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MODELLING THE CHANGES IN THE HUMAN POPULATION OF ORJI IN OWERRI NORTH LOCAL GOVERNMENT AREA OF IMO STATE NIGERIA.

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Abstract

A non linear differential equation model is proposed to examine the Changes in the Human Population of Orji In Owerri North Local Government Area of Imo State Nigeria. The dynamical system is used to explain the changes in Human population profile whenever there is percentage birth rate increase over death rate and vice versa, whereas the impact of Fertility (birth and death) rate which plays a key role in a demographic study of any country was observed. The method of computational modelling otherwise called numerical simulation is adopted in this study. Detailed deterministic quantifications of the effect of varying the fertility rates on the growth of populations Orji communities is also investigated. Results show that changes in human population can be influenced by variation of fertility rate. Decreasing fertility rates produced an increase on the population growth of Orji populations. Also, an increase in fertility rates produces depletion (decrease) on the population growth of

[redacted]

Orji populations. Thereby creating more opportunity of economic growth which may not be automatic, important investments in education and health sector are needed for actualization of demographic dividend in Orji , Owerri North Local Government Area , Imo State , Nigeria.

KEYWORDS: *Population Projections, Fertility Rate, Deterministic Quantification, Numerical Simulation and demography.*

INTRODUCTION

Human population can be described as a group of individuals of the same species that inhabit the same area. In the context of the demographic analysis of human population, there are several factors that defines a change in the human population. Such factors can include the intrinsic growth rate, the self-interaction coefficient, the migration factor due to labour force movement and fertility rate. As a result of continuous outrageous growth witnessed in the human population, an English Philosopher, Thomas Robert Malthus, (1798), in Thomas Malthus' theory of human population, states that changes in human population grows faster than food supply. To him, human population undergoes exponential growth, which occurs when the increase in the human population is proportional to the amount of available food or resources. Malthus predicted that if the population growth is not checked or controlled, that increase in population over time, will lead to a depletion of resources, increased pollution, overcrowd and increase in unemployment in labour force. As a result of that, there will be starvation, increase in diseases, crime, poverty and war as this continues over time, it results in outrageous death and population declines.

The size of the suburban population has increased in a rapid continuous pattern. The growth in population was as a result of an increase in fertility and migration in sub-urban regions. In the same work, they observed that central cities have shown varied patterns of growth over decades but no evidence exists that they are typically experiencing major growth in population. Within the sub-urban rings of metropolitan areas, the major factors affecting their recent growth are previous population density (low = high overall growth) and the movement of the foreign-born (high in - movement = high overall growth). They equally carried out some analysis on the sub-urbanization of the United States and the growth of suburban areas around metropolitan areas in the less developed world and their findings depict that recent decades characterized in many countries around the world by very high metropolitan population growth, including their suburban ring.(Guest and Brown, 2005)

In most demographic analysis of fertility rates published kinds of literature in Nigeria, it is popular to find the extensive application of a

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survey method form which vital socio-demographic data are collected and fertility rates policies were derived from these data. To the best of our knowledge, it is rare to find detailed deterministic quantifications of the effect of varying the fertility rates on the growth of populations in two related suburban communities in Nigeria. Furthermore, most of the studies on demography lack numerical quantification (the application of numerical mathematics) to study the impact of varying a demographic variable such as the fertility rate on the population prediction of interacting sub – urban populations. It is against this background that we proposed to implement a mathematical approach to tackle the problem of fertility control as an extension of the earlier birth control analysis among rural communities in the Imo state of Nigeria, (Nwachukwu and Obasi,2008). For this study, two related interacting communities (Irete in Owerri West Local Government Area and Orji in Owerri North Local Government Area) both in Imo State , Nigeria are used.

Etukudo and Effiong (2016) have conducted a study on an aspect of fertility behaviour in rural Nigerian community by using the method of multiple regression. The scholars examined the changes in fertility level that involves a variation of the following factors. Educational level, occupational type, age at first marriage and religion/culture. One of the key results of this study is stated as follows, that the low level of education, labour force participation, infant and child mortality as well as a political consideration, were found to have influenced the fertility behaviour in the chosen area of study. United Nations (2015), stated that the three components of population change are fertility, mortality and migration. In addition to this, Cunningham, (2013), dictated births ,deaths, immigration and emigration as some of the factors that causes increase or decrease in human population .In respect to this , Yadav (2017) in his study on Demographic attributes and population Dynamics stated that both decrease and increase in population growth can be experienced in backward and rural areas while cities encounters difficulties of over population as a result of out – migration gaining space in the state due to rural to urban, district to district, and state to state migration.

Demographic transition implies the change in the condition of human from high mortality and high fertility to low mortality and low fertility according to Caldwell (2012), He also stated that an average woman gives birth to six (6) or seven (7) especially in the less developing countries. Following Caldwell (1987), fertility rate is the number of children born to women yearly per 1000 of the population.

Nigeria following Caldwell, (1987), defines Fertility Rate as the average number of children born to women during their reproductive years (15 – 49). In other words, fertility rate is the total number of birth per woman. The most important factor in population growth is the total fertility rate (TFR). Total Fertility Rate is often refer to as fertility rate.

World fertility report (2015), predicted population projections through 2100 empirical data, underlying fertility rate estimates and its effects on population growth. Also Fertility Rate – Our world in Data (2017) observed that as health improves and the mortality in the population decreases there was a typical acceleration in population growth which was resolved as the fertility rate drops to two (2) children per 1000women within the age bracket of 15-49 years in one (1) year. According to Akanni and Uche (2014), total fertility rates in Nigeria have assumed a downward trend from an average of 6 children per woman in 1990 to 5.5 in 2013.

Nigeria's population Projected – to – double – by – 2050, stated, with Nigeria's population growing at more than 3% a year, Nigerian authorities are offering free family planning methods and advices Nigerian families in an effort to slow down population growth. Nigeria is predicted to have more than 400 million People by 2050, doubling the present population.

Mathematical Formulations

For the purpose of this study, the following dynamical systems of a nonlinear first order ordinary differential equations that have the following mathematical structure is considered.

$$\frac{dP_1(t)}{dt} = \alpha_1 P_1 - \beta_1 {P_1}^2 + r_1 P_1 P_2 - f_1 {P_1}^2 P_2 \qquad (3.1)$$

$$\frac{dP_2(t)}{dt} = \alpha_2 P_2 - \beta_2 {P_2}^2 + r_2 P_1 P_2 - f_2 P_1 {P_2}^2 \qquad (3.2)$$

with the initial population sizes;

$P_1(0)=P_{10}>0$ and $P_2(0)=P_{20}>0$ at time $t = 0$

Here, $P_1(t)$represents Irete (the first suburban) human population size at a time (t) and $P_2(t)$ represents Orji (the second sub – urban) human population size at a time (t). $\beta_1 and \beta_2$ represents the intra - competition coefficients due to the interaction between the two suburban cities of Owerri for the purpose of business, traditional rights, and other social-economic scenarios. r_1 and r_2 represents the contribution of each sub - urban population to inhibit the growth of each individual in suburban population size due to migration flow. $f_1$and f_2 represents the fertility rate of the first and second suburban populations which is here estimated by using a standard determinants fertility rate in Nigeria. Denotation "t" represents a unit of time. α_1 and α_2 denotes the intrinsic growth rate of Irete human population and the intrinsic growth rate of Orji human population respectively. $\frac{dP_1(t)}{dt}$ is the rate of change of the human population of Irete city with respect to time (t). $\frac{dP_2(t)}{dt}$ is the rate of change of the human population of Orji city with respect to time (t). The models $\beta_1,\ \beta_2,\ r_1\ and\ r_2$ are non – linear parameter values while $\alpha_1\ and\ \alpha_2$ are linear parameter values. $P_1(0)$ defines the initial human population size of Irete in Owerri West Local Government Area. Whereas $P_2(0)$ defines the initial human population size of Orji in Owerri North Local Government Area.

These initial conditions $P_1(0) = P_{10} > 0$

$$P_2(0) = P_{20} > 0$$

specifies the starting population sizes on which the stimulation modelling is based. This mathematical structure is a modified Lotka – Volterra formulation. (Ekaka-a , 2009, Yan & Ekaka-a , 2011 , Ford, Lumb & Ekaka-a , 2010).

For the purpose of this work, we are interested in everyone (1) month (every 30 days) population projections using numerical methods to predict the following data values.

$P_1(1), P_1(31), P_1(91), P_1(121), P_1(151), P_1(181), P_1(211), P_1(241), P_1(271), P_1(301), P_1(331)$.

And also;

$P_2(1), P_2(31), P_2(91), P_2(121), P_2(151), P_2(181), P_2(211), P_2(241), P_2(271), P_2(301), P_2(331)$.

Method of Analysis

For the present study, we are interested to quantify the effect of varying fertility rate values together on the population predictions of two interacting sub - urban of Owerri city by using first order ordinary differential equations of order 45(ODE 45), which is considered to be computationally more efficient than its counterpart numerical methods such as ODE 23, ODE 23tb and ODE15s. The variation of the fertility rate values together can either produce a depletion or an increase on the population predictions.

In the scenario when all the model parameters are fixed, the population predictions is expected to produce either an increasing monotonically behaviour or decreasing monotonically behaviour. In the context of a numerical simulation analysis, the expected data that are predicted when all the model parameters are fixed are classified as old data. Whereas, when the fertility rate values varied, the new similar data obtained are classified as new data. In this context, when the new data values are smaller than the old data values, depletion has occurred. This depletion can be quantified by using the following mathematical expressions in percentage terms in which EPD represents the Estimated Proportion Depleted in terms of percentage.

$$EPD\ (\%) = \left[\frac{Old\ \ Population\ Data - New\ Population\ Data}{Old\ Population\ Data}\right]\ (100)$$

Alternatively, when the new population data out weights the old population data, the above depletion formula is replaced with a new formula which is defined as follows in which EPI represents the Estimated Proportion Increase in terms of percentage.

$$EPI(\%)\ =\ \left[\frac{New\ Population\ Data\ \ - Old\ Population\ Data}{Old\ Population\ Data}\right] (100)$$

These two mathematical formulae were applied in this work to the desirable results stated below.

To calculate the Best Fit Bifurcation Point:

The Upper Limit Bifurcation Interval (ULBI) is at 101% fertility rate variation

$$ULBI = (1.01)(5.74)$$
$$= 5.797$$

The Lower Limit Bifurcation Interval (LLBI) is at 99.98% variation of fertility rate.

$$LLBI = (0.9998)(5.74)$$
$$= 5.739$$

Metric function of 5.74 at 99.98% variation:

$$d(LLBI, ULBI) = d(5.739, 5.797)$$
$$= |\,5.739 - 5.797\,|$$
$$= |-0.058|$$
$$= 0.058$$

Therefore, the BEST FIT BIFURCATION POINT is at 99.98% variation of the fertility rate because the lower limit bifurcation interval is very close to the assumed fertility rate parameter value. Hence it is after this point that fertility rate witnessed increase in variation and decrease in human population commenced.

Results

The results of this work is recorded as follows in the tables below :

1. Numerical analysis of population projections due to a decrease in the variation of the two fertility rates parameter values together.
2. Numerical analysis of population projections due to an increase in the variation of the two fertility rates parameter values together.

Each suburban population projection for every 30 days is multiplied by 100,000

Table 1.1:

Quantifying the impact of decreasing the fertility rate by 10% variation of the fertility rate on the population projections of Orji Population Projection (PP) in Imo State using ODE 45 numerical simulation; $f_1 = f_2 = 0.574$

Example	Time (d)	PP (ORJI) old	PP (ORJI) new	EPI (%)
1	1	5.500000000000000	5.500000000000000	0.000000000000000
2	31	0.000002865441584	0.000009062473894	0.002162679687295

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3	61	0.000002691058836	0.000008510764099	0.002162607961678
4	91	0.000002526060254	0.000007989514482	0.002162836067927
5	121	0.000002372568587	0.000007503731806	0.002162703850515
6	151	0.000002226981551	0.000007043960722	0.002163008116115
7	181	0.000002091651985	0.000006615804421	0.002162956585243
8	211	0.000001963369513	0.000006210547129	0.002163208498982
9	241	0.000001843913630	0.000005832784646	0.002163263479446
10	271	0.000001730988195	0.000005475879746	0.002163441415407
11	301	0.000001625487082	0.000005142309030	0.002163549613186
12	331	0.000001526119098	0.000004828183927	0.002163700612898

Table 1.2:

Quantifying the impact of decreasing the fertility rate by 15% variation of the fertility rate on the population projections of Orji Population Projections (PP) in Imo State using ODE45 numerical simulation; $f_1 = f_2 = 0.861$

Example	Time (d)	PP (ORJI) old	PP (ORJI) new	EPI (%)
1	1	5.500000000000000	5.500000000000000	0.000000000000000
2	31	0.000002865441584	0.000007399196136	0.001582218453128
3	61	0.000002691058836	0.000006946546965	0.001581343400143
4	91	0.000002526060254	0.000006523244880	0.001582378970979
5	121	0.000002372568587	0.000006124527534	0.001581391141686
6	151	0.000002226981551	0.000005751194656	0.001582506645579
7	181	0.000002091651985	0.000005400094865	0.001581736781530
8	211	0.000001963369513	0.000005070614961	0.001582608586065
9	241	0.000001843913630	0.000004761312149	0.001582177424605
10	271	0.000001730988195	0.000004470621204	0.001582698840331
11	301	0.000001625487082	0.000004197971070	0.001582592698917
12	331	0.000001526119098	0.000003941662196	0.001582801172114

Table 1.3:

Quantifying the impact of decreasing the fertility rate by 20% variation of the fertility rate on the population projections of Orji Population Projections (PP) in Imo State using ODE 45 numerical simulation; $f_1 = f_2 = 1.148$

Example	Time (d)	PP (ORJI) old	PP (ORJI) new	EPI (%)
1	1	5.500000000000000	5.500000000000000	0.000000000000000
2	31	0.000002865441584	0.000006405802555	0.001235537653224
3	61	0.000002691058836	0.000006012270371	0.001234165337185

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4	91	0.000002526060254	0.000005647416617	0.001235661879812
5	121	0.000002372568587	0.000005299761507	0.001233765352882
6	151	0.000002226981551	0.000004978894528	0.001235714312363
7	181	0.000002091651985	0.000004672855817	0.001234050334443
8	211	0.000001963369513	0.000004389505012	0.001235699894084
9	241	0.000001843913630	0.000004120342142	0.001234563525550
10	271	0.000001730988195	0.000003869811245	0.001235608108918
11	301	0.000001625487082	0.000003633095831	0.001235081331004
12	331	0.000001526119098	0.000003411569682	0.001235454418784

Table 2.1:

Quantifying the impact of increasing the fertility rate by 101% variation of the fertility rate on the population projections of Orji Population Projection (PP) in Imo State using ODE 45 numerical simulation; $f_1 = f_2 = 5.797$

Example	Time (d)	PP (ORJI) old	PP (ORJI) new	EPD (%)
1	1	5.500000000000000	5.500000000000000	0.000000000000000
2	31	0.000002865441584	0.000002851128087	0.000004995215053
3	61	0.000002691058836	0.000002677520038	0.000005031029910
4	91	0.000002526060254	0.000002513439377	0.000004996269274
5	121	0.000002372568587	0.000002360613520	0.000005038870978
6	151	0.000002226981551	0.000002215846801	0.000004999929470
7	181	0.000002091651985	0.000002081111520	0.000005039301719
8	211	0.000001963369513	0.000001953542901	0.000005004973270
9	241	0.000001843913630	0.000001834629784	0.000005034859771
10	271	0.000001730988195	0.000001722313914	0.000005011172961
11	301	0.000001625487082	0.000001617313625	0.000005028312681
12	331	0.000001526119098	0.000001518460917	0.000005018075850

Table 2.2:

Quantifying the impact of increasing the fertility rate by 105% variation of the fertility rate on the population projections of Orji Population Projection (PP) in Imo State using ODE 45 numerical simulation; $f_1 = f_2 = 6.027$

Example	Time (d)	PP (ORJI) old	PP (ORJI) new	EPD (%)
1	1	5.500000000000000	5.500000000000000	0.000000000000000
2	31	0.000002865441584	0.000002795909198	0.000024265853678
3	61	0.000002691058836	0.000002625324765	0.000024426842423

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4	91	0.000002526060254	0.000002464764023	0.000024265546185
5	121	0.000002372568587	0.000002314537447	0.000024459204566
6	151	0.000002226981551	0.000002172910258	0.000024280081505
7	181	0.000002091651985	0.000002040498196	0.000024456166471
8	211	0.000001963369513	0.000001915659828	0.000024299900761
9	241	0.000001843913630	0.000001798871873	0.000024427259715
10	271	0.000001730988195	0.000001688887357	0.000024321851812
11	301	0.000001625487082	0.000001585844722	0.000024387988090
12	331	0.000001526119098	0.000001488967502	0.000024343837887

Table 2.3b:
Quantifying the impact of increasing the fertility rate by 110% variation of the fertility rate on the population projections of Orji Population Projection (PP) in Imo State using ODE 45 numerical simulation; $f_1 = f_2 = 6.314$

Example	Time (d)	PP (ORJI) old	PP (ORJI) new	EPD (%)
1	1	5.500000000000000	5.500000000000000	0.000000000000000
2	31	0.000002865441584	0.000002731282063	0.000046819841716
3	61	0.000002691058836	0.000002565053990	0.000046823519352
4	91	0.000002526060254	0.000002407383228	0.000046981075218
5	121	0.000002372568587	0.000002261573110	0.000046782831897
6	151	0.000002226981551	0.000002122603626	0.000046869685552
7	181	0.000002091651985	0.000001993808417	0.000046778130149
8	211	0.000001963369513	0.000001871472014	0.000046806012678
9	241	0.000001843913630	0.000001757600485	0.000046809755040
10	271	0.000001730988195	0.000001650020701	0.000046775301249
11	301	0.000001625487082	0.000001549342183	0.000046844358045
12	331	0.000001526119098	0.000001454754232	0.000046762317616

Discussion of Results

The results of this study are presented as displayed on tables 1.1 to 1. 3, for the effect of decreasing fertility rate and tables 2.1 and 2.3 for the effect of increasing the fertility rate on Population Projections (PP) of Orji communities. In these tables, the first column represents the months (duration) of the study. The length of the study season is twelve (12) months. The second column represents the time in days (331) of the study. The third column data shows the Population Projection values

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when all the model parameter values are fixed. The fourth column represents the Population Projection values when only the fertility rates of Orji is varied. The fifth column represents the Estimated Proportion Increase Percentage (EPI %) for the decrease in fertility rate and/or Estimated Proportion Depleted Percentage (EPD %) for an increase in the fertility rate respectively. The first row of all the tables is called the initial human population condition and the Estimated Proportion Increase Percentage (EPI%) and Estimated Proportion Depleted Percentage (EPD%) is zero (0) in the two suburban populations. This is because the values of their old and new Population Projections are the same (equal) at this initial condition or stage and when their difference is divided by their old Population Projection (PP) data gives zero.

From tables 1.1, where the fertility rate $f = 5.74$ was decreased by 10%, the fertility rate of the second suburban population, Orji ; $f_2 = 0.574$, we observed from the results that the new Population Projections (PP) outweighed the old Population Projections (PP). This yielded an increase in the columns of the Estimated Proportion Increase Percentage (EPI%). This result is in agreement with human population projection theory and works done by previous demographers (researchers on human population predictions)

From tables 1.2, where the fertility rate $f = 5.74$ was decreased by 15%, the fertility rate of the second suburban population, Orji ; $f_2 = 0.861$, we observed from the results that the new Population Projections (PP) outweighed the old Population Projections (PP) . This yielded an increase in the columns of the Estimated Proportion Increase Percentage (EPI%). This result is in agreement with human population projection theory and works done by previous demographers (researchers on human population predictions)

From tables 1.3, where the fertility rate $f = 5.74$ was decreased by 20%, the fertility rate of the second suburban population, Orji ; $f_2 = 1.148$, we observed from the results that the new Population Projections (PP) outweighed the old Population Projections (PP) . This yielded an increase in the columns of the Estimated Proportion Increase Percentage (EPI%). This result is in agreement with human population projection theory and works done by previous demographers (researchers on human population predictions) as cited earlier in this work.

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From tables 2.1, where the fertility rate $f = 5.74$ was increased by 101%, the fertility rate of the second suburban population, Orji ; $f_1 = 5.794$, we observed from the results that the old Population Projections (PP) outweighed the new Population Projections (PP) . This yielded a decrease in the columns of the Estimated Proportion Depleted Percentage (EPD%). This result is in agreement with human population projection theory and works done by previous demographers (researchers on human population predictions) as cited earlier in this work

Also, fom tables 2.2, where the fertility rate $f = 5.74$ was increased by 105%, the fertility rate of the second suburban population, Orji ; $f_2 = 6.0270$, we observed from the results that the old Population Projections (PP) outweighed the new Population Projections (PP). This yielded a decrease in the columns of the Estimated Proportion Depleted Percentage (EPD%). This result is in agreement with human population projection theory and works done by previous demographers (researchers on human population predictions) as cited earlier in this work

From tables 2.3, where the fertility rate $f = 5.74$ was increased by 110%, the fertility rate of the second suburban population, Orji ; $f_2 = 6.3140$, we observed from the results that the old Population Projections (PP) outweighed the new Population Projections (PP). This yielded a decrease in the columns of the Estimated Proportion Depleted Percentage (EPD%). This result is in agreement with human population projection theory and works done by previous demographers (researchers on human population predictions) as cited earlier in this work

Conclusion

This research work numerically analysed the system of two nonlinear ordinary differential equation involving Changes in the Human Population of Orji In Owerri North Local Government Area of Imo State Nigeria, from which evidence shows that changes in human population can be influenced by variation of fertility rate. A decrease in fertility rates yields an increase on the population growth of the sub–urban populations of Orji . Also, increase in fertility rates produces depletion on the population growth of the Orji populations. Therefore, the study observe that investments in education and health sector will required in the actualization of demographic dividend in Orji , Owerri North Local Government Area Imo State , Nigeria.

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