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A Monte Carlo Simulation Approach in Assessing Risk and Uncertainty Involved in Estimating the Expected Earnings of an Organization: A Case Study in Nigeria

H. I. Okagbue, S. O. Edeki*, A. A. Opanuga

Department of Mathematics, College of Science & Technology, Covenant University, Otta, Nigeria

Abstract This work provides a simulation-based approach of assessing the risk and uncertainty involved in estimating the expected earnings of an organization. The procedure involves using Monte Carlo Simulation (MCS) in creating various possible outcomes and scenarios. The MCS is found to be more effective than single point estimates or guesswork. Hence, it is an efficient and useful tool in risk management analysis. The analysis of the output of the simulation reveals that the expected earnings is a little bit lower than the most likely forecasted value of N30m but there is 37% chance that the expected earnings might drop below or rise above the estimated value by margin of N10.9m and the wide range of possible outcomes make the venture to be very risky as uncertainties in unit sales, unit price or variable cost can push the earnings to assume any value within the wide range. It is also observed that a large increase in the unit sales and a moderate increase in the unit price will increase the expected revenue which will in turn increase the earnings. The regression analysis gives almost the same result as MCS.

Keywords Monte Carlo Simulation, Risk Analysis, Expected Earnings

1. Introduction

Business environment involves risk, and we often have difficulty in estimating the expected earnings of an organization, especially for the upcoming year. In finance, there is a fair amount of uncertainty and risk involved when estimating the future values of figures (expected earnings and revenues) due to wide variety of potential outcomes. Most organizations give a single point estimate of their projected earnings which may be misleading [1]. Some even resort to guesswork or trial and error method. This is also is a poor method. We live in an environment faced with risk and operate our businesses in a risky world, as higher rewards only come with risks. Planning in any organization is risky when the elements of risk are neglected. The availability of computers has made simulation possible; some of these techniques include Monte Carlo Simulation used in this paper. It helps in creating and forecasting the future (expected earnings) while investigating the risk involved in the process. MCS is a technique that converts uncertainties in input variables of model into probability distributions. It is a very effective technique, widely accepted for true results [2]. It is characterized by a unique feature for running multiple simulations by using multiple randomly generated numbers for the prediction of outcomes for risk variables [3]. It is used as a substitute for numerical integration [4-5]. The MCS as a class of computational algorithms depend on a repeated random sampling to obtain numerical results.

Jonathan in [6] wrote that risk and uncertainty are very different animals, but they are of the same species, the lines of demarcation are often blurred. Risk is something one bears and it is the outcome of uncertainty. Only using the results from an uncertainty simulation analysis like Monte Carlo Simulation and finding ways to hedge or mitigate the quantified fluctuations and downside risk of the organization's market performance in this work, would be constructed as having performed risk analysis and management.

Risk can be seen as any uncertainty that affects a system in an unknown fashion whereby the ramifications are also unknown but bears with it great fluctuation in value and outcome [6-7]. What we can do to understand risks better is through a systematic assessment of measuring, monitoring and managing risks, otherwise simply noting that risks exist and moving on is not optional [8]. Risk analysis is a technique for enhancement of results and not an alternative for standard investment appraisal methodology [3]. Edeki *et al* noted the effects of stochastic capital reserve on actuarial risk analysis with regard to ruin and survival probabilities [9].

Knight in [3] argued that risk and certainty were initially

* Corresponding author:
soedeki@yahoo.com (S. O. Edeki)
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not the same; stressing that risks cover events whose outcomes are known or can be quantified as a result of historical evidence and probability distribution. Many researchers reject the validity of Knight's view to risks [10-12].

2. Formulation of the Mathematical Problem & Model Description

In this section, we describe the problem to be solved, objectives of the study and a brief but concise description of the model to be used.

The research work is based on the application of MCS to a probabilistic model which bears a risk.

2.1. Formulation of the Mathematical Problem

A big sized bakery located at Ogudu G.R.A., Lagos, Nigeria, owned by a promising entrepreneur was faced with the problem of assessing the risk involved in calculating the expected earnings in the coming year. He wanted to know exactly how their market performance will be before he can talk of diversification, expansion, recruitment of staff etc. He was very concerned with the uncertainties in the prices of the raw materials like wheat flour, butter, sugar, yeasts, vegetable oil, others and the diesel used in powering the bakery in the absence of power.

Based on their market performance for the past 3 years, the manager then assumed that their revenue and earnings before tax will be the data shown below:

We denote Unit price as P_N^u, Unit sales as S_N^u, Revenue as R_N, Variable cost as V_C, Fixed cost as F_C, Total costs as T_C, Earnings as E_N, and Costs C_N, (all in ₦'000:00).

Table 1. Market performance for the last 3 years

Year	P_N^u	S_N^u	R_N	V_C	F_C	T_C	E_N
1	160	280	44,800	16,000	4000	20000	24800
2	150	350	52500	18000	4000	22500	30000
3	150	380	57000	21000	4000	25000	32000

Table 2. Forecasted Market Performance

Year 4	P_N^u	S_N^u	R_N	V_C	F_C	C_N	E_N
Min	140	240	33600	15000	4000	19000	14600
Most likely	150	360	54000	20000	4000	24000	30000
Max	160	480	76800	25000	4000	29000	47800

We define the Earnings before income tax as:

$$E_N = \left(P_N^U \times S_N^U\right) - \left(V_C + F_C\right) \quad (1)$$

2.2. Objectives of the Research

a. We will be investigating how the uncertainty in the unit price, unit sales and variable costs affect the expected earnings.

b. Comparing the single point estimate and the Monte Carlo various possible outcomes and scenarios and then drawing conclusion.

c. Investigating the amount of risk involved in predicting the earning of the organization.

d. Demonstrating the use of Monte Carlo Simulation as an efficient risk management tool and evaluating its forecasting power.

e. Calculate the amount of risks using different methods like; probability of occurrence, standard deviation, volatility etc.

f. Critical examination of the behavior of our distribution at small samples, which is area of interest because theoretical substantiation for most parametric inference techniques is based on large sample theory [13-15].

g. Making inference on the comparison of the theoretical and the simulated results of all the variables of the model.

h. Running a convergence test to determine the efficiency of the Monte Carlo method and also comparing it and regression forecasts.

2.3. Model Description and Methodology

$$\begin{aligned} Earnings &= \left(Unit\ \text{Price} \times Unit\ Sales\right) \\ &\quad - \left(Variable\ Cost + Fixed\ Cost\right) \\ &= Revenue - Total\ Cost \end{aligned}$$

Thus, for a fixed cost of ₦4000, (1) becomes:

$$E_N = \left(P_N^U \times S_N^U\right) - \left(V_C + 4000\right) \quad (2)$$

The variables in the model based on the above table follow a triangular distribution. The triangular distribution describes a situation where the minimum, maximum and most likely value are known to occur. The most likely value falls between the minimum and maximum value forming a triangular – shaped distribution, which shows that values near the minimum and maximum are likely to occur than those near the most likely value.

The research was carried out by simulation. The aim being to recreate many artificial scenarios based on the collected data. The data was collected from a bakery. The mode of data collection was manual.

Since a model has been assumed and the variables are identified to follow triangular distribution which is just an improvement on the uniform distribution, we are going to simulate the variables using the SPSS 17.0. It is important to note that since we do not have data points on the SPSS data window, we must write a program for the simulation.

Henceforth, a program was written and run on the syntax window to generate the required data. In this case, we simulate for the unit price (140,160), the unit sales (240000, 480000), and the total cost (15000000, 25000000).

The variables are arranged in columns with their corresponding data points in rows on a spreadsheet form. The outputs show that the computer randomly resamples the data and the descriptive as it would be seen later are closer to the forecasted values based on the model.

3. Data Analysis: The Simulated and the Theoretical Results

3.1. Comparison between the Simulated & Theoretical Results at both Large & Small Samples

Before any analysis is done, we first of all compare the results of the simulated data with that of the theoretical data. This is done by substituting the values obtained from the simulation into the equations of the triangular distribution to determine the mean and the standard deviation respectively, since the model assumptions is based on the fact that all the variables follow the triangular distribution. The aim of this comparison is to investigate whether the simulated values of all the variables are close to their corresponding theoretical values. The theoretical results was based on the following formulae of the triangular distribution

$$Theoritical\ Mean = \frac{\left(Min_{\Delta} + Mean_{\Delta} + Max_{\Delta}\right)}{3} \quad (3)$$

$$Theoritical\ SD = \sqrt{\frac{\left(\begin{array}{l} Min_{\Delta}{}^2 + Mean_{\Delta}{}^2 + Max_{\Delta}{}^2 \\ -Min_{\Delta}Mean_{\Delta} - Min_{\Delta}Max_{\Delta} \\ -Mean_{\Delta}Max_{\Delta} \end{array}\right)}{18}} \quad (4)$$

where Min_{Δ} is simulated minimum, $Mean_{\Delta}$ is simulated mean, and Max_{Δ} is simulated maximum.

It can be clearly seen that the values of both the simulated and the theoretical are closer on their average values than their standard deviation when compared together.

Apart from the high standard deviations of the respective variables, the theoretical values differs greatly from the simulated one, meaning that the smaller the sample size, the higher the bias. This implies that the higher the sample size, the more efficient Monte Carlo Simulation becomes in estimating the various variables.

Table 3. Comparison between the Theoretical & Simulated results at large sample

	Theoretical		Simulated	
Variables	Mean	Std. Deviation	Mean	Std. Deviation
Earnings	30,477,523	10,392,187.91	29,769,855.8	10,980,275.1
Price	149.9986	4.08	149.9958	5.75
Unit Sales	359,546.24	48,970.8	358,613.39	69,275.8955
Variable Cost	20,007,857.33	2,040,899.67	20,022,217.3	2,873,246.71
Revenue	54,653,417.7	8,716,673	53,792,073.2	10,606,408.4
Total Cost	24,007,857.4	2,040,889.7	24,022,217.4	2,873,246.71

Table 4. Comparison between the theoretical & simulated results at small sample

	Theoretical		Simulated	
Variables	Mean	Std. Deviation	Mean	Std. Deviation
Earnings	31,900,330	9,261,481	30,380,228	13,012,795
Price	149.4452	3.94	148.72	6.51
Unit Sales	362,766.1	46,416.17	356,051.8	74,082.24
Variable Cost	19,420,629.33	1,835,668.8	18,729,896	2,597,866
Revenue	55,162,629	14,366,969.3	53,110,124	12,016,751
Total Cost	23,420,784	1,835,669	22,729,896	2,597,866

Table 5. Descriptive for the Earnings

		Statistic	Std. Error
EARNINGS Mean		29,769,855.8	1,09803E5
95% Confidence Interval for Mean	Lower Bound	29,554,620.3	
	Upper Bound	29,985,091.3	
5% Trimmed Mean		29,709,568.1	
Median		29,467,040.9	
Variance		1.206E14	
Std. Deviation		10,980, 275.1	
Minimum		5,383,177.6	
Maximum		56,279,535.9	
Range		50,896,358.3	
Interquartile Range		17,927,389.9	
Skewness		.071	.024
Kurtosis		-948	.049

Measurement of Risk

Standard deviation of the earnings is ₦10,980,275

Coefficient of Variation: Coefficient of Variation (CV) is simply the ratio of Standard Deviation to the mean i.e. the measure of risk per unit earnings, or when inverted can be used as a measure of earnings per unit of risk. Thus, for profit optimization, we will be interested in minimizing the CV and maximizing the inverse of the CV:

$$CV = \frac{SD}{Mean} = \frac{10980275.1}{29769855.8} = 0.37 \quad \text{and} \quad \frac{1}{CV} = 2.71$$

Table 6. Coefficient Correlations of the Independent Variables

Model		VARIABLE COST	PRICE	SALES
1	Correlations	1.000	.002	-.003
	VARIABLE COST	.002	1.000	-.004
	PRICE	-.003	-.004	1.000
	SALES			

Dependent Variable: EARNINGS.

Table 7. Nonparametric Correlations

		Earnings	*Price*	*Sales*	*Variable Cost*
Spearman's rho	*Earnings* -Correlation Coefficient Sig. (2-tailed)	1.000 .	.178 .000	.950 .000	-.244 .000
	Price - Correlation Sig. (2-tailed)	.178 .000	1.000	.004 .683	-.003 .802
	Sales - Correlation Coefficient Sig. (2-tailed)	.950 .000	.004 .683	1.000 .	. 004 .722
	Variable Cost- Correlation coefficient Sig. (2-tailed)	-.244 .000	-.003 .802	.004 .722	1.000

Correlation is significant at the 0.01 level (2-tailed)

Table 8. Nonparametric Correlations

		Earnings	*Revenue*	*Total Cost*
Spearman's rho	*Earnings* -Correlation Coefficient Sig. (2-tailed)	1.000 .	.967 .000	-.244 .000
	Revenue - Correlation Sig. (2-tailed)	.967 .000	1.000 .	-.003 .742
	Total Cost - Correlation coefficient Sig. (2-tailed)	-.244 .000	-.003 .742	1.000 .

Correlation is significant at the 0.01 level (2-tailed).

Table 9. Summary of analysis of the Kolmogonov – Simorov test for the 2 distribution

	Normal				Uniform		
	Z	**1-α/2**	**C.I**		**Z**	**1-α/2**	**C.I**
Earnings	4.910	0.9207	84.14%	**E**	12.937	0.9927	98.54%
Price	5.982	0.9934	98.68%	**P**	0.524	0.6985	39.7%
Sales	6.115	0.9956	99.12%	**S**	1.266	0.8980	79.6%
Variable Cost	5.698	0.9861	97.00%	**V**	0.773	0.7794	55.88%

Table 10. Model Summary for the Regression[b]

Model	1
R	.999[a]
R Square	.999
Adjusted R Square	.999
Std. Error of the Estimate	4.01930E5
R Square Change	.999
F Change	2484151.504
df1	3
Df2	9996

a. Predictors: (Constant), VARIABLE COST, PRICE, SALES.
b. Dependent Variable: EARNINGS

Table 11. Comparison of the forecasted earnings of MCS and Regression

	Minimum	Maximum	Mean	Std. Deviation	₦
Regression	4,260,962.	55,271,860	29,769,855.8	10,972,918.5	10000
Monte Carlo	5,383,177	56,279,535	29,769,855.8	10,980,275.1	10000

The predictions are the same but regression analysis gave a smaller risk.

Table 12. Summary of the effects of P.S.V. on E

	Price	Unit Sales	Variable Cost
Regression	0.187	0.946	-0.262
Monte Carlo	0.178	0.950	-0.244

The effect of the impacts of the price, sales, and the variable cost are approximately the same in both analytical methods.

Table 13. MCS Convergence test

Variable	Min	Max	Mean
Earnings	29617404	30286287	29,972,148.06
Revenue	53610208	54256305	53,970,543.72
Total cost	23875390	24072126	23,996,651.73

Table 14. The analyses are summarized as follows

	₦	Mean	Std. Deviation
EARNINGS	10000	N29,769,855.8	N10,980,275.1
REVENUE	10000	N53,792,073.1	N10,606,408.4
TOTAL COST	10000	N24,022,217.3	N2,873,246.7

3.2. Discussion of Results

Here, we will briefly discuss and highlight the key findings as revealed by the analysis of our results as follows:

a. Values of both the simulated and the theoretical are closer on their average values than their standard deviation when compared together at large samples.

b. Apart from the high standard deviations of the respective variables, the theoretical values differs greatly from the simulated one, meaning that the smaller the sample size, the higher the bias. This implies that the higher the sample size, the more efficient Monte Carlo Simulation becomes in estimating the various variables.

c. The expected earnings are likely to be ₦29,769,855. We are also 95% confident that the expected earnings, the standard deviation is estimated to be ₦10,980,275 which is the measure of risk. The large SD implies that there is high probability that the expected earnings might drop below or rise above the forecasted earnings which is very risky especially when it falls below the forecasted earnings. Also the wide range of ₦50, 896,358 means that the expected earnings can assume a wide range of values which can be lower or higher. Also this is very risky as uncertainties in unit price, unit sales or variable costs can push the earnings to assume any value within the wide range.

d. The minimum and maximum values of the simulated earnings are in variance with their respective forecasted values.

e. The skewness equals 0.071 means there is a small probability of expecting lower earnings.

f. The Kurtosis estimate is – 0.948 which means that we will expect large losses/gains-that is, the probability of having the outliers as our potential earnings despite the uncertainties in the unit price, unit sales or variable costs, this is as a result of the thinner shape of the distribution and few outliers. Statistically, it implies that the probability of the earnings to assume values outside the range is small.

g. The coefficient of variation CV equals 0.37 means that there is 37% chance that the expected earnings can deviate by ₦10,980,275.

h. The correlation between the unit sales & earnings and between unit price & expected earnings is positive. Variable costs and earnings, on the other hand, are negatively correlated.

i. The correction between the revenue and the expected earnings is positive. Total cost and earnings, on the

other hand, are negatively correlated.

j. The price and the variable cost are positively correlated. While the unit sales and the variable cost are negatively correlated. Also the price and the unit sales are negatively correlated

k. Kolmogorov-Smirnov test reveals that all the simulated data approximately fits the normal distribution.

l. Comparison between MCS and regression reveals that the model actually fits; the forecast are almost the same but regression analysis gives a higher risk. The effects of the impacts of the price, sales, and the variable cost on the earnings are approximately the same in both MCS and Regression.

m. The result of the convergence test shows that the simulation falls between the accepted ranges and hence, the simulated data are closer to the forecast one.

4. Conclusions and Recommendations

From the analysis, Monte Carlo Simulation is straight forward and flexible in application. However, it cannot wipe out uncertainty and risk, but it makes them easier to be understood by ascribing probabilistic characteristics to the inputs and the outputs of a model. It can be very helpful for determining different risks and factor that affect forecasted variables and, therefore, leads to accurate predictions. As seen, it was used to recreate and recover a process, thereby creating a scenario comparable with the forecasted data. MCS estimate as compared to a single value estimate is more accurate and effective. The uncertainties in the unit price, the unit sales, and the variable costs affect the expected earnings positively or negatively. MCS also provides a probability of the entire earnings outcomes allowing the decision makers to explore any pertinent scenarios associated with their expectation. Finally, MCS provides managers with critical information on which risk factors and assumptions that are driving the projected probability of earnings outcomes, giving them all important feedback they need to focus their resources on, addressing those risk assumptions that will have the greatest positive impact on their business, improving their efficiency and profit optimization.

The firm is therefore, advised to plan effectively since there are chances that the expected earnings might fall or rise above the forecasted. Hence, to ensure profitability, they should improve on the quality to maximize unit sales at a more customer friendly price. On the other hand, they should devise ways to minimize production costs, since the estimated value are unlikely to deviate greatly as seen in the analysis.

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