WEALTH ASSESSMENT OF TWO CORPORATE INVESTORS WHEN RETURN RATES FOLLOWS LINEAR AND QUADRATIC FUNCTIONS

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Abstract. Modeling in financial mathematics is motivating uniqueness involving stochastic systems. Therefore, this examined stochastic systems with changes to measure the value of wealth for each corporate investor through linear and quadratic returns. The stochastic systems were solve analytical by implementing the Ito's method of solution .The sufficient conditions were achieved which gave room for assessing each wealth for corporate investors. Consequently, the imprints on each solution of investors were analyzed accordingly. From the stochastic analysis of the table solutions we have as follows ; increase in the intrinsic growth rate increases in investors wealth; an increase in stock prices does indeed increase the value of wealth; when interest rates rise, the value of wealth decreases; a decrease in the interest rate increases the value of wealth; an increase in volatility decreases the value of wealth; more increase in volatility due to periodic parameter, the value of wealth becomes more sensitive to changes in the volatility of the underlying assets and finally, the second corporate investors has the largest value of wealth in the portfolio of investments. However, the effects of the significant parameters of stochastic variables were successfully discussed as it affects each independent corporate investor.
Keywords: *stochastic systems, linear and quadratic returns, investors, wealth and corporate investors*

Introduction

Generally, investments are ventures linked with risk which cannot be over emphasized. The human lives and day-to-day activities, are associated with risk; thus, risk is a determinant to effectively manage investment portfolios, because it is instrumental to the ascertainment of fluctuation or variations of returns on the stock and portfolio, which furnishes the investor a mathematical framework for investment decisions; bonds, stocks, property, etc., are all prototypes of the risk associated to securities. Nevertheless, because of the risk involved in the management of investment portfolios, insurance companies deemed it pertinent for lives, properties, etc., to be insured. In point of fact, insurance companies share third party in the management and control of their financial results. Risk transfer or risk sharing is the methodology employed by insurance firm on financial outcomes of its coverage duty in a number of ways with risk transfer agreement, risk among numerous insurance firms globally. Therefore, in a situation of astronomical loses from financial situation as insurance company will not encounter risk, particularly, reinsurance means the division and distribution of risk. In general, risk is an established factor as long as humans are concerned, since we secure risky or riskless assets properly.

The stock exchange market or the share market or the equity market is a part of the capital market in which prime lenders are able to access long term funding in form of securities. The stock owners and a trader (investor) and may be or can include the provision of facilities for the issuing and redemption of financial instruments with the inclusion of the payment of incentives and dividends. The stock exchange market is a free market economy that offers investors opportunities to increase their income without the high risk of entering into their own business as a result of high overhead cost on working capital and also offers the companies the opportunities to increase their worth by accessing the capital for exponential expansion. The stock market is one of the largest sectors of the financial industry. By its involvement in the transferring of available funds from investors to the equity issuers it plays a vital role in business development and economic growth. Though, a better way to model these factors is as the trajectory or path of a diffusion process defined on many basic or fundamental probability space, possessing the geometric Brownian motion, used as the standard reference model (Osu, 2010) modeling financial concepts cannot be overstated because of its copious applications in real life, for example (Adeosun et al., 2015) considered stochastic analysis of stock market price model, using the Nigerian stock exchange (NSE) as a case study. Farnoosh et al. (2015) studied analytical solutions of stochastic differential equations connected to Martingale processes. Nevertheless, Amadi and Vivian (2022) whereas studying a stochastic analysis of stock price variation assessments, adopted stochastic analysis of Markov chain on the closing of stock by transforming the stock prices into probability matrix solution for each independent year. Amadi and Okpoye (2022) studied the problem of system of stochastic differential equation of time varying investments where multiplicative inverse affects, additive effects, additive inverse effects were applied as key parameters in the model to obtain stock rate of returns. Amadi and Anthony (2022) measured the differential and stochastic differential equations of time varying investment returns and obtained precise conditions which govern asset price return rates. Also Osu and Amadi (2022) studied the stochastic analysis of stock market expected returns for investors and considered the detailed conditions for obtaining the drifts varieties. More so, Jankauskienė and Miliūnas (2020) applied Lambert function method to analyze market price stability. The roots of the transcendental characteristic equation corresponding to the differential equation having a delay argument was analyzed. Hence, so many scholars has written broadly on stochastic systems namely Amadi et al. (2021; 2022), Davies et al. (2019), Ofomata et al. (2017), Osu (2010), Osu et al. (2009), etc.

The aim of this study is to measure the wealth of two corporate investors through linear and quadratic returns respectively. All the same, it is apparent that Ekakaa et al. (2016) applied systems of equations involving interacting investors in stock markets. The improvement of this present study over the work of Ekakaa et al. (2016) is that the present study considered return rates which follows linear and quadratic function to assess wealth of independent corporate investor for stock markets; as this will widen the scope of this area of study.

Mathematical formulation

A stochastic differential equation is a differential equation with stochastic term. Therefore assume that $(\Omega, \mathrm{F}, \wp)$ is a probability space with filteration $\{f_t\}_t \geq 0$ and $W(t) = (W_1(t), W_2(t), ..., W_m(t))^T, t \geq 0$ an m-dimensional brownian motion on the given probability space. We have sde in coefficient functions of f and g *as* follows

$dX(t) = f\left(t, X(t)\right)dt + g\left(t, X(t)\right)dZ(t),\ 0 \le t \le T,\ X\left(0\right) = x_0,$ Where $T > 0,\ x_0$ is an n-dimensional random variable and coefficient functions are in the form $f : [0, \mathrm{T}] \times \mathbb{R}^n$ *and* $g : [0, T] \times \mathbb{R}^n \to \times \mathbb{R}^{n \times n}$. Sde can also be written in the form of integral as follows:

$$X(t) = x_0 + \int_0^t f\left(S, X(S)\right)dS + \int_0^t g\left(S, X(S)\right)dZ(S) \qquad \text{Eq. (1)}$$

Theorem 1 (Ito's Lemma): Let $f\left(S,t\right)$ be a twice continuous differential function on $[0,\infty) \times \mathrm{A}$ and let S_t denotes an Ito's process $dS_t = a_t dt + b_t dz(t), t \ge 0$ Applying taylor series expansion of F gives

$$dF_t = \frac{\partial F}{\partial S_t} dS_t + \frac{\partial F}{\partial t} dt + \frac{1}{2}\frac{\partial^2 F}{\partial S_t^2}\left(dS_t\right)^2 + \text{higer order terms } \left(h.\mathrm{o,t}\right) \qquad \text{Eq. (2)}$$

So, ignoring h.o.t and substituting for dS_t we obtain:

$$dF_t = \frac{\partial F}{\partial S_t}\left(a_t dt + bdz(t)\right) + \frac{\partial F}{\partial t} dt + \frac{1}{2}\frac{\partial^2 F}{\partial S_t^2}\left(a_t dt + bdz(t)\right)^2 \qquad \text{Eq. (3)}$$

$$= \frac{\partial F}{\partial S_t}\left(a_t dt + bdz(t)\right) + \frac{\partial F}{\partial t} dt + \frac{1}{2}\frac{\partial^2 F}{\partial S_t^2} b_t^2 dt, \qquad \text{Eq. (4)}$$

$$= \left(\frac{\partial F}{\partial S_t} a_t + \frac{\partial F}{\partial t} dt + \frac{1}{2}\frac{\partial^2 F}{\partial S_t^2} b_t^2\right)dt + \frac{\partial F}{\partial S_t} b_t dz(t) \qquad \text{Eq. (5)}$$

More so, given the variable $S(\mathrm{t})$ denotes stock price, then following gbm implies (5) and hence, the function $F\left(S,t\right)$,ito's lemma gives:

$$dF = \left(\mu S \frac{\partial F}{\partial S} + \frac{\partial F}{\partial t} + \frac{1}{2}\sigma^2 S^2 \frac{\partial^2 F}{\partial S^2}\right)dt + \sigma S \frac{\partial F}{\partial S} dz(t) \qquad \text{Eq. (6)}$$

Problem formulation

Here, let the wealth of stock exchange corporate investors be defined as: $V\left(t\right) = \left\{V_1\left(t\right) \text{ and } V_2\left(t\right)\right\}$. The corporate investor depends on the application of system of nonlinear stochastic differential equations. This stochastic systems describes wealth of stock exchange corporate investors in the following manners: the rate of change of wealth of stock exchange on corporate investors depends on the interest rates, growth rates, expected rate of returns: linear and quadratic functions, the initial investments are all positive , stock volatility and some stock variables which measure the levels of independent changes of each investors all at time t. Therefore, the model governing this processes have the following system of stochastic differential equations below:

$$dW_1(t) = \mu_1^2(\alpha_1 + \beta_1)W_1(t)dt + \sigma W_1(t)dW_t^1 \qquad \text{Eq. (7)}$$

$$dW_2(t) = \mu_2^2(\alpha_2 + \beta_2)^2 W_2(t)dt + \sigma W_2(t)dW_t^2 \qquad \text{Eq. (8)}$$

$$W_1(0) = W_{10} > 0,\ W_2(0) = W_{20} > 0, > 0, \} \qquad \text{Eq. (9)}$$

Where μ is an expected rate of returns on stock, σ is the volatility of the stock, dt is the relative change in the wealth during the period of time and $W_t^1 = W_t^2 = W_t^3$ is a wiener process, K are constant and $\tanh$ is rate of returns which follows periodic events, $V_1(t)$ is the dependent variable that measures the wealth of the first stock exchange corporate investors at trading time t, $V_2(t)$ is the dependent variable that measures the wealth of the second stock exchange corporate investors at trading time t, α_1 measures the intrinsic growth rate of the value of stock held by the first corporate investors, α_2 measures the intrinsic growth rate of the value of stock held by the second corporate investors, β_1 measures the interest rate of the first stock exchange corporate investor, β_2 measures the interest rate of the second stock exchange corporate investor, while (3) are initial wealth of each corporate investors.

Materials and Methods

From Eq. (7) let $f(W_1(t),t) = \ln W_1(t)$ taking the partial derivatives yields:

$$\frac{\partial f}{\partial W_1(t)} = \frac{1}{W_1(t)},\ \frac{\partial^2 f}{\partial W_1^2(t)} = -\frac{1}{W_1^2(t)},\ \frac{\partial f}{\partial t} = 0 \Big\} \qquad \text{Eq. (10)}$$

According to Ito's theorem gives:

$$df(W_1(t),t) = \sigma W_1(t)\frac{\partial f}{\partial W_1(t)}dW_t^1 + \left(\mu_1^2(\alpha_1+\beta_1)\frac{\partial f}{\partial W_1(t)} + \frac{1}{2}\sigma^2 W_1^2(t)\frac{\partial^2 f}{\partial W_1^2(t)} + \frac{\partial f}{\partial t}\right)dt \qquad \text{Eq. (11)}$$

Substituting (3.6) into (3.7) gives:

$$df(W_1(t),t) = \sigma W_1(t)\frac{1}{W_1(t)}dW_t^1 + \left(\mu_1^2(\alpha_1+\beta_1)\frac{W_1(t)}{W_1(t)} + \frac{1}{2}\sigma^2 W_1^2(t)\left(-\frac{1}{\partial W_1^2(t)}\right) + 0\right)dt \qquad \text{Eq. (12)}$$

$$= \sigma W_1(t)\frac{1}{W_1(t)}dW_t^1 + \left(\mu_1^2(\alpha_1+\beta_1)\frac{W_1(t)}{W_1(t)} - \frac{1}{2W_1^2(t)}\sigma^2 W_1^2(t)\right)dt = \sigma dW_t^1 + \left(\mu_1^2(\alpha_1+\beta_1) - \frac{1}{2}\sigma^2\right)dt$$

$$= \left(\mu_1^2(\alpha_1+\beta_1) - \frac{1}{2}\sigma^2\right)dt + \sigma dW_t^1$$

Integrating the above expression and taking limits from 0 to t gives:

$$\int_1^t d\ln W_1(t) = \int_0^t df\left(W_1(t)u,u\right) = \int_0^t\left(\mu_1^2(\alpha_1+\beta_1)-\frac{1}{2}\sigma^2\right)du + \int_0^t \sigma dW_t^1$$

$$\ln W_1(t) - \ln W_1 0 = \left(\mu_1^2(\alpha_1+\beta_1)\text{u}-\frac{1}{2}\sigma^2 u\right)_0^t + \left(\sigma dWu\right)_0^t = \ln\left(\frac{W_1(t)}{W_1 0}\right) = \left(\mu_1^2(\alpha_1+\beta_1)-\frac{1}{2}\sigma^2\right)+\sigma W_t^1$$

Taking the ln of both sides gives:

$$W_1(t) = W_1 0e\left(\mu_1^2(\alpha_1+\beta_1)-\frac{1}{2}\sigma^2\right)t+\sigma W_t^1$$

From Eq. (8) let $f\left(W_2(t),t\right) = \ln W_2(t)$, taking the partial derivatives yields:

$$\left.\frac{\partial f}{\partial W_2(t)} = \frac{1}{W_2(t)}, \frac{\partial^2 f}{\partial W_2^2(t)} = -\frac{1}{W_2^2(t)}, \frac{\partial f}{\partial t} = 0\right\} \quad \text{Eq. (13)}$$

According to Ito's gives:

$$df\left(W_2(t),t\right) = \sigma W_2(t)\frac{\partial f}{\partial W_2(t)}dW_t^2 + \left(\mu_2^2(\alpha_2+\beta_2)^2\frac{\partial f}{\partial W_2(t)}+\frac{1}{2}\sigma^2 W_2^2(t)\frac{\partial^2 f}{\partial W_2^2(t)}+\frac{\partial f}{\partial t}\right)dt \quad \text{Eq. (14)}$$

Substituting Eq. (13) into Eq. (14) gives:

$$df\left(W_2(t),t\right) = \sigma W_2(t)\frac{1}{W_2(t)}dW_t^2 + \left(\mu_2^2(\alpha_2+\beta_2)^2\frac{W_2(t)}{W_2(t)}+\frac{1}{2}\sigma^2 W_2^2(t)\left(-\frac{1}{\partial W_1^2(t)}\right)+0\right)dt \quad \text{Eq. (15)}$$

$$= \sigma W_2(t)\frac{1}{W_2(t)}dW_t^2 + \left(\mu_2^2(\alpha_2+\beta_2)^2\frac{W_2(t)}{W_2(t)}-\frac{1}{2W_2^2(t)}\sigma^2 W_2^2(t)\right)dt = \sigma dW_t^2 + \left(\mu_2^2(\alpha_2+\beta_2)^2-\frac{1}{2}\sigma^2\right)dt$$

$$= \left(\mu_2^2(\alpha_2+\beta_2)^2-\frac{1}{2}\sigma^2\right)dt+\sigma dW_t^2$$

Integrating the above expression and taking limits from 0 to *t* gives:

$$\int_1^t d\ln W_2(t) = \int_0^t df\left(W_2(t)u,u\right) = \int_0^t\left(\mu_2^2(\alpha_2+\beta_2)^2-\frac{1}{2}\sigma^2\right)du + \int_0^t \sigma dW_t^2 \quad \text{Eq. (16)}$$

$$\ln W_2(t) - \ln W_2 0 = \left(\mu_2^2(\alpha_2+\beta_2)^2\text{u}-\frac{1}{2}\sigma^2 u\right)_0^t + \left(\sigma dWu\right)_0^t = \ln\left(\frac{W_2(t)}{W_2 0}\right) = \left(\mu_2^2(\alpha_2+\beta_2)^2-\frac{1}{2}\sigma^2\right)+\sigma W_t^2 \quad \text{Eq. (17)}$$

Taking the ln of both sides gives:

$$W_2(t) = W_2 0e\left(\mu_2^2(\alpha_2+\beta_2)^2-\frac{1}{2}\sigma^2\right)t+\sigma W_t^2 \quad \text{Eq. (18)}$$

Results and Discussion

This section presents the graphical results for whose solutions are in Eq. (7) to Eq. (9) respectively. Hence the following parameter values were used in the simulation study:

$$\alpha_1 = 0.0370,\ \alpha_2 = 0.0300, \beta_1 = 0.0014,\ \beta_2 = 0.0010,\ \mu_1 = \mu_2 = 0.25, \sigma = 0.03,$$
$$\mathrm{t} = 5.0000, W_t^1 = W_t^2 = 1.0000,\ V_{10} = 60.77,\ V_{20} = 50.25.$$

Table 1 and *Table 2* shows increase in intrinsic growth rate also increases the value of wealth: when the intrinsic growth rate increases, which in turn leads to an increase in investor wealth. This is because a higher growth rate means that the company is expected to generate more income in the future, and therefore the value of its shares will be higher. However, an increase in stock price does indeed increase the value of wealth, but the magnitude of this increase depends on several factors. Firstly, the percentage increase in stock price matters. A large percentage increase will result in a larger increase in wealth than a small percentage increase. Secondly the number of shares will see a larger increase in wealth than an investor with a small number of shares. Finally, the investor's marginal propensity to consume will see a larger increase in wealth than an investor with a low propensity to consume. Also Table 3 and Table 4 show when interest rates rise, the value of wealth decreases because the present value of future cash flows is reduced. This because the increase in interest rates means that future cash flows are discounted at a higher rate, which reduces their present value. To illustrate this, consider a simple example. If an investor expects to receive one hundred dollars in one year's time, and the interest rate is five percent, the present value of this future cash flow is ninety five dollars. If the interest rate rises to ten percent, the present value of the future cash flow falls to ninety dollars. Thus, the increase in interest rates has resulted in a decrease in the value of wealth. Similarly a decrease in the interest rate increases the value of wealth because the present value of future cash flows increases. To understand why this is the case, let's look at an example. Suppose an investor expects to receive one hundred in five years' time, and the interest rate is five percent. The present value of this future cash flow is eighty one dollars. If the interest rate decreases to three percent, the present value of the future cash flow increases to eighty six dollars. In other- words, the decrease in the interest rate has resulted in an interest in the value of the investor's wealth. This is because the lower interest rate means that the future cash flow. In general, there are comparisons on the value of wealth from *Table 1 Table 4*. The second corporate investor has the largest value of wealth in the portfolio of investments which stands as a guide to investors in terms of decision making

***Table 1**. The effect of intrinsic growth rate to measure the wealth of first corporate investors.*

V_{10}	α_1	σ	Time (t)	$V_1(t)$	α_1	$V_1(t)$
60.77	0.1	0.20000	5.0000	75.5728	1.1	215.9607
	0.2	0.20000	5.0000	85.6352	1.2	298.8962
	0.3	0.20000	5.0000	107.2429	1.3	338.6937
	0.4	0.20000	5.0000	134.3027	1.4	383.7903
50.25	0.1	0.20000	5.0000	62.4903	1.1	218.1124
	0.2	0.20000	5.0000	70.8107	1.2	247.1537
	0.3	0.20000	5.0000	80.2391	1.3	280.0619
	0.4	0.20000	5.0000	90.9228	1.4	317.3516

40.10	0.1	0.20000	5.0000	49.8678	1.1	174.05587
	0.2	0.20000	5.0000	56.5077	1.2	197.2311
	0.3	0.20000	5.0000	64.0316	1.3	223.4922
	0.4	0.20000	5.0000	72.5573	1.4	253.2498
36.0000	0.1	0.20000	5.0000	44.7691	1.1	156.2596
	0.2	0.20000	5.0000	50.7301	1.2	177.0654
	0.3	0.20000	5.0000	57.4847	1.3	200.6413
	0.4	0.20000	5.0000	65.1387	1.4	227.3564

***Table 2**. The effect of intrinsic growth rate to measure the wealth of second corporate investors.*

V_{20}	α_2	σ	Time (t)	$V_2(t)$	α_2	$V_2(t)$
5.0000	0.1	0.20000	5.0000	7.9999	1.1	340.1674
	0.2	0.20000	5.0000	11.6399	1.2	494.9407
	0.3	0.20000	5.0000	16.9359	1.3	720.1344
	0.4	0.20000	5.0000	24.6416	1.4	1001.6841
6.0000	0.1	0.20000	5.0000	9.5999	1.1	408.2009
	0.2	0.20000	5.0000	13.9679	1.2	593.9288
	0.3	0.20000	5.0000	20.3231	1.3	864.1613
	0.4	0.20000	5.0000	29.5699	1.4	1202.0209
5.7000	0.1	0.20000	5.0000	2.679	1.1	387.7909
	0.2	0.20000	5.0000	13.2695	1.2	564.2324
	0.3	0.20000	5.0000	19.3070	1.3	820.9533
	0.4	0.20000	5.0000	28.09148	1.4	1141.9198
5.2000	0.1	0.20000	5.0000	8.3199	1.1	353.7741
	0.2	0.20000	5.0000	12.1055	1.2	514.7383
	0.3	0.20000	5.0000	17.6134	1.3	748.9398
	0.4	0.20000	5.0000	25.6273	1.4	1041.7514

***Table 3**. The effect of interest rate to measure the wealth of first corporate investors.*

V_{10}	β_1	α_1	Time (t)	$V_1(t)$	β_1	$V_1(t)$
60.77	0.1	0.0370	5.0000	42.6636	0.8	1.2883
	0.2	0.0370	5.0000	25.8768	0.6	3.5020
	0.3	0.0370	5.0000	15.6951	0.4	9.5195
	0.4	0.0370	5.0000	9.5195	0.2	25.8768
50.25	0.1	0.0370	5.0000	35.2780	0.8	1.0653
	0.2	0.0370	5.0000	21.3972	0.6	2.8958
	0.3	0.0370	5.0000	12.9781	0.4	7.8716
	0.4	0.0370	5.0000	7.8716	0.2	21.3972
40.10	0.1	0.0370	5.0000	28.1522	0.8	0.8501
	0.2	0.0370	5.0000	17.0752	0.6	2.3109
	0.3	0.0370	5.0000	10.3566	0.4	6.2816
	0.4	0.0370	5.0000	6.2816	0.2	17.0752
36.0000	0.1	0.0370	5.0000	25.2738	0.8	0.7632
	0.2	0.0370	5.0000	15.3293	0.6	2.0746
	0.3	0.0370	5.0000	9.2977	0.4	5.6394
	0.4	0.0370	5.0000	5.6394	0.2	15.3293

***Table 4**. The effect of interest rate to measure the wealth of second corporate investors.*

V_{20}	β_2	α_1	Time (t)	$V_2(t)$	β_2	$V_2(t)$
5.0000	0.1	0.030000	5.0000	3.7507	0.8	0.1133
	0.2	0.030000	5.0000	2.2750	0.6	0.3079

	0.3	0.030000	5.0000	1.3800	0.4	0.837
	0.4	0.030000	5.0000	0.8370	0.2	2.2750
6.0000	0.1	0.030000	5.0000	4.5006	0.8	0.1359
	0.2	0.030000	5.0000	2.7300	0.6	0.3694
	0.3	0.030000	5.0000	1.6560	0.4	1.0044
	0.4	0.030000	5.0000	1.0044	0.2	2.73
5.7000	0.1	0.030000	5.0000	4.2756	0.8	0.1291
	0.2	0.030000	5.0000	2.5935	0.6	0.3510
	0.3	0.030000	5.0000	1.5732	0.4	0.9542
	0.4	0.030000	5.0000	0.9542	0.2	2.5935
5.2000	0.1	0.030000	5.0000	3.9005	0.8	0.1178
	0.2	0.030000	5.0000	2.3660	0.6	0.3202
	0.3	0.030000	5.0000	1.4352	0.4	0.8705
	0.4	0.030000	5.0000	0.8705	0.2	2.366

Conclusion

The stochastic differential equations are well known predominant mathematical gears used for the prediction of stock market variables. Therefore, we considered system of stochastic differential equations with disparities of more stock parameters in the model. These problems were solved analytical by adopting the Ito's lemma method of solution and two different solutions were obtained accurately. From the analysis of the table solutions we deduce that; increase in the intrinsic growth rate increases in investors wealth; an increase in stock prices does indeed increase the value of wealth; when interest rates rise, the value of wealth decreases; a decrease in the interest rate increases the value of wealth; the second corporate investors has the largest value of wealth in the portfolio of investments; which implies returns which follows quadratic function accrues more profit again for investors. To this end, considering the uniqueness of the stock parameters as it affects capital markets will be an interesting study.

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Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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