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DYANAMICS MODEL OF FINACIAL ANALYST IMPACT IN NIGERIAN STOCK EXCHANGE

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Abstract

Mathematical model was developed in this paper in the form of SEIR model to study NSE market dynamics of the interaction between potential investor, conservative investor, equity analyst and quitting investor in Nigeria. The equilibrium points of the model were determined and their stability analysis was performed. The research investigates the stability of the free NSE financial market equilibrium in Nigeria, revealing that it is locally and globally asymptotically stable. Local stability analysis shows the market's ability to recover from small perturbations, while global stability analysis confirms that it will stabilize over time regardless of the magnitude of disturbances. These findings provide real-life investors with confidence in the Nigerian financial market's resilience to both minor and significant shocks. The assurance that the market will return to equilibrium despite fluctuations in stock prices, trading volumes, or larger economic events encourages long-term investments and participation in the NSE.

Keywords: NSE, Lyapunov Function, LaSalle's Invariance Principle

INTRODUCTION

Over the past few decades, Nigeria's financial system has experienced tremendous modifications and grown to become a crucial part of the nation's economic development. The Nigerian Stock Exchange (NSE), which was founded in 1960, is the main venue for trading securities and has played a significant role in raising money for investments across a range of industries. Scholars like Olowe (1999) and Osazevbaru (2014) have emphasized the NSE's contribution to economic expansion and offering investors a variety of options for generating money. The complexities of investment techniques used by the NSE are examined in this essay, with an emphasis on the variables affecting both market performance and investment choices.

The NSE offers a wide range of financial instruments, including equities, bonds, and exchange-traded funds (ETFs). The market has witnessed substantial growth, driven by regulatory reforms, technological advancements, and increased participation from domestic and international investors Ewah *et al.,* (2009) and Odior (2013). However, despite these positive developments, the Nigerian financial market faces several challenges, such as market volatility, liquidity issues, and regulatory constraints. Understanding these dynamics is crucial for investors seeking to optimize their returns while managing risks effectively. The research presents some scholars contribution of the body of knowledge regarding financial market investments conducted by the NSE. It draws attention to important topics including risk management, investor behavior, and market efficiency by combining the results of other studies. They highlight existing gaps in their research, providing guidance for future research topics that may improve our comprehension of investment strategies in the Nigerian financial sector which includes.

Market Capability: Olowe (1999) Okpara (2010) and Ibekwe (2010). examine the NSE's efficiency in "Weak Form Efficiency of the Nigerian Stock Market: Further Evidence." Based on historical prices being able to forecast future prices, the study concluded that the NSE is not weak-form efficient using the serial correlation test and the runs test. It can be inferred that technical analysis has the ability to yield anomalous returns for investors. Its dependence on past price data, which can miss other aspects impacting market efficiency, is the study's drawback.

Investor Conduct: The impact of behavioral biases on stock market volatility in the NSE was studied by Osazevbaru (2014) and (Adamu, & Sanni (2005).) in "Behavioral Finance and Stock Market Volatility in Nigeria". The study discovered, through statistical analysis and a survey approach, that cognitive biases like herd mentality and overconfidence play a major role in market volatility. The study showed that illogical decisions based on feelings rather than facts are frequently made by both individual and institutional investors. The study's concentration on a small sample size, which might not accurately represent the market as a whole, is one of its limitations.

Techniques for Risk Management: The impact of corporate governance on the financial performance of companies listed on the NSE was examined by Ewah *et al.* (2009) and Emenike (2010), Nwidobie(2014), Okoye, & Nwisienyi (2013) in their paper "Corporate Governance and the Performance of Nigerian Publicly Listed Companies." The association between corporate governance practices and firm performance was evaluated by the study using a panel data regression analysis. The results showed that enhanced risk management and higher financial performance are directly related to robust corporate governance procedures. One disadvantage of the research is that it focuses solely on corporate governance, ignoring other risk factors that could influence investment returns

Regulatory Reforms: Effects The effect of regulatory changes on the operation and expansion of the NSE was covered by Oteh (2010) and Acha (2011) in "The Role of the Nigerian Stock Exchange in Economic Development". The study assessed the efficacy of certain regulatory actions put in place by Nigeria's Securities and Exchange Commission (SEC) through qualitative analysis. The results indicated that market performance has been significantly impacted by measures such increased investor protection, stronger disclosure laws, and increased transparency. The absence of quantitative information to back up the qualitative conclusions, however, is a constraint.

Progress in Technology: Yahaya *et al.* (2011) and Enwegbara (2010). looked into how technical developments have affected the growth of the NSE in their study "The Impact of Information Technology on Stock Market Development in Nigeria." The study, which employed a mixed-methods approach combining quantitative data analysis and qualitative interviews, discovered that the use of information technology had enhanced trading efficiency, decreased transaction costs, and broadened market accessibility. Because the study relies on self-reported data from market participants, it may be biased, which is a problem.

FORMULATION OF NSE MODEL

The NSE model was formulated with the knowledge pattern of SEIR model which consists of four compartments. The compartment is classified as potential investor (P), conservative investor (C), equity analyst and quitting investor (R). The model was developed follows this assumption. The potential investor are recruited through birth or immigration at π and decline through the interaction between the potential investor and equity analyst βES and natural death rate δS. The conservative investor likewise increases at βES rate and decrease due to natural death and contact rate of potential investors with the equity analyst at (δ, η) respectively. Meanwhile, the equity analyst increase through the contact with the potential investor at η rate and decline in contact rate γ of leaving investors and natural death rate δ. And finally, the quitting investor is increase leaving investor contact rate γ and decrease by natural death δ. It also assumes all positive parameter.

The formulated model assumption resulted to these nonlinear ordinary differential equations below

$$\left.\begin{aligned} \frac{dt}{dS} &= \pi - \beta ES - \delta S \\ \frac{dt}{dC} &= \beta ES - (\eta + \delta)C \\ \frac{dt}{dE} &= \eta C - (\gamma + \delta)E \\ \frac{dt}{dR} &= \gamma E - \delta)R \end{aligned}\right\} \quad (0.1)$$

Having initial conditions as

$$S(0) = S_0 > 0, C(0) = C_0 > 0, E(0) = E_0 > 0, R(0) = R_0 > 0$$

UNIQUE SOLUTION OF THE MODEL

The developed mathematical model is use to predict the prospect of NSE system from its current state at time t_0, the initial value problem

$$y' = f(t, y), y(t_0) = y_0 \quad (0.2)$$

It has existing unique solution.

Now, let establish conditions for the existence and uniqueness of solution for the model system equations (0.1)

$$\left.\begin{aligned} f_1(t,y) &= \pi - \beta ES - \delta S \\ f_2(t,y) &= \beta ES - (\eta + \delta)C \\ f_3(t,y) &= \eta C - (\lambda + \delta)E \\ f_4(t,y) &= \gamma E - (\delta)R \end{aligned}\right\} \quad (0.3)$$

So that

$$x' = f(t,y) = f(x)$$

Theorem 1: The feasible region of the NSE financial market denoted as Ω

$$|t - t_0| \le a, \|y - y_0\| \le b, y = (y_1, y_2, \dots, y_n), y_0 = (y_{10}, y_{20}, \dots, y_{n0}) \quad (0.4)$$

Assuming Lipchitz condition such that $f(t,y)$ is satisfies then,

$$\|f(t,y_1) - f(t,y_2)\| \le \varphi\|y_1 - y_2\| \quad (0.5)$$

When the pairs (t,y) and (t,y_2) belong to Ω where τ is a positive constant.

Then, there exist a constant $\alpha > 0$ such that, there exist a unique continuous vector solution $y(t)$ of the system (0.2) in the interval $|t - t_0| \le \alpha$.

Noting the important of condition (0.5) requirement that $\frac{df_i}{dy_j}, i, j = 1, 2 \dots n$ be continuous and bounded in Ω to be satisfied.

Lemma 2. Suppose $f(t,y)$ has continuous partial derivative

$\frac{df_i}{dy_j}$ on a bounded closed convex domain, and then it satisfies a Lipchitz condition in R

The region is our interest, $1 \le \sigma \le \mathbb{R}$ (0.6)

Then, we look for a bounded solution of the form $0 < \mathbb{R} < \infty$ (0.7)

EXISTENCE OF THE MODEL

The existence theorem is shown as follow.

Theorem II. If G' denote the region defined in (0.5) such that (0.6) and (0.7) hold. Then the model system (0.3) solution exists and is bounded in the region G'.

Proof. Let

$$\left.\begin{aligned} f_1 &= \pi - \beta es - \delta s, \\ f_2 &= \beta es - (\eta + \delta)c, \\ f_3 &= \eta c - (\gamma + \delta)e, \\ f_4 &= \gamma e - (\theta + \delta)r. \end{aligned}\right\} \tag{0.8}$$

It suffices to show that $\frac{\partial f_i}{\partial y_j}, i, j = 1, 2, 3, 4$ are continuous.

Consider the partial derivatives

$$\frac{\partial f_1}{\partial s} = -\beta e^* - \delta, \left|\frac{\partial f_1}{\partial s}\right| = |-\beta e^* - \delta| < \infty,$$

$$\frac{\partial f_1}{\partial e} = 0, \left|\frac{\partial f_1}{\partial e} = |0|\right| < \infty$$

$$\frac{\partial f_1}{\partial c} = -\beta s^*, \left|\frac{\partial f_1}{\partial c}\right| = |-\beta s^*| < \infty$$

$$\frac{\partial f_1}{\partial r} = 0, \left|\frac{\partial f_1}{\partial r}\right| = 0 < \infty$$

Similarly,

$$\frac{\partial f_2}{\partial s} = \beta e^*, \left|\frac{\partial f_2}{\partial s}\right| = |\beta e^*| < \infty,$$

$$\frac{\partial f_2}{\partial c} = -(\delta + \eta), \left|\frac{\partial f_2}{\partial c} = |-(\delta + \eta)|\right| < \infty,$$

$$\frac{\partial f_2}{\partial e} = \beta s^*, \left|\frac{\partial f_2}{\partial e}\right| = |\beta s^*| < \infty,$$

$$\frac{\partial f_2}{\partial r} = 0, \left|\frac{\partial f_2}{\partial r}\right| = 0 < \infty,$$

And also,

$$\frac{\partial f_3}{\partial s} = 0, \left|\frac{\partial f_3}{\partial s}\right| = 0 < \infty,$$

$$\frac{\partial f_3}{\partial e} = -(\delta + \gamma), \left|\frac{\partial f_3}{\partial e}\right| = |-(\delta + \gamma)| < \infty,$$

$$\frac{\partial f_3}{\partial c} = \eta, \left|\frac{\partial f_3}{\partial c}\right| = |\eta| < \infty,$$

$$\frac{\partial f_3}{\partial r} = 0, \left|\frac{\partial f_3}{\partial r}\right| = 0 < \infty,$$

Then we finally have,

$$\frac{\partial f_4}{\partial s} = 0, \left|\frac{\partial f_4}{\partial s}\right| = 0 < \infty,$$

$$\frac{\partial f_4}{\partial c} = 0, \left|\frac{\partial f_4}{\partial c}\right| = 0 < \infty,$$

$$\frac{\partial f_4}{\partial e} = \gamma, \left|\frac{\partial f_4}{\partial i}\right| = |\gamma| < \infty,$$

$$\frac{\partial f_4}{\partial r} = -(\ \delta), \left|\frac{\partial f_4}{\partial r}\right| = |-(\ \delta)| < \infty,$$

It shows that all these partial derivatives are continuous and bounded with a unique solution of model system (0.3) in the region Ω by theorem (II),

Invariant region

It follows from system (0.1) that

$$(S + C + E + R)' = \pi - \delta(S + C + E + R):$$

Then, $\lim_{t\to\infty} sup\ (S + C + E + R) \leq \frac{\pi}{\delta}$. Thus, the feasible region for system (0.1) is

$$\varphi = \left\{S + E + I + R \leq \frac{\pi}{\delta}, S > 0, C \geq 0, E \geq 0, R \geq 0\right\}$$

It's shown mathematically and epidemiologically that the region $\acute{\Gamma}$ is positively invariant with respect to system $\mathbb{R}_+^4$

EQUILIBRIUM POINT OF THE NSE FINANCIAL MARKET

Free equilibrium point of NSE financial market

$$C = 0, E = 0, R = 0, S = \frac{\pi}{\delta}$$

Equilibrium point of the coincidence of NSE financial market

$$C = \frac{\pi\beta\delta\eta + \pi\beta\eta\theta - \delta^4 - \delta^3\eta - \delta^3\gamma - \delta^3\theta - \delta^2\eta\gamma - \delta^2\eta\theta}{\eta\left(\delta^2 + \delta\eta + \delta\theta + \eta\theta\right)\beta},$$

$$E = \frac{\pi\beta\delta\eta + \pi\beta\eta\theta - \delta^4 - \delta^3\eta - \delta^3\gamma - \delta^3\theta - \delta^2\eta\gamma - \delta^2\eta\theta}{\left(\delta^2 + \delta\eta + \delta\gamma + \delta\theta + \eta\gamma + \eta\theta\right)\beta\delta},$$

$$R = \frac{\gamma\left(\pi\beta\delta\eta + \pi\beta\eta\theta - \delta^4 - \delta^3\eta - \delta^3\gamma - \delta^3\theta - \delta^2\eta\gamma - \delta^2\eta\theta\right)}{\beta\delta\left(\delta^3 + \delta^2\eta + \delta^2\gamma + 2\delta^2\theta + \delta\eta\gamma + 2\delta\eta\theta + \delta\gamma\theta + \delta\theta^2 + \eta\gamma\theta + \eta\theta^2\right)},$$

$$S = \frac{\delta\left(\delta^2 + \delta\eta + \delta\gamma + \delta\theta + \eta\gamma + \eta\theta\right)}{\beta\eta\left(\delta + \theta\right)}$$

Financial Market Reproduction Number

The reproduction number, often denoted as R_0 in epidemiology, is a metric used to describe the contagiousness of an infectious disease. It represents the average number of secondary infections produced by one infected individual in a completely susceptible population. When ($R_0 < 1$) each infected person, on average, causes less than one new infection, leading to a decline in the number of cases over time. The disease will eventually die out and when ($R_0 > 1$) each infected person, on average, causes more than one new infection, leading to an increase in the number of cases over time. The disease has the potential to spread widely and become an epidemic or pandemic.

Akpienbi *et al.,* (2021) applied these concept of the reproduction number to drug abuse in Taraba, providing a useful framework for understanding how certain behaviors or phenomena can spread within a population. This concept can also be applied to financial markets to describe how financial events propagate

In financial markets, the concept of the reproduction number can be adapted to describe how financial events, behaviors, or shocks propagate through the market. Financial Market Reproduction Number can be defined as a theoretical metric that quantifies the average number of subsequent financial events triggered by an initial event. These events could include market crashes, significant price movements, investor behaviors, or any other financial phenomenon that has the potential to spread. When the financial market ($R_0 < 1$), it indicates that an initial financial shock or event leads to less than one subsequent event on average which imply that the impact of the initial event is contained and diminishes over time. The market absorbs the shock, and stability is quickly restored and when the financial market ($R_0 > 1$), it indicates that an initial financial shock or event leads to more than one subsequent event on average which also imply that the impact of the initial event spreads through the market, potentially leading to widespread disruption and instability.

Next generation matrix method Driessche and Watmough, (2002) was use to obtain basic financial market reproduction number (R_0). From the system of equation(0.1)we have

$$R_0 = \frac{\beta\pi\eta}{\delta(\delta+\gamma)^2}$$

NSE Stability analysis

The Jacobian matrix of the model system (0.1) are obtain when taking partial derivative in equation.

Now, evaluate the Jocabian matrix at free equilibrium of NSE financial market $\left(\frac{\pi}{\delta}, 0,0,0\right)$Thus,

$$J_{NSE1} := \begin{bmatrix} -\delta-\lambda & 0 & -\frac{\beta\pi}{\delta} & 0 \\ 0 & -\delta-\eta-\lambda & \frac{\beta\pi}{\delta} & 0 \\ 0 & \eta & -\gamma-\delta-\lambda & 0 \\ 0 & \theta & \gamma & -\delta-\alpha-\lambda \end{bmatrix} \qquad (0.9)$$

The eigenvalue of NSE stability analysis of free NSE financial market equilibrium

$\lambda = -\delta$

$\lambda = -\delta$

$$\lambda = \frac{1}{2}\,\frac{-\delta\gamma-2\delta^2-\eta\delta+\sqrt{4\pi\beta\delta\eta+\delta^2\eta^2-2\delta^2\eta\gamma+\delta^2\gamma^2}}{\delta}$$

$$\lambda = -\frac{1}{2}\,\frac{\delta\gamma + 2\delta^2 + \eta\delta + \sqrt{4\pi\beta\delta\eta + \delta^2\eta^2 - 2\delta^2\eta\gamma + \delta^2\gamma^2}}{\delta}$$

When $\frac{-2\delta^2 + (-\eta - \gamma - 2\lambda)\delta}{\delta} < \frac{\sqrt{\left(\frac{1}{4}(\eta-\gamma)^2\delta + \pi\beta\eta\right)\delta}}{\delta}$

Therefore, all of the eigenvalues are determined by the Routh-Hawirtiz Criterion if free NSE market include real roots that are detrimental simply if and only if $\ddot{A}_i(i = 1, 3) > 0$ and $\Delta = \ddot{A}_1\ddot{A}_2 - \ddot{A}_3 > 0.$ Then the NSE market indicate to be asymptotically stable As a result, the disc centered at dii contains all of the eigenvalues of free NSE market. Thus, all of the eigenvalues would exist in the left half plane as well is locally asymptotically stable if and only if the following necessary criterion is fulfilled if the diagonal elements are negative as threshold $R_0 > 1$

Global Stability Analysis of NSE Coincidence of the Equilibrium

Theorem 4 The NSE financial market is globally asymptotically stable whenever $R_0 > 1$.

Proof. Suppose Lyapunov function V such that

$$V(S^*, C^*, E^*, R^*) = \left(S - S^* - S^* ln\frac{S}{S^*}\right) + A\left(C - C^* - C^* ln\frac{C}{C^*}\right) + B\left(E - E^* - E^* ln\frac{E}{E^*}\right) + D\left(R - R^* - R^* ln\frac{R}{R^*}\right)$$

Taking the derivative of the V to obtain the system solution has

$$\frac{dt}{dt} = \left(\frac{S - S^*}{S}\right)\frac{dS}{dt} + \left(\frac{C - C^*}{C}\right)\frac{dC}{dt} + \left(\frac{E - E^*}{E}\right)\frac{dE}{dt} + \left(\frac{R - R^*}{R}\right)\frac{dR}{dt}$$

And substitute to have

$$\frac{dt}{dt} = \left(\frac{S - S^*}{S}\right)[\pi - \beta ES - \delta S] + \left(\frac{C - C^*}{C}\right)[\beta ES - (\eta + \delta)C]$$
$$+\left(\frac{E - E^*}{E}\right)[\eta C - (\lambda + \delta)E] + \left(\frac{R - R^*}{R}\right)[\gamma E - (\delta)R] \tag{10.0}$$

Thus, expanding (10.0) to have

$$\frac{dt}{dt}=\pi-\beta ES-\delta S-\frac{\pi S^{*}}{S}+\beta ES^{*}+\delta S^{*}+\beta ES-(\eta+\delta)C-\frac{\beta EC^{*}S}{C}-(\eta+\delta)C^{*}$$
$$+\eta C-(\gamma+\delta)E-\eta E^{*}C+(\gamma+\delta)E^{*}+\gamma E-(\delta)R-\frac{\gamma R^{*}E}{R}-(\delta)R^{*}$$

$$\frac{dt}{dt}=\pi-\frac{\pi S^{*}}{S}+\beta ES^{*}+\delta S^{*}+\beta ES+\eta C+(\gamma+\delta)E^{*}+\gamma E-(\gamma+\delta)E-\beta ES$$
$$-\delta S-\eta E^{*}C-(\eta+\delta)C-\frac{\beta EC^{*}S}{C}-(\eta+\delta)C^{*}-(\delta)R-\frac{\gamma R^{*}E}{R}-(\delta)R^{*} \qquad (10.1)$$

Let x and y present the positive and negative function in equation (999-1)

$$x=\pi-\frac{\pi S^{*}}{S}+\beta ES^{*}+\delta S^{*}+\beta ES+\eta C+(\gamma+\delta)E^{*}+\gamma E$$
$$y=-(\gamma+\delta)E-\beta ES-\delta S-\eta E^{*}C-(\eta+\delta)C-\frac{\beta EC^{*}S}{C}-(\eta+\delta)C^{*}-(\delta)R-\frac{\gamma R^{*}E}{R}-(\delta)R^{*}$$

Hence, $\frac{dt}{dt}=x-y$

Therefore if $x<y$, then $\frac{dt}{dt}\leq 0$. And $\frac{dt}{dt}=0$ if and only if $S=S^{*},C=C^{*},E=E^{*}$ and $R=R^{*}$. The largest compact invariant set in $\left\{(S,C,E,R):\sigma\frac{dV}{dt}=0\right\}$ is a singleton R_0. This show that the coincidence NSE financial market equilibrium is globally asymptotically stable in the

invariant σ if $x<y$ according to LaSalle (1976).

CONCLUSION

Nigeria stock exchange financial market was model with SEIR ideology and investigated to ascertain the interaction of equity analyst and potential investor in the market. The research findings indicate that the free NSE financial market equilibrium in Nigeria is locally asymptotically stable, as demonstrated by local stability analysis. This implies that the market can recover from small perturbations and return to equilibrium. Additionally, global stability analysis reveals that the equilibrium is globally asymptotically stable, ensuring that the market will stabilize over time regardless of the magnitude of disturbances. These results provide assurance that the Nigerian financial market is resilient both to minor and significant shocks. Small fluctuations in stock prices or trading volumes will not disrupt the market's overall stability, and even in the face of larger economic events or policy changes, the market will eventually return to equilibrium. This stability can enhance investor confidence, encouraging long-term investments and participation in the NSE.

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