A Compartmental Modelling of the Dynamics of Poverty and Cybercrime in South-South Zone of Nigeria

Abstract

Poverty and cybercrime are two topical concepts that has attracted a lot of interest in Nigeria, and also in the global community today. This study used the compartmental mathematical modelling approach to provide a comprehensive framework for analysing the dynamics of poverty and its relationship with cybercrime in the South-South region of Nigeria. The model is derived from a five-compartment representation that resulted in a set of five ordinary differential equations (ODEs) that capture its dynamic nature. The study employed the Routh Array criterion for stability analysis, and to determine the conditions for stability at the steady state. The ODEs were solved numerically using the fourth-order Runge-Kutta method. Findings indicate that intervention programmes at various levels can effectively reduce the number of individuals in both impoverished and cybercrime compartments in the region.

Keyword: Compartmental Model, Poverty, Cybercrime, Stability Analysis, Ordinary Differential Equation, Runge-Kutta Method.

1. Introduction

The issue of poverty has always been a subject of interest in both developed and developing nations of the world. Great amount of efforts and resources are invested annually by Governmental and Non-Governmental agencies to tackle the menace of its scourge. Instead of abating, it is rather expanding. Fields (1994) defines poverty as the inability, by individuals and communities, to command sufficient resources to satisfy basic needs and necessities of life. United Nations (1998) explained the effects of poverty to include denial of decent choices and opportunities, violation of human worth and dignity, and lack of capacity to participate meaningfully and effectively in society. Cybercrime refers to a class of criminal activities that involve the use of computers and network devices to defraud or inflict pain on others. Common cybercrimes include phishing, identity theft, hacking, hijacking, cyber stalking, virus attacks, software piracy, spreading of hate and terror, and forms of pornography. Most cybercrimes are committed by those who want to make money, and this has proved to be attractive to youths as a means of acquiring wealth. Adesina (2017) concluded that there was a strong relationship between poverty and cybercrime in Nigeria, while Alabi et al (2023) also identified poverty, as well as peer pressure as major determinants of youth involvement in cybercrime in Nigeria. Ugwuanyi et al (2020) identified common cybercrimes in Nigeria to include ATM fraud, phishing, and identity theft, and observed that a sizeable proportion of internet users in Nigeria have encountered cybercrimes of varying degrees. The SIR class of epidemiological models have been used extensively to simulate the effect of intervention programmes on the dynamics of a disease. For instance Aghanenu et al (2022) simulated the effect of vaccines on the spread of covid-19, while Urumese and Igabari (2023) investigated the effect of social distancing and community lockdown on the spread of the pandemic. Compartmentalized epidemiological models have been adapted by several researchers to explain the spread of social diseases such as poverty, and such mathematical models have been instrumental in analyzing, predicting, and suggesting strategies to minimize poverty and its associated social vices. In a study on poverty and drug addiction in Bangladesh, Sakib, Islam, Shahrear, and Habiba (2017) developed a compartmental model to investigate the impact of governmental and non-governmental intervention programmes. Their model classified the population into five groups: non-impoverished, impoverished, drug-addicted, rehabilitated, and recovered. Their findings indicated that intervention programs could significantly reduce poverty and drug addiction rates. Building on this work, Islam, Sakib, Shahrear, and Rahman (2017) included the aspect of snatching in their model, examining the influence of intervention programs on the rate of poverty, drug addiction, and snatching. Their simulation results demonstrated that intervention programmes from the government, individuals, and religious organizations could effectively reduce these issues. In Nigeria, Oduwole and Shehu (2013) developed a compartmental model addressing both poverty and prostitution. Their study considered a population divided into five groups: non-impoverished, impoverished, prostituted, disease-infected, and rehabilitated. The results showed that intervention programs could mitigate both prostitution and poverty. Akinpelu and Ojo (2016) used a similar population classification but different flow diagrams, concluding that government intervention is crucial in controlling the spread of poverty. In West Malaysia, Roslan, Zakaria, Alias, and Malik (2018) developed a mathematical model with three compartments, namely, impoverished, poor, and criminal. Their simulation results indicated that substantial government intervention could reduce both crime and poverty rates. After reviewing the existing literature and considering the direct relationship between poverty and cybercrime, our study aims to develop a compartmental model that elucidates the interplay between poverty and cybercrime and explores strategies for their significant reduction.

2. Model Formulation

Putting a total end to cybercrime is almost impossible but, intensifying interventions in order to control poverty rate in a bid to lower the rate of cybercrime is possible. This model considered five classes of people in the South South region of Nigeria. The classes considered includes: non-impoverished class $N(t)$, impoverished class $P(t)$, cybercrime class $C(t)$, jailed class $J(t)$, and rehabilitation class $R(t)$. The selected classes are dynamic in nature, i.e., they are meant to change with time. Based on this fact, sets of first order ordinary differential equations were developed from Figure 1, which are shown in equations 1 to 5. Aside those five model variables listed above, there are also model parameters in Figure 1. The detailed description of the model variables and parameters are as shown in Tables 1 and 2, respectively. The model was established on the following assumptions:

1. There will be movement from $N(t)$ class to $P(t)$ class at the rate of β due to an increase in

the rate of unemployment or low-paying jobs. At times, some government policies may lead to this transition also.

2. The tendency is very high that people will go into $C(t)$ class as a result of poverty at the rate of γ.

3. There is a probability (though very low) that some individuals in $N(t)$ class will also move to $C(t)$ class at the rate of α.

4. There is a probability that someone in the $C(t)$ class will be caught and jailed at the rate of ϕ.

5. There is a probability that someone who has been rehabilitated can still go back to cyber-crime at the rate of ω due to the influence from their close associates who are still in $C(t)$ class.

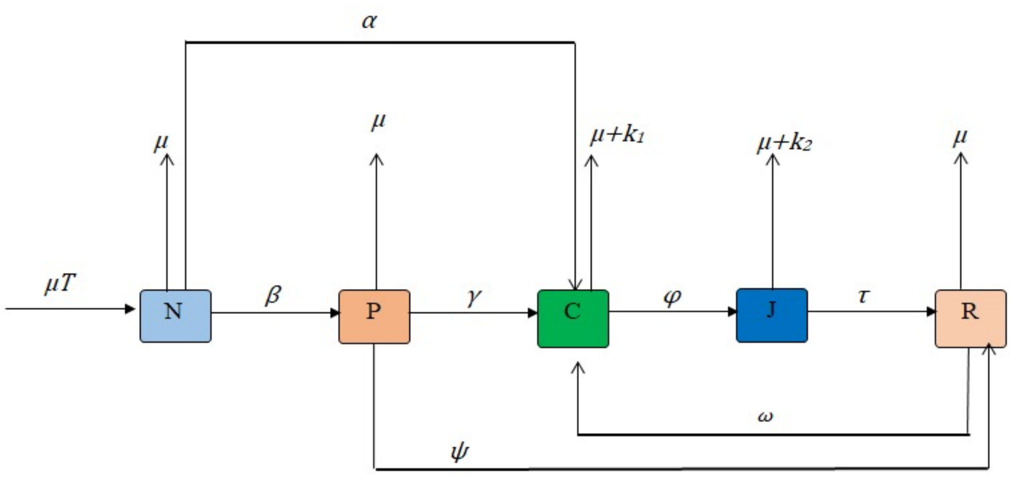

Figure 1: Flow diagram for the dynamic behaviour of the system

The variables and parameters used in the model are defined in Tables 1 and 2 respectively

Table 1: Description of the Model Variables

Variables	Description
$N(t)$	Non-impoverished class
$P(t)$	Impoverished class
$C(t)$	Cybercrime class
$J(t)$	Jailed class
$R(t)$	Rehabilitation class
$T(t)$	Total Population

Table 2: Description of the Model Parameters

Parameter	Description
β	Rate of movement from non-impoverished class $N(t)$ to impoverished class $P(t)$
α	Rate at which individuals in the non-impoverished class $N(t)$ engage cybercrime $C(t)$
γ	Rate at which individuals in the impoverished class $P(t)$ get involved in cybercrime $C(t)$
φ	Rate at which people in the cypercrime class $C(t)$ get caught by law enforcement agencies and moved to jailed class $J(t)$
τ	The rate at which individuals in the Jailed class $J(t)$ moved to rehabilitation class $R(t)$
ω	Transition rate from rehabilitation class $R(t)$ to cybercrime class $C(t)$
ψ	The rate of transition from impoverished class $P(t)$ to rehabilitation class $R(t)$
k_1	Death rate due to unnatural death in the cybercrime class $C(t)$
k_2	death rate due to gun duel in the jailed class $J(t)$
μ	Birth/Death rate

$$\frac{dN}{dt} = \mu T - \frac{\alpha NC}{T} - (\beta + \mu)N \tag{1}$$

$$\frac{dP}{dt} = \beta N - \frac{\gamma PC}{T} - (\psi + \mu)P \tag{2}$$

$$\frac{dC}{dt} = \frac{\gamma PC}{T} + \frac{\alpha NC}{T} + \frac{\omega RC(\alpha + \gamma)}{T} - (\varphi + \mu + k_1)C \tag{3}$$

$$\frac{dJ}{dt} = \varphi C - (\tau + \mu + k_2)J \tag{4}$$

$$\frac{dR}{dt} = \tau J - \frac{\omega RC(\alpha + \gamma)}{T} + \psi P - \mu R \tag{5}$$

3. Mathematical analysis of the Model at Steady State

A steady state in Mathematical modelling refers to a condition where the variables of a system remain constant over time, despite ongoing processes that strive to change them. This means that the system has reached a point of equilibrium where the rates of input and output are balanced. This simply means that $\frac{dA}{dt} = 0,\ A = N, P, C, J, andR$. Subjecting equations 1 to 5 to definition of steady state, gives:

$$0 = \mu T - \frac{\alpha NC}{T} - (\beta + \mu)N = f_1 \tag{6}$$

$$0 = \beta N - \frac{\gamma PC}{T} - (\psi + \mu)P = f_2 \tag{7}$$

$$0 = \frac{\gamma PC}{T} + \frac{\alpha NC}{T} + \frac{\omega RC(\alpha + \gamma)}{T} - (\varphi + \mu + k_1)C = f_3 \tag{8}$$

$$0 = \varphi C - (\tau + \mu + k_2)J = f_4 \tag{9}$$

$$0 = \tau J - \frac{\omega RC(\alpha + \gamma)}{T} + \psi P - \mu R = f_5 \tag{10}$$

To determine if the system is stable under steady state condition, firstly Jacobian matrix have to be defined:

$$JM = \begin{bmatrix} \frac{\partial f_1}{\partial N} & \frac{\partial f_1}{\partial P} & \frac{\partial f_1}{\partial C} & \frac{\partial f_1}{\partial J} & \frac{\partial f_1}{\partial R} \\ \frac{\partial f_2}{\partial N} & \frac{\partial f_2}{\partial P} & \frac{\partial f_2}{\partial C} & \frac{\partial f_2}{\partial J} & \frac{\partial f_2}{\partial R} \\ \frac{\partial f_3}{\partial N} & \frac{\partial f_3}{\partial P} & \frac{\partial f_3}{\partial C} & \frac{\partial f_3}{\partial J} & \frac{\partial f_3}{\partial R} \\ \frac{\partial f_4}{\partial N} & \frac{\partial f_4}{\partial P} & \frac{\partial f_4}{\partial C} & \frac{\partial f_4}{\partial J} & \frac{\partial f_4}{\partial R} \\ \frac{\partial f_5}{\partial N} & \frac{\partial f_5}{\partial P} & \frac{\partial f_5}{\partial C} & \frac{\partial f_5}{\partial J} & \frac{\partial f_5}{\partial R} \end{bmatrix} \tag{11}$$

Substituting equations 6 to 10 into equation 11 gives:

$$\begin{pmatrix} (-\frac{\alpha C}{T}-(\beta+\mu)) & 0 & -\frac{\alpha N}{T} & 0 & 0 \\ \beta & (-\frac{\gamma C}{T}-(\psi+\mu)) & -\frac{\gamma P}{T} & 0 & 0 \\ \frac{\alpha C}{T} & (\frac{\gamma C}{T}) & (\frac{\gamma P}{T}+\frac{\alpha N}{T}+\frac{\omega R(\alpha+\gamma)}{T}-(\varphi+\mu+k_1)) & 0 & \frac{\omega C(\alpha+\gamma)}{T} \\ 0 & 0 & \varphi & -(\tau+\mu+k_2) & 0 \\ 0 & \psi & (-\frac{\omega R(\alpha+\gamma)}{T}) & \tau & (-\frac{\omega C(\alpha+\gamma)}{T}-\mu) \end{pmatrix}$$

Secondly, the characteristics equation has to be defined. Following Islam et al., (2017) approach, the characteristics equation is given as:

$$\left[s-\left(-\frac{\alpha C}{T}-(\beta+\mu)\right)\right]\left[s-\left(-\frac{\gamma C}{T}-(\psi+\mu)\right)\right]\left[s-\left(\frac{\gamma P}{T}+\frac{\alpha N}{T}+\frac{\omega R\,(\alpha+\gamma)}{T}-(\varphi+\mu+k_1)\right)\right]$$
$$[s+(\tau+\mu\ +k_2)]\left[s-\left(-\frac{\omega C\,(\alpha+\gamma)}{T}-\mu\right)\right]=0$$

Let $\left(-\frac{\alpha C}{T}-(\beta+\mu)\right)=a$, $\left(-\frac{\gamma C}{T}-(\psi+\mu)\right)=b$, $\left(\frac{\gamma P}{T}+\frac{\alpha N}{T}+\frac{\omega R(\alpha+\gamma)}{T}-(\varphi+\mu+kS_1)\right)=c$, $(\tau+\mu+k_2)=d$, $\left(-\frac{\omega C(\alpha+\gamma)}{T}-\mu\right)=e$

$$(s-a)\,(s-b)\,(s-c)\,(s+d)\,(s-e)=0 \tag{12}$$

Expansion of equation 12 gives:

$$\begin{aligned} &s^5+(-e+d-c-b-a)\,s^4+(-cd-bd+bc-ad+ac+ab-de+ce+ae+be)\,s^3+ \\ &(bcd+acd-abc+cde+bde-bce+ade-ace-abe+abd)\,s^2+ \\ &(-bcde-acde-abde-abde+abce-abcd)\,s+abcde=0 \end{aligned} \tag{13}$$

Let $-e+d-c-b-a=a_1$, $-cd-bd+bc-ad+ac+ab-de+ce+ae+be=a_2$, $bcd+acd-abc+cde+bde-bce+ade-ace-abe+abd=a_3$, $-bcde-acde-abde-abde+abce-abcd=a_4$, $abcde=a_5$
The characteristics equation becomes:

$$s^5+a_1s^4+a_2s^3+a_3s^2+a_4s^1+a_5=0 \tag{14}$$

Lastly, we apply the Routh Array method to obtain condition for stability in equation (14)

$$\begin{array}{cccc} s^5 & 1 & a_2 & a_4 \\ s^4 & a_1 & a_3 & a_5 \\ s^3 & b_1 & b_2 & 0 \\ s^2 & b_3 & b_4 & 0 \\ s^1 & b_5 & 0 & 0 \\ s^0 & b_6 & 0 & 0 \end{array}$$

$b_1 = -\frac{1}{a_1}\begin{vmatrix} 1 & a_2 \\ a_1 & a_3 \end{vmatrix}$, $b_2 = -\frac{1}{a_1}\begin{vmatrix} 1 & a_4 \\ a_1 & a_5 \end{vmatrix}$, $b_3 = -\frac{1}{b_1}\begin{vmatrix} a_1 & a_3 \\ b_1 & b_2 \end{vmatrix}$, $b_4 = -\frac{1}{b_1}\begin{vmatrix} a_1 & a_5 \\ b_1 & 0 \end{vmatrix}$, $b_5 = -\frac{1}{b_3}\begin{vmatrix} b_1 & b_2 \\ b_3 & b_4 \end{vmatrix}$, $b_6 = -\frac{1}{b_5}\begin{vmatrix} b_3 & b_4 \\ b_5 & 0 \end{vmatrix}$

The system is stable if all values of $b_i \, (i = 1, 2, 3, 4, 5, 6)$ are positive. it becomes unstable if any value of b_i is negative.

4. Numerical analysis of the Model

The system flow diagram in $Figure 1$ was simulated numerically using classical 4th order Runge-Kutta method in MATLAB environment. The algorithm for the simulation is given below:
Step 1: Initial value of $N(1), P(1), C(1), J(1), R(1)$.
Step 2: Choose a step size (h).
Step 3: Find the increment of each population class that make up the model.

$$k_1 = \mu \cdot T(i) - \frac{\alpha \cdot N(i) \cdot C(i)}{T(i)} - (\beta + \mu) \cdot N(i)$$
$$m_1 = \beta \cdot N(i) - \frac{\gamma \cdot P(i) \cdot C(i)}{T(i)} - (\psi + \mu) \cdot P(i)$$
$$p_1 = \frac{\gamma \cdot P(i) \cdot C(i)}{T(i)} + \frac{\alpha \cdot N(i) \cdot C(i)}{T(i)} + \frac{\omega \cdot R(i) \cdot C(i) \cdot (\alpha+\gamma)}{T(i)} - (\varphi + \mu + k_1) \cdot C(i)$$
$$j_1 = \varphi \cdot C(i) - (\tau + \mu + k_2) \cdot J(i)$$
$$r_1 = \tau \cdot J(i) - \frac{\omega \cdot R(i) \cdot C(i) \cdot (\alpha+\gamma)}{T(i)} - \psi \cdot P(i) - \mu \cdot R(i)$$

$$k_2 = \mu \cdot T(i) - \frac{\alpha \cdot \left(N(i)+\frac{k_1}{2}\right) \cdot \left(C(i)+\frac{p_1}{2}\right)}{T(i)} - (\beta + \mu) \cdot \left(N(i) + \frac{k_1}{2}\right)$$
$$m_2 = \beta \cdot \left(N(i) + \frac{k_1}{2}\right) - \frac{\gamma \cdot \left(P(i)+\frac{m_1}{2}\right) \cdot \left(C(i)+\frac{p_1}{2}\right)}{T(i)} - (\psi + \mu) \cdot \left(P(i) + \frac{m_1}{2}\right)$$
$$p_2 = \frac{\gamma \cdot \left(P(i)+\frac{m_1}{2}\right) \cdot \left(C(i)+\frac{p_1}{2}\right)}{T(i)} + \frac{\alpha \cdot \left(N(i)+\frac{k_1}{2}\right) \cdot \left(C(i)+\frac{p_1}{2}\right)}{T(i)} + \frac{\omega \cdot \left(R(i)+\frac{r_1}{2}\right) \cdot \left(C(i)+\frac{p_1}{2}\right) \cdot (\alpha+\gamma)}{T(i)} - (\varphi + \mu + k_1) \cdot \left(C(i) + \frac{p_1}{2}\right)$$
$$j_2 = \varphi \cdot \left(C(i) + \frac{p_1}{2}\right) - (\tau + \mu + k_2) \cdot \left(J(i) + \frac{j_1}{2}\right)$$
$$r_2 = \tau \cdot \left(J(i) + \frac{j_1}{2}\right) - \frac{\omega \cdot \left(R(i)+\frac{r_1}{2}\right) \cdot \left(C(i)+\frac{p_1}{2}\right) \cdot (\alpha+\gamma)}{T(i)} - \psi \cdot \left(P(i) + \frac{m_1}{2}\right) - \mu \cdot \left(R(i) + \frac{r_1}{2}\right)$$

$$k_3 = \mu \cdot T(i) - \frac{\alpha \cdot \left(N(i)+\frac{k_2}{2}\right) \cdot \left(C(i)+\frac{p_2}{2}\right)}{T(i)} - (\beta + \mu) \cdot \left(N(i) + \frac{k_2}{2}\right)$$
$$m_3 = \beta \cdot \left(N(i) + \frac{k_2}{2}\right) - \frac{\gamma \cdot \left(P(i)+\frac{m_2}{2}\right) \cdot \left(C(i)+\frac{p_2}{2}\right)}{T(i)} - (\psi + \mu) \cdot \left(P(i) + \frac{m_2}{2}\right)$$
$$p_3 = \frac{\gamma \cdot \left(P(i)+\frac{m_2}{2}\right) \cdot \left(C(i)+\frac{p_2}{2}\right)}{T(i)} + \frac{\alpha \cdot \left(N(i)+\frac{k_2}{2}\right) \cdot \left(C(i)+\frac{p_2}{2}\right)}{T(i)} + \frac{\omega \cdot \left(R(i)+\frac{r_2}{2}\right) \cdot \left(C(i)+\frac{p_2}{2}\right) \cdot (\alpha+\gamma)}{T(i)} - (\varphi + \mu + K_1) \cdot \left(C(i) + \frac{p_2}{2}\right)$$
$$j_3 = \varphi \cdot \left(C(i) + \frac{p_2}{2}\right) - (\tau + \mu + k_2) \cdot \left(J(i) + \frac{j_2}{2}\right)$$
$$r_3 = \tau \cdot \left(J(i) + \frac{j_2}{2}\right) - \frac{\omega \cdot \left(R(i)+\frac{r_2}{2}\right) \cdot \left(C(i)+\frac{p_2}{2}\right) \cdot (\alpha+\gamma)}{T(i)} - \psi \cdot \left(P(i) + \frac{m_2}{2}\right) - \mu \cdot \left(R(i) + \frac{r_2}{2}\right)$$

$$k_4 = \mu \cdot T(i) - \frac{\alpha \cdot (N(i)+k_3) \cdot (C(i)+p_3)}{T(i)} - (\beta + \mu) \cdot (N(i) + k_3)$$
$$m_4 = \beta \cdot (N(i) + k_3) - \frac{\gamma \cdot (P(i)+k_3) \cdot (C(i)+p_3)}{T(i)} - (\psi + \mu) \cdot (P(i) + m_3)$$
$$p_4 = \frac{\gamma \cdot (P(i)+m_3) \cdot (C(i)+p_3)}{T(i)} + \frac{\alpha \cdot (N(i)+k_3) \cdot (C(i)+p_3)}{T(i)} + \frac{\omega \cdot (R(i)+r_3) \cdot (C(i)+p_3) \cdot (\alpha+\gamma)}{T(i)} - (\varphi + \mu + K_1) \cdot (C(i) + p_3)$$
$$j_4 = \varphi \cdot (C(i) + p_3) - (\tau + \mu + k_2) \cdot (J(i) + j_3)$$
$$r_4 = \tau \cdot (J(i) + j_3) - \frac{\omega \cdot (R(i)+r_3) \cdot (C(i)+p_3) \cdot (\alpha+\gamma)}{T(i)} - \psi \cdot (P(i) + m_3) - \mu \cdot (R(i) + r_3)$$

Step 4: Calculate the next step of N, P, C, J and R.

$$N(i+1) = N(i) + \frac{h}{6} \cdot (k_1 + 2 \cdot k_2 + 2 \cdot k_3 + k_4)$$

$P(i+1) = P(i) + \frac{h}{6} \cdot (m_1 + 2 \cdot m_2 + 2 \cdot m_3 + m_4)$
$C(i+1) = C(i) + \frac{h}{6} \cdot (p_1 + 2 \cdot p_2 + 2 \cdot p_3 + p_4)$
$J(i+1) = J(i) + \frac{h}{6} \cdot (j_1 + 2 \cdot j_2 + 2 \cdot j_3 + j_4)$
$R(i+1) = R(i) + \frac{h}{6} \cdot (r_1 + 2 \cdot r_2 + 2 \cdot r_3 + r_4)$
$t(i+1) = t(i) + h$
Step 5: Repeat steps 3 and 4 until desired t is achieved.

5. Model Simulation

Data used for the simulation are as shown in Tables 3 and 4. To simulate and analyse the model, data obtained from Nigeria Bureau of Statistics NBS (2019) and field survey for research purpose were used to derived initial value of the model variables (Table 3). Parameters value were assumed after careful comparison with what is obtainable in literature. Results of simulation are illustrated in Figures 2, 3, 4, and 5.

Table 3: Initial value of the model variables

Variables	T	N(0)	P(0)	C(0)	J(0)	R(0)
Values	33980000	25480000	8500000	260780	83084	151660

Source: NBS, (2019), Field Survey.

Table 4: Estimated value of the model parameters

Parameters	β	α	γ	φ	τ	ω	ψ	k_1	k_2
Values	0.078	0.31	0.32	0.22	0.35	0.44	0.09	0.02	0.0071

Source: Assumed.

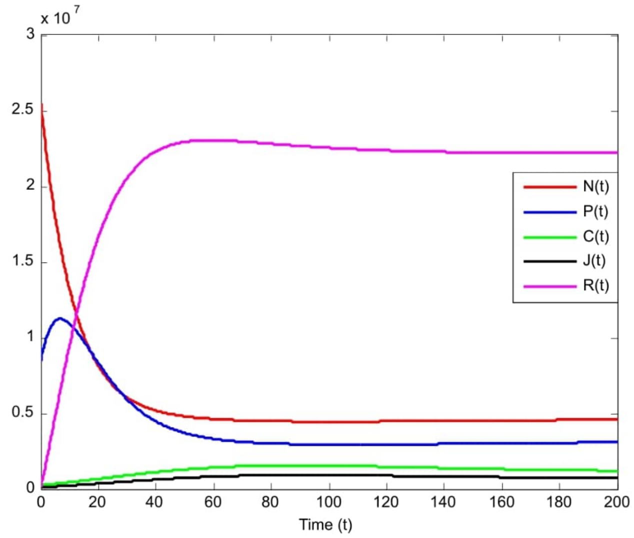

Figure 2: Simulation of different classes under intervention programmes.

.

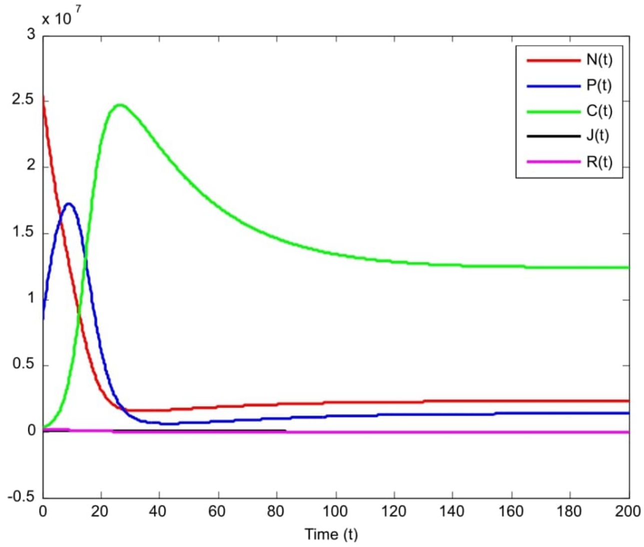

Figure 3: Simulation of different classes without an intervention programme.

.

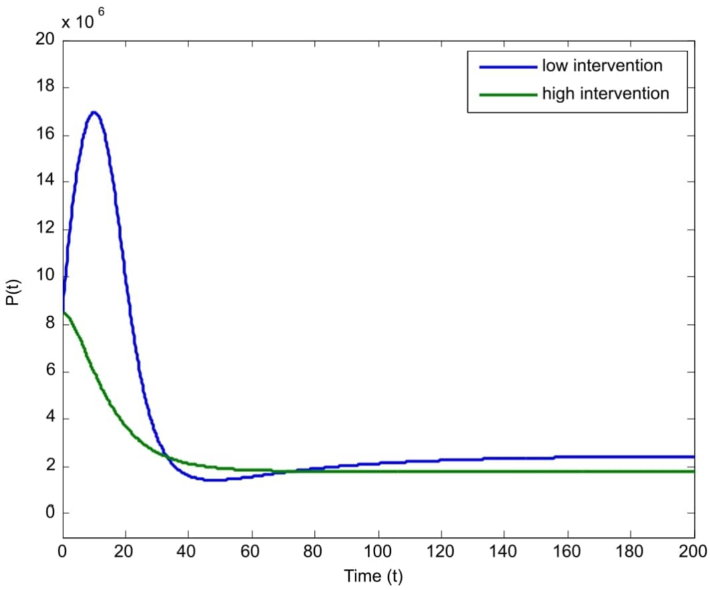

Figure 4: Simulation of $P(t)$ class under low and high intervention programmes.

.

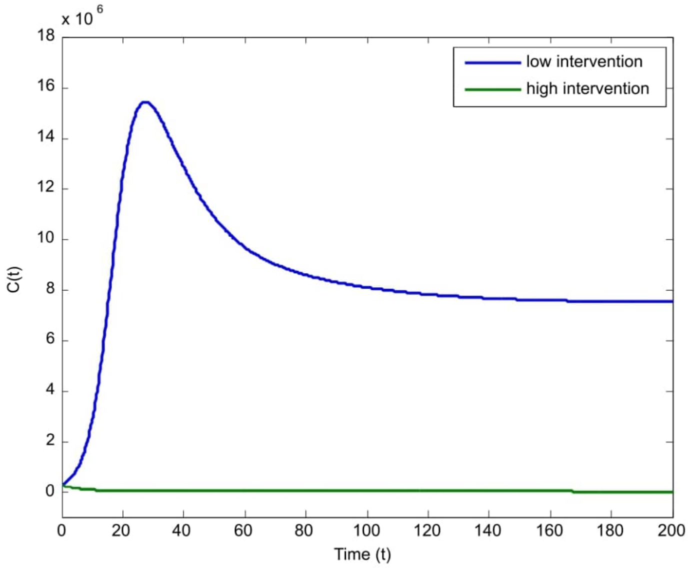

Figure 5: Simulation of $C(t)$ class under low and high intervention programmes.

.

6. Discussion

The simulation result under an intervention programme is as shown in Figure 2. The three intervention parameters of the model are φ, τ, and ψ and their numeric values are shown in Table 4. The following observations were drawn from Figure 2:

1. The $N(t)$ class reduces over time to a certain point, after which it becomes constant.
2. The $P(t)$ class increases slightly from the initial value, then continuously decreases over time and stabilizes.
3. The $C(t)$ and $J(t)$ classes have almost the same progression. Both classes increase over time for a period and then become stable.
4. The $R(t)$ class increases over time for a period and then becomes stable.

Under non-intervention programme, φ, τ, and ψ were all equal to 0. Simulation result under non-intervention programme is as shown in Figure 3. The $J(t)$ and $R(t)$ classes are 0 in Figure 3 when there was no intervention programme. Comparing Figures 3 with 2, it was revealed that lack of intervention programmes increases the rates of those in impoverished and cybercrime classes. This experiment observed the reason why both governmental and non-governmental organisations in South-South region of Nigeria should invest in well meaning programmes that will mitigate against rise in poverty and cybercrime mostly among the youth. Having shed light on the need for intervention programmes, there is also need to numerically investigate the influence of low and high intervention in the control of poverty and cybercrime. For the low intervention the values of φ, τ, and ψ were assumed to be 0.05, 0.07 and 0.01 respectively while at high intervention the values were 0.42,0.53 and 0.21 respectively. Figures 4 and 5 revealed that poverty and cybercrime rate can be reduced with the help of intervention programmes.

7. Conclusion

In this study, we have developed a compartmental mathematical model that provides a comprehensive framework for understanding the dynamics of poverty and its relationship with cybercrime in the South-South region of Nigeria. Our findings indicate that both poverty and cybercrime can be significantly reduced in this region through concerted efforts by both governmental and non-governmental organizations. Effective intervention programs, which include policies and initiatives aimed at lifting individuals out of poverty, are crucial. These programs should focus on providing education, vocational training, and employment opportunities to reduce the economic incentives for engaging in cybercrime. Furthermore, our model suggests that rehabilitation programs for individuals involved in cybercrime are essential for breaking the cycle of poverty and crime. By offering support and resources for reintegration into society, these programs can help former offenders build sustainable livelihoods and reduce recidivism. Future research could explore the impact of specific intervention strategies in more detail, as well as the role of technology and digital literacy in preventing cybercrime. Additionally, longitudinal studies could provide deeper insights into the long-term effects of these interventions on poverty and cybercrime dynamics.

References

1. Adesina, S. O. (2017). *Cybercrime and Poverty in Nigeria. Canadian Social Science*, 13(4), 19?29. DOI: 10.3968/9394.

2. Aghanenu, E. O.; Igabari, J. N.; Jenije, R.; and Arunaye, F. I. (2022). *Simulating Models for the Transmission Dynamics of a Novel Coronavirus under the Administration of an Imperfect Vaccine in Nigeria. Journal of Mathematical and Computational Science*, 12, 155. DOI: 10.28919/jmcs/7254. ISSN: 1927-5307.

3. Akinpelu, F., and Ojo, M. (2016). *A Mathematical Model for the Dynamic Spread of Infection Caused by Poverty and Prostitution in Nigeria. International Journal of Mathematical Science Research*, 4, 33?47.

4. Alabi, A.; Bamidele, A. H.; and Oladimeji, A. B. (2023). *Poverty and Youth Engagement in Cybercrime in Nigeria: An Overview of Its Effects on National Security. Gombe Journal of Administration and Management (GJAM)*, 5(1), 94?106.

5. Fields, G. (1994). *Poverty Changes in Developing Countries.* In R. Van Der Honven and R. Anken (Eds.), *Poverty Monitoring: An International Concern.* New York: St Martins Press.

6. Hassan, A. B., Lass, F. D., and Makinde, J. (2012). *Cybercrime in Nigeria: Causes, Effects, and the Way Out. ARPN Journal of Science and Technology*, 2(7).

7. Islam, M. A., Sakib, M. A., Shahrear, P., and Rahman, S. M. S. (2017). *The Dynamics of Poverty, Drug Addiction, and Snatching in Sylhet, Bangladesh. IOSR Journal of Mathematics*, 13(3), 78?89.

8. Oduwole, H. K., and Shehu, S. L. (2013). *A Mathematical Model on the Dynamics of Poverty and Prostitution in Nigeria. Mathematical Theory and Modeling*, 3(12), 74?80.

9. Roslan, U. A. M., Zakaria, S., Alias, A., and Malik, S. M. Abd. (2018). *A Mathematical Model on the Dynamics of Poverty, Poor, and Crime in West Malaysia. Far East Journal of Mathematical Sciences*, 107(2), 309?319.

10. Sakib, M. A., Islam, M. A., Shahrear, P., and Habiba, U. (2017). *Dynamics of Poverty and Drug Addiction in Sylhet, Bangladesh. Journal of Multidisciplinary Engineering Science and Technology*, 4(2), 6562?6569.

11. Ugwuanyi, S., Okechukwu, A., Prince, O., Okechukwu, N., and Irvine, J. (2020). *Cybercrimes in Southern Nigeria and Survey of IoT Implications.* In *1st IEEE Multi-Conference Technical Series (MCTS) 2020, AUN, Nigeria.*

12. United Nations. (1998). *Statement of Commitment for Action to Eradicate Poverty.* Adopted by Administrative Committee on Coordination. Press Release. ECOSOC/5759.

13. Urumese, B. D., and Igabari, J. N. (2023). *A Mathematical Model of the Effects of Social Distancing and Community Lockdown on the Spread of the COVID-19 Pandemic in Nigeria. Nigerian Journal of Science and Environment*, 21(1), 156?173.