimation. The Gaussian copula and well specific marginal may be used to provide a forecast of asset distribution using Monte-Carlo simulation. Allowing for empirical features in stock returns (such as auto-regression, asymmetric volatility, skewness, and kurtosis) in the modelling process is thought crucial. Negatively based correlations and variance co-variances suffer from substantial estimate errors if these qualities are not taken into consideration. Fluctuations in market prices and other market factors play major role on the market value of an investment. One of the most significant and underappreciated aspects of market risk monitoring and modelling is model risk. It casts a long shadow over all aspects of risk management, and prudence dictates that we treat it seriously. We rely on data and indexes to estimate volatility. We should continue to question ourselves what would happen if our assumptions were to collapse.

## Financial risk

According to Blaauw (6), Group Chief Risk Officer of United Bank for Africa PLC, market risk can occur when banks accept financial assets subject to market price volatility as collateral for loans. Poor market risk management procedures can swiftly result in considerable losses in turbulent market conditions, as well as catastrophic institutional collapse in extreme cases. According to Kallestrap (7), the global market crisis has revealed that markets are becoming more interconnected, complicated, and unpredictable than previously thought. The management of market risk is highly complex but size of the market risk exposure can be reduced in such a way to allow banks avoid potential losses that can be incurred under extreme and adverse market volatility (8).

Financial losses as a result of market volatility have resulted in a gradual deterioration in our economic basis and foreign reserves. This has also discouraged small and medium-sized businesses, which are one of the primary drivers of any economy. In banking, the knowledge of market risks and how to model them are very crucial to successful business operations. Enyi and Adebawo (9) suspected that the 2008 financial sector collapse in Nigeria was caused by an incorrect risk assessment and exposure model. Portfolio theory and the capital asset price model should be reviewed periodically in order to guide investors on risk of loss of financial value due to fluctuations in market prices and other factors as many forms of market risks arise. Bankruptcy is the most dramatic example of market risk management failure. Deriving variance parameters from past market rate data might aid in estimating the probable risk scenario for a particular statistical confidence limit. Interest rate risk is defined by Elton and Gruber (10) as the likelihood that changes in interest rates will have a negative impact on a certain financial instrument or portfolio. According to Emilia (11), the most often utilized methods for analyzing bank interest rate risk include discrepancy analysis, simulation methods, and duration methods. The Discrepancy Analysis Method measures the difference between interest-sensitive assets and liabilities over a specific time period. When the amount of the assets being examined during a specific time exceeds the sum of the liabilities, the bank has a positive disparity. If a bank has a negative disparity and interest rates rise, net interest income will fall since higher interest rates have more obligations than assets.

In the same vein, revenues will also decrease if the bank has a positive difference and interest rates fall. Therefore, the discrepancy helps to show the risk to which interest income is exposed. Unfortunately, this method does not record changes in payment dates that may occur as a result of changes in the interest environment. This method is suitable when there is identical movement of interest rates. A new model is required due to the non-similar behavior of interest rates across different time periods in dynamic markets. The simulation approach is based on the idea that interest rate fluctuations are dynamic rather than static. Monte-Carlo simulation is used as a standard for the evaluation of portfolios, and incorporates many market variables. But in order for this model to be reliable, it is necessary at each calculation to perform a sufficiently large number of repetition/recalculation. This is a very demanding

task in terms of computing power. Due to the demands and complexity of this system, it is sometimes difficult for a bank's management to keep track of what their risk man- agers are actually doing.

Profit/loss is uncertain due to movement of the market factors. Therefore, a framework is needed to measure financial risk effectively. Berkowitz (12) believed that the traditional solution assumes a mean-variance framework. In other words, we estimate market risks in terms of the mean and variation or standard deviation of profit/loss. Nonetheless, the assumption of normality has its limitations as the distribution requires only two parameters [i.e., first moment (mean) and second moment (variance) (13)]. According to Elton and Gruber (10), Portfolio theory, for example, assumes that the behavior of the returns on any group of assets can be characterized in terms of an expected return vector and a variance- covariance matrix that describes the relationship between individual returns. As previously indicated, one of the most serious VaR has the drawback of not being sub-additive. To solve this difficulty, we must first explain the concept of sub-additivity. A risk measure p(ǔ) is said to be non-sub-additive if the total of the measured risks of positions X and Y is less than or equal to the total of the various positions' estimated risks when examined independently, i.e.

$$P(X + Y) < P(X) + P(Y) \qquad (1)$$

Sub-additive indicates that the sum of individual hazards does not raise total risks. If risks are sub-additive, combining them will overestimate combined risk, meaning that the sum of risks can be used as a conservative estimate of combined risk. This enables decentralized decision making inside a firm since a supervisor may always use the total of the risks of the units reporting to him as a cautious risk assessment. If the risks are not sub-additive, however, adding them together leads in an underestimate of the overall risk, making the sum of hazards useless as a risk measure. We want our risk assessments to be conservatively or impartially biased in risk management. As a result, for any risk measure, sub-additive is a highly desirable attribute. Unfortunately, VaR is seldom sub-additive, and it can only be if we make the implausible assumption that Profit/Loss or returns are slightly more widely or consistently distributed. In addition, by meeting the sub-additive criterion, coherent risk metrics accurately rep- resent diversification effects and simplify decentralized decision-making.

For instance, if X and Y are two risk positions' future values, a risk measure p() is said to be coherent if it satisfies the following properties.

$$P(X) + P(Y) \le P(X + Y)(sub - additivity) \qquad (2)$$

$$P(tX) = tP(X)(homogeneity) \qquad (3)$$

$$P(X) \ge P(Y), if X \le Y(monotonicity) \qquad (4)$$

$$P(X + n) = P(X) - n(risk - free condition) \qquad (5)$$

Where

n = any number
t = positive number

The sub-additive property has already been explained. The homogenous and monotonous properties are plausible a priori criteria, and combined they indicate that the function p() is convex (14). Last but not least the condition specifies that adding a fixed amount n to the position will reduce risk by the same volume since the end-of-period portfolio value will grow. The highest predicted loss on a collection of loss values and their associated probabilities can be viewed as a consistent risk indicator.

Risk modelling uses a number of strategies to analyze a portfolio and anticipate the potential losses sustained for a variety of hazards. Econometric approaches are used in financial risk modelling to assess the aggregate risk in a financial portfolio (15). Many big financial intermediary organizations use risk modelling to assist portfolio managers in determining the amount of capital reserves to keep and to steer their purchases and sales of various classes of financial assets. Previously, risk analysis was done subjectively, but now that sophisticated computing tools is available, quantitative risk analysis can be done rapidly and easily.

According to Mandelbrot and Richard (16), modeling changes with limited variance distributions is known to be ineffective. They discovered that price changes in financial markets do not follow a Gaussian distribution. Large changes up or down are more common than what a Gaussian distribution with an assumed standard deviation would predict. Furthermore, the fair value or future cash flows of a specific financial instrument may fluctuate due to changes in currency exchange rates. Understanding and management of risk in currency exchange rate volatility can be very complicated because there exists an imperfect correlation between currency exchange rates and interest market rates (17).

## Insurance risk

In a competitive insurance market, the market risk load indicates equilibrium pricing (18). The market risk load and the insurer specific risk load can be calculated independently from the total risk load for a policy. Through premium payments, uncertainty of future loss is eliminated or reduced by the insured. The premiums collected by the insurer serve as the reward for taking the insured risk. Therefore, the premiums serve as the cost of the insurance market risk. The actuarial estimate of insurance market risk has evolved significantly. According to classic premium principles, a risk load is determined by the volatility of the insured loss itself, and volatility is quantified by the variance or standard

deviation. According to Zhang, these methodologies are unsatisfactory since they quantify the risk of the insured but not the risk of the insurer.

Because the insurance market is competitive and market participants are rational decision makers, an effective insurance risk model should account not just the volatility of the policy loss but also the insurance company's portfolio and market competitive risk. The frictional cost of capital is one of the risk factors associated with an insurer's capital structure. As a result, it's appropriate to divide the insurer's total risk into two categories: market risk and specific risk, which may be quantified separately. Kato and Yoshiba [19] discovered that the risk model reflects two key pricing perspectives: actuarial and financial. The risk/return of the insurance companies is addressed under actuarial view while the financial view examines portfolio of shareholders. The actuarial technique handles mutual selection but pays little consideration to the well-being of the shareholders. The two models work well together.

## Backtest and stresstest

### Backtesting

Backtesting might provide us with additional information regarding the appropriateness or insufficiency of the risk model being utilized. This procedure helps to evaluate the market risk model. In order to do so, a certain VaR confidence level, specific market instrument positions, and a specific collection of market price/return data must be supplied. When evaluating market risk models, backtesting is crucial. It necessitates the use of quantitative statistical approaches to determine whether or not a market evaluation model is acceptable. It may be used for three different things. The first is to allow the conclusion that the evaluations are statistically consistent with the relevant outputs to be reached. It also assists risk managers in detecting flaws within their risk models. Finally, it aids in ranking the performance of several alternative market models. The validity of the value at risk models, like that of other models, should be verified on a regular basis.

### Stress tests

In the similar vein, stress tests are required to verify whether a financial organization is strong enough to withstand major market shocks. Because previous volatility may not hold in the future, we must stress-test historical parameters to assure the robustness of maximum loss estimations. This is best accomplished through simulation, in which a portfolio is run through a large number of probable market situations [20]. The tests assess the impact of unusual, but not impossible, market situations on revenue or financial positions. In doing so, a decision should be made as to whether to stress only one variable over time or a group of numerous variables. The stress test findings can be utilized for a variety of purposes, including risk reporting and identification, risk limit establishment, capital allocation, and premium adjustment. With stress tests, the effects of exceptional events in the market are analyzed.

# Methodology and model specification

## Introduction

This section describes how data and resources for the study were acquired. It states some problems encountered in the process of data gathering. It also focuses on the many models and metrics that will be used to provide empirical support for the study.

## Research design

Design refers to the plan and strategy of investigation conceived so as to control variances [21]. Data collecting is not confined to a single method. Personal interviews and/or business observations were conducted with specialists, acquaintances, and family members in the relevant organizations. The majority of the secondary data came from the internet, periodic reports, forums, articles, newspapers, textbooks, paper presentations, journals, and other publications from business or business-related organizations.

## Population of the study

This study focuses on the analysis of Nigerian market risks through the use of different models. The study's geographical scope is not restricted to Nigerian businesses but may also be applied to broader scenarios.

## Sample size of the study

Based on the models, analyzes will be carried out on insurance and financial risks. Furthermore, in order for this study to be a resounding success, the major analysis will be done on the lending interest rates in Nigeria (from 1970 to 2018) obtained from the Central Bank of Nigeria. The focus is to derive estimates for future interest rates so that the market players can position/prepare themselves against adverse movements of these rates. The sample size is determined by the size of the population studied.

## Problems encountered

The main issue in this study was financial firms' unwillingness to provide their data for research purposes.

Some claimed that the main reason was to prevent competitors from gaining access to their secrets through detailed analysis of their raw data, while others claimed that a letter or directive from the office of the "Governor of Central Bank or President of the Federal Republic of Nigeria (GCFR)" was required before sensitive data could be released for research purposes. This caused delay in the duration of the study. Also, figures of the major data obtained from different sources were slightly different form each other. For instance, a lending rate of 16.23% in a particular year from one source could be 16.22% in another source. This might be due to approximation or fluctuation problems. Through properly constructed and precisely formulated models, steps were made to limit the consequences of this to a bare minimum. Nonetheless, the quality of data collected/used was highly praised and suggested for future researchers or persons directly involved in the study by concerned fans of this field of study.

## Model specification

This section describes the models that will be utilized on the various metrics to provide empirical evidence for the study.

### Financial risk

***Value at risk (VaR) model.*** A random variable X is given a typical distribution, which mean $\mu$ and variance $\sigma^2$ (or standard deviation $\sigma$) for the probability that X takes the value x, f(x) obeys the following probability density function (pdf).

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{1}{2}[(x - \mu)/\sigma]^2\right] \qquad (6)$$

Where x is defined over $-\infty < x < \infty$.
   If the mean $(\mu) = 0$ and the standard deviation $(\sigma) = 1$, this is known as a standard normal.

***Duration model.*** To calculate the duration, one needs to calculate the Net Present Value (NPV) first.
   The summation is then divided by the instrument value in order to arrive at the duration.

$$NPV = \sum_{i=1}^{n} \frac{P_i}{(1 + r)^i} \qquad (7)$$

Where
   i = year of payment; P = principal to be paid; r = interest rate.

***Least square model.*** **Table 1** will be analyzed by Least Square Method which will give a practical estimate of the time trend. It is assumed that the trend is linear. Hence the equation of the linear trend is defined as:

$$\hat{Y} = a + bX \qquad (8)$$

Where:

   **X** = transformed time (t);
   **Y** = the estimated trend value for a given period;
   a = value of the trend line at time zero (i.e., @ t = 0);
   b = the slope of the trend line (i.e., the change in Y per unit change in time).

The constants **a** and **b** can be calculated using:

$$b = \frac{n\sum XY - \sum X \sum Y}{n\sum X^2 - (\sum X)^2} \qquad (9)$$

$$a = \frac{n\Sigma X^2 \Sigma Y - \Sigma X \Sigma Y}{n\Sigma X^2 - (\Sigma X)^2} \qquad (10)$$

At $\Sigma X = 0$;

$$b = \frac{\Sigma XY}{\Sigma X^2} \qquad (11)$$

$$a = \frac{\Sigma Y}{n} \qquad (12)$$

## Standard error of the estimate ($S_e$)

Standard error of the estimate is a measure that assesses the reliability of the result obtained. It measures the variability or scattering of the observed values around the regression line. It is evaluated using the formula below.

$$Se = \sqrt{\frac{\Sigma(Y - Y)^2}{n - 2}} \qquad (13)$$

## Insurance risk

Assuming an insurance market contains $N$ policies with random losses $x_1$, $x_2$,...$x_N$, where the market premium for policy ***i*** is $P_i$.
   The premium will be invested in a risk free asset with rate of return rf. If $R_i$ is the rate of return on premium, the mean and the covariance of the random returns are:

$$\mu_i = E(R_i) = (1 + r_f) - \frac{E(X_i)}{P_i} \qquad (14)$$

$$\begin{aligned} \sigma_{ij} &= Cov(R_i, R_i) \\ &= cov(\frac{xi}{pi}, \frac{xj}{pj}) \\ &= \frac{1}{P_iP_j}cov(X_iX_j) \end{aligned} \qquad (15)$$

**TABLE 1** | Historical lending interest rates in Nigeria (1970–2018).

| Year | Interest rate (%) | Year | Interest rate (%) | Year | Interest rate (%) | Year | Interest rate (%) |
|------|------|------|------|------|------|------|------|
| 1970 | 7 | 1982 | 10.25 | 1994 | 21 | 2006 | 16.90 |
| 1971 | 7 | 1983 | 10 | 1995 | 20.18 | 2007 | 16.94 |
| 1972 | 7 | 1984 | 12.5 | 1996 | 19.74 | 2008 | 15.48 |
| 1973 | 7 | 1985 | 9.25 | 1997 | 13.54 | 2009 | 18.36 |
| 1974 | 7 | 1986 | 10.25 | 1998 | 18.29 | 2010 | 17.59 |
| 1975 | 6 | 1987 | 17.5 | 1999 | 21.32 | 2011 | 16.02 |
| 1976 | 6 | 1988 | 16.5 | 2000 | 17.98 | 2012 | 16.79 |
| 1977 | 6 | 1989 | 26.8 | 2001 | 18.29 | 2013 | 16.72 |
| 1978 | 7 | 1990 | 25.5 | 2002 | 24.4 | 2014 | 16.55 |
| 1979 | 7.5 | 1991 | 20.01 | 2003 | 20.48 | 2015 | 16.85 |
| 1980 | 7.5 | 1992 | 29.8 | 2004 | 19.15 | 2016 | 16.87 |
| 1981 | 7.75 | 1993 | 36.09 | 2005 | 17.95 | 2017 | 17.88 |
|  |  |  |  |  |  | 2018 | 18.00 |

CBN statistical bulletin (www.cbn.gov.ng).

# Data analysis, presentation, and interpretation

## Insurance risks

From the Equations (14) and (15) stated in section "Insurance risk", it is easy to model the risk for a single policy **i** and the overall market risk for all **n** policies.

The risk of ith policy can be derived by multiplying the premium discount factor $\left(i.e. \quad \frac{P_i}{1+rf}\right)$ by its expected value in Equation (14).

$$\frac{P_i}{(1+rf)}X\mu_i = \frac{P_i}{(1+rf)}X\left[(1+rf) - \frac{E(X_i)}{P_i}\right]$$
$$= P_i - \frac{E(X_i)}{P_i} \tag{16}$$

Also, for n policies, the overall market risk load is;

$$P^N - \frac{E(X^N)}{1+rf} \tag{17}$$

## Financial risks

### *Value at risk (VaR) model*

In line with Equation (6), **Figure 1** is derived and explained below.

### *Interpretation*

According to the graph, it's more likely that the consequences will occur towards the mean μ. The standard deviation determines the distribution of probability mass around the mean σ . To put it another way, the higher the standard deviation, the more scattered the probability mass.

As a result, the pdf is symmetric about the mean. The random variable **X** is as likely to take a particular value $x$–μ

as to take the corresponding negative value–$(x$–μ ). The pdf tails away on both sides, with the left-hand tail corresponding to extremely low random realizations.

Variables, while the right-hand tail corresponds to high realization and more likely occurrence of random event.

Assuming a particular x-value (say 1.645) is chosen from a normal distribution table, we can regard this value as a profit of −1.645 (left-hand side) or loss of 1.645 (right-hand side). Invariably, it means that there is a 5% (0.05) probability of making a loss or 95% (0.95) probability of making profit.

The value 1.645 can then be described as the value at risk (VaR) at 95% confidence level.

### *Sub-additivity of VaR model*

A portfolio of two short bets on very-out-of-the-money binary options is a good counter-example that shows VaR's sub-additivity. Assume that each binary choice has a **6%** probability of a payout of 1.5 m and a **94%** probability of a payout of 0.

The rewards are based on separately distributed underlying variables, therefore the payoff on one binary option is independent of the payout on the other. If the VaR confidence level (cl) is set to 95% and the holding period is set to the amount of time before the options expire, each position has a VaR of 0 at the 95% level. If we combine the two positions, however, the probability of a N0 payout falls to less than **95%** and the VaR is positive and equal to 1.5 m. As a result, the VaR of combined positions is larger than the sum of the VaRs of individual positions, as shown in Equation (2). Therefore, VaR is not sub-additive. The illustration of the given example is explained in the **Table 2**. Furthermore, VaR is not sub-additive and so is not a consistent risk measure. As a result, another idea for gauging market risk is the conditional value-at-risk (CVaR). This is sub-addictive and coherent for generic loss distributions, including discrete distributions. However, the presumption of normalcy has
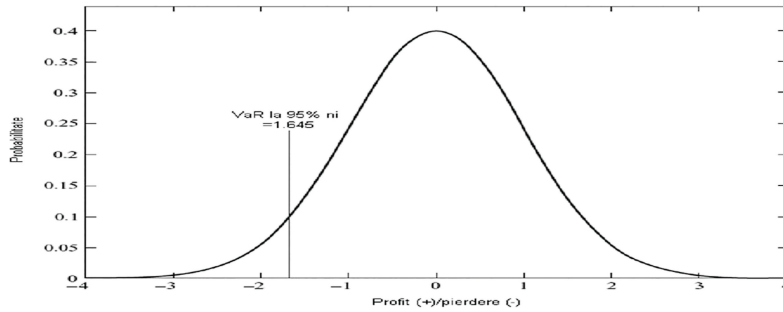
**FIGURE 1 |** The normal probability density.

**TABLE 2 |** The value at risk (VaR) of individual positions.

| Position X | | Position Y | |
|---|---|---|---|
| (₦′) payout | Probability | (₦″ m) payout | Probability |
| −1.5 | 0.06 | −1.5 | 0.06 |
| 0 | 0.94 | 0 | 0.94 |
| VaR at 95 cl | 1.00 | VaR at 95 cl | 1.00 |

**TABLE 3 |** The value at risk (VaR) of combined positions.

| Payout (₦″000,000) | Calculation | Probability |
|---|---|---|
| −3 | $0.06^2 = 0.06 \times 0.06$ | 0.0036 |
| −1.5 | $(0.06)(0.94) + (0.94)(0.06) = 2(0.94)(0.06)$ | 0.1128 |
| 0 | $0.94^2 = 0.94 \times 0.94$ | 0.8836 |
| VaR at confidence level (cl) | | 1.00 |

limitations as the distribution requires only two parameters [i.e., first moment (mean) and second moment (variance) (13)]. Other instances (third and fourth) can be crucial. The third instant indicates the distribution's asymmetry. This causes skewness.

$$Skewness = \frac{E(x - \mu)^3}{\sigma^3} \qquad (18)$$

A symmetric or normal distribution has a skewness coefficient of 0, while an asymmetric distribution has a skewness coefficient of non-zero.

If the distribution is skewed, we must account for its skewness if we are to appropriately estimate its risk probabilities. The fourth moment (kurtosis) parameter indicates the fatness of the distribution's tails.

$$Kurtosis = \frac{E(x - \mu)^4}{\sigma^4} \qquad (19)$$

The tails of the distribution will be the same as the normal distribution if the kurtosis parameter is set to 3. A kurtosis value greater than 3 shows broader tails, implying that an extreme event (i.e., loss severity) is more frequent but less likely to be huge. A tail value of less than 3 suggests

that extreme occurrences are less likely to be greater than expected. The extreme events here can either result to gain or loss. Except when dealing with a symmetric (i.e., zero-skew) distribution with a kurtosis of 3, the normality assumption is unsuitable and can lead to substantial mistakes in market risk analysis. Because of its strong relationship with some of the most prominent ways to financial risk measurement, it is critical to verify for normalcy. For example, VaR coupled with daily market risk monitoring and control, cap the risk/loss at a certain level of confidence.

Implementing volatility-based limits, which adjust the size of position limits automatically in response to rising market volatility, is a good way to guarantee market risks are capped at any pre-determined level.

### Duration model

In accordance with Equation (7), imagine a bank purchases a 5 year bond with a nominal value of $2,000 and an annual interest rate of 10%.

$$NPV = \sum_{i=1}^{5} \frac{\$2000}{(1 + 0.1)^i} = \$7, 581.57 \qquad (20)$$

$$Duration(D) = \frac{\$7, 581.5}{\$2, 000} = 3.79 years \qquad (21)$$

Interpretation: The period of 3.79 years is a measure of the average life-cycle of the interest sensitivity of the 5 year bond.

Unfortunately, this method does not record changes in payment dates that may occur as a result of changes in the interest environment. The duration method for resolution displays the time and quantity of cash flows received before the instrument's contractually stated maturity term. The longer the maturity period and the wait for the next change in the instrument price, the lower the payments received ahead to maturity. Because the period is longer, a change in interest rates has a higher influence on economic value.

### Least square model

In this section, Table 1 was be analyzed by using Least Square Model in relation to Equations (8) to (13) already stated in the previous section. From Equation (12),

$$a = \frac{153.27}{9} = 17.03 \qquad (22)$$

**TABLE 4 |** Prime lending rate analysis (2010–2018).

| Year | Interest rate (Y) | Transformed time trend (X) | X,Y | $X^2$ | Y | $(Y-Y)^2$ |
|---|---|---|---|---|---|---|
| 2010 | 17.59 | −4 | −70.36 | 16 | 16.52933 | 1.125014 |
| 2011 | 16.02 | −3 | −48.06 | 9 | 16.6545 | 0.40259 |
| 2012 | 16.79 | −2 | −33.58 | 4 | 16.77967 | 0.000107 |
| 2013 | 16.72 | −1 | −16.72 | 1 | 16.90483 | 0.034163 |
| 2014 | 16.55 | 0 | 0 | 0 | 17.03 | 0.2304 |
| 2015 | 16.85 | 1 | 16.85 | 1 | 17.15517 | 0.093127 |
| 2016 | 16.87 | 2 | 33.74 | 4 | 17.28033 | 0.168373 |
| 2017 | 17.88 | 3 | 53.64 | 9 | 17.4055 | 0.22515 |
| 2018 | 18.00 | 4 | 72.00 | 16 | 17.53067 | 0.220274 |
| | $\Sigma Y = 153.27$ | $\Sigma X = 0$ | $\Sigma X,Y = 7.51$ | $\Sigma X^2 = 60$ | | $\Sigma = 2.499198$ |

**TABLE 5 |** Prime lending rate analysis (2011–2017).

| Year | Interest rate (Y) | Transformed time trend (X) | X,Y | $X^2$ | Y | $(Y-Y)^2$ |
|---|---|---|---|---|---|---|
| 2011 | 16.02 | −3 | −48.06 | 9 | 16.1825 | 0.026406 |
| 2012 | 16.79 | −2 | −33.58 | 4 | 16.39214 | 0.15829 |
| 2013 | 16.72 | −1 | −16.72 | 1 | 16.60179 | 0.013975 |
| 2014 | 16.55 | 0 | 0 | 0 | 16.81143 | 0.068345 |
| 2015 | 16.85 | 1 | 16.85 | 1 | 17.02107 | 0.029265 |
| 2016 | 16.87 | 2 | 33.74 | 4 | 17.23071 | 0.130115 |
| 2017 | 17.88 | 3 | 53.64 | 9 | 17.44036 | 0.193286 |
| | $\Sigma Y = 117.68$ | $\Sigma X = 0$ | $\Sigma X,Y = 5.87$ | $\Sigma X^2 = 28$ | | $\Sigma = 0.619682$ |

**TABLE 6 |** Prime lending rate analysis (2012–2018).

| Year | Interest rate (Y) | Transformed time trend (X) | X,Y | $X^2$ | Y | $(Y-Y)^2$ |
|---|---|---|---|---|---|---|
| 2012 | 16.79 | −3 | −50.37 | 9 | 16.4225 | 0.135056 |
| 2013 | 16.72 | −2 | −33.44 | 4 | 16.64643 | 0.005413 |
| 2014 | 16.55 | −1 | −16.55 | 1 | 16.87036 | 0.102629 |
| 2015 | 16.85 | 0 | 0 | 0 | 17.09429 | 0.059676 |
| 2016 | 16.87 | 1 | 16.87 | 1 | 17.31821 | 0.200896 |
| 2017 | 17.88 | 2 | 35.76 | 4 | 17.54214 | 0.114147 |
| 2018 | 18 | 3 | 54 | 9 | 17.76607 | 0.054723 |
| | $\Sigma Y = 119.66$ | $\Sigma X = 0$ | $\Sigma X,Y = 6.27$ | $\Sigma X^2 = 28$ | | $\Sigma = 0.672539$ |

Using Equation (11),

$$b = \frac{7.51}{60} = 0.12517 \qquad (23)$$

From Equation (8),

$$\hat{Y} = 17.03 + 0.12517 \qquad (24)$$

From Equation (13),

$$Se = 0.5975 \qquad (25)$$

$$\hat{Y} = 16.8114 + 0.2096X \qquad (26)$$

$$Se = 0.352 \qquad (27)$$

$$\hat{Y} = 17.0943 + 0.2239X \qquad (28)$$

$$Se = 0.3668 \qquad (29)$$

From **Table 7**, the best equation to be used for the estimates of future lending interest rate is Y = 16.8114 + 0.2096X as

**TABLE 7 |** Comparison of results.

| Table | Decision equation | Standard error (Se) | Probability of error |
|-------|-------------------|---------------------|----------------------|
| 4 | Y = 17.03 + 0.12517X | 0.5975 | 35.70% |
| 5 | Y = 16.8114 + 0.2096X | 0.3520 | 12.93% |
| 6 | Y = 17.0943 + 0.2239 X | 0.3668 | 13.45% |

**TABLE 8 |** Estimated lending rates (2023–2025).

| Year | X | Interest rate (%) |
|------|---|-------------------|
| 2023 | 9 | 18.70 |
| 2024 | 10 | 18.91 |
| 2025 | 11 | 19.12 |

derived from **Table 5** because the standard error and the chance of error are the least.

# Final result

## Conclusion and recommendation

### Conclusion and summary

Any financial or non-financial entity with a portfolio of financial assets is exposed to many types of risks and, as a result, should apply risk measurement and management strategies to optimize the way a risk is taken. As a result, the risk of large economic losses or even bankruptcy is reduced, and the institutions become more competitive. Once the estimates of the distribution of future changes are available (e.g., as shown in **Table 8**), to estimate the risk, you'll need to use a risk measurement. It is also necessary to validate the model through back-testing (as shown in **Table 7**). The risk attached to a particular investment is related to the return on such investment. Management of the risk can be effectively attained when historical information reflects the current market process of securities and insider privilege information is publicly available. Risks develop not just as a result of changes in market factors, but also as a result of actions taken by market players who are willing to take risks (i.e., risk seekers), transfer risks (i.e., risk averters) or are risk indifferent (i.e., risk neutrals). To have precisely recorded amounts and parameters, market risk requires sufficient management and analytical systems to analyze major risk factors and to utilize commonly accepted financial concepts and procedures for risk measurement.

### Recommendations

Faced with continuously changing market rudiments and increasing regulations, financial institutions (i.e., bank and non-bank) need to regularly review and optimize their models, processes and systems for measuring and managing risks. This will be followed by a planned and cost-effective use of resources to reduce, monitor, and manage the likelihood or impact of unanticipated occurrences, or to optimize the realization of possibilities, so that risk uncertainty does not detract from the endeavor's commercial objectives. Various financial organizations should have suitable processes in place that reflect their market risk exposure.

In agreement with Banjo (3), avoiding market risks and other uncertainties with negative effects is a common strategy for managing market risks and other uncertainties with negative repercussions (i.e., risk avoidance); reducing the negative effect/probability of the risks (i.e., pre-loss and post-loss risk minimization); transmitting all or part of the danger to a third party (insurance) (i.e., risk transfer mechanism); and even keeping some or all of the risks' potential/actual repercussions (i.e., risk retention).

Therefore, choice of a model depends on the positions for which the model is to be used; and the user's risk management capacities and technical possibilities.

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