MODELING ON POPULATION GROWTH AND COMPARATIVE ANALYSIS BETWEEN INDIA AND BRAZIL

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Certificate

This is to certify that this project report entitled " Model on Population Growth and Cooperative analysis between India and Brazil" submitted by "Abhishek , Shivam and Md Amir" for partial fulfillment of the **B.tech Degree** (First Semester) offered by the **Cluster Innovation Centre, University of Delhi** during the academic year 2021-2022 is a bonafide record of work done by students under my supervision , and this work has not formed the basis for award of any Degree, Diploma or such other titles.

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<u>Abstract</u>

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ANALYSIS BETWEEN INDIA AND BRAZIL

by

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We analyse the simple model of temporal behaviour of population growth model of India and Brazil. The biggest challenge in the world is population growth and determining how society adapt to it as it as it directly affects the fundamental human rights. India is the second most population country in the world, with over 1.3 billion people more than $1/6^{th}$ world population . We made two mathematical model using the concept of Differential Equation on the subject of population growth model and compare the analysis between two different country population data, it is found that all projection data from 2000-2021 using the Logistic Growth Model was very closer to actual data.

Introduction

Population growth increase the demand for food, water energy and other facilities such as education , health care, transportation, etc.

India is the second most populous country in the world with almost 1/6th of the world population . According to latest data, India's current population is 1393,409,038 in 2021 and in 2021 population density of India is 423.88 people per square km.

Brazil is 6th most populous country in the world located in South America. Based on the most recent statics. The current population of Brazil is 213,993,437 in 2021 and population density of Brazil is 25.13 person per square km. in 2021

Very little research has been done on the projection of population growth in Brazil . After study, we analysed data , forecasted Brazil using Logistic model and Exponential Growth model, we has drawn a comparative scenario of Brazil and India.

Methodology

The key goal of paper is to highlight critical issue and emerging future challenges and opportunities related to population growth and adaptation. The study is based on projection analysis using a population growth model.

It important to know the rate of population growth in order to project the future population of a given country.

IMPLEMENTATION $\rightarrow$ The population model is a type of mathematical model that can be used for population dynamic research. In this paper population projection using the two mathematical model are :- (a)Exponential Model (b) Logistic Model.

Exponential growth model

Suppose the population P_0 at a certain time $t = t_0$ and to know the population P to forecast a particular time $t = t_1$ in initial conditions is

$P(t_0) = P_0$

$$\frac{dP}{dt} = rP(t) \quad , \qquad t_0 \leq t \leq t_1 \quad , \qquad P(t_0) = P_0$$

By integrating

$$\frac{dP}{dt} = rP(t) \quad \Rightarrow \frac{dP}{P} = rdt \quad \Rightarrow \int \frac{dP}{dt} = \int rdt$$

$$\Rightarrow \ln P = rt + C \quad \Rightarrow P = e^{rt+C} \Rightarrow P = e^{rt} \cdot e^C$$

$$\Rightarrow P = A\, e^{rt} \qquad ....(i)$$

For intial condition, $P(t_0) = P_0$ ....(ii)

$$P(t_0) = A\, e^{rt_0} \qquad ....(iii)$$

from Eq^n (ii) &(iii)

$$P_0 = A\, e^{rt_0} \quad \Rightarrow A = P_0 e^{-rt_0}$$

Putting the value of A in Eq^n (i)

$$P(t) = P_0 e^{-rt_0} \cdot e^{rt} \qquad \Rightarrow P(t) = P_0 e^{r(t-t_0)} \quad ....(iv)$$

Calculation for Exponential growth model

We determine the growth rate of both India and Brazil

From table 1 $\qquad t_0 = 2000$ & t= 2021 . The population of India is $P_0 = 1056.58$ & P = 1391.95 and the population of Brazil is $P_0 = 174.79$ & P = 213.99

For India $\qquad P(t) = P_0 e^{r(t-t_0)}$

$$\Rightarrow 1391.95 = 1056.58 e^{r(2021-2000)}$$

$$\Rightarrow r = 0.0131$$

For Brazil $\qquad P(t) = P_0 e^{r(t-t_0)}$

$$\Rightarrow 213.99 = 174.79 e^{r(2021-2000)}$$

$$\Rightarrow r = 0.0096$$

Logistic Growth model

We know ,

$$\frac{dP}{dt} = a\, P - bP^2$$

$$\Rightarrow \frac{dP}{dt} = b\,P\left(\frac{a}{b} - P\right) \qquad\qquad \Rightarrow \frac{dP}{dt} = KP\,(M - P)$$

where , K=b and $M = \frac{a}{b}$ are constant

$$\Rightarrow \int \frac{dP}{P(M-P)} = \int K dt \qquad\qquad \Rightarrow \frac{1}{M}\int \left(\frac{1}{P} - \frac{1}{M-P}\right) dP = \int K dt \quad \text{i}$$

$$\Rightarrow \int \left(\frac{1}{P} - \frac{1}{M-P}\right) dP = \int MK dt \;\Rightarrow\; \ln P - \ln(M-P) = MKt + C \qquad ....(v)$$

For initial conditions : $t = t_0$; $P(t_0) = P_0$

$$t = t_1 ; \; P(t_1) = P_1$$

$$t = t_2 ; \; P(t_2) = P_2$$

we put all three initial condition in equation (v) , we get

$$P(t) = \frac{M\,P_0}{P_0 + (M - P_0)e^{KM(t_0 - t)}} \qquad .,................(vi)$$

Calculatioin for logistic growth model

  Again ,

from table 1 , $t_0 = 2000$, $t_1 = 2010$ & $t_2 = 2020$. The population of India is $P_0 = 1056.58$, $P_1 = 1234.28$ & $P_2 = 1380$ and   the population of Brazil is $P_0 = 174.79$, $P_1 = 195.71$ & $P_2 = 212.55$ (in millions)

We get from (vi) then

For India, M=1723.23 and K =0.000023   and

For Brazil, M =263.56   and K = 0.00011

Now, the general equation of logistic Model for India and Brazil is

$$P(t) = \frac{1820730.35}{1056.58 + 666.65 e^{0.039(2000 - t)}}$$

$$P(t) = \frac{46067.6524}{174.79 + 88.77 e^{0.029(2000 - t)}}$$

Result :-

From table 1 , It is indicate that the growth rate of population of Brazil is approximately 1.43% , 1.15% , 0.49% , 0.84% , 0.72% in 2000 , 2005 , 2010 , 2015 , 2020 respectively which are nearly close with finding in this paper of growth rate of 1.71% by Exponential model and 3.89% by Logistic model and the growth rate of population in India is approximately 1.78% , 1.59% , 1.36% ,

1.12% , 0.99% , in 2000 , 2005 , 2010 , 2015 , 2020 which is nearly closer to finding in this paper of growth rate of population , 1.13% by Exponential model and 3.52% by Logistic model . Based on this result , the projected population in 2050 using two model :- Exponential growth model and logistic growth model , comes out to be 2023.34 million and 1581.28 million in India respectively and also come out to be 282.47 million and 238.94 million in Brazil respectively.

➢ Actually Population and Growth Rate both of India and Bangladesh from 2000 to 2021 :

Year	Actual Population (in Millions)		Population Growth (in percent)	
	India	Brazil	India	Brazil
2000	1056.58	174.79	1.78%	1.43%
2001	1075.00	177.19	1.74%	1.38%
2002	1093.32	179.53	1.70%	1.32%
2003	1111.52	181.80	1.67%	1.27%
2004	1129.62	184.00	1.63%	1.21%
2005	1147.61	186.12	1.59%	1.15%
2006	1165.49	188.16	1.56%	1.10%
2007	1183.21	190.13	1.52%	1.04%
2008	1200.62	192.03	1.48%	1.00%
2009	1217.73	193.88	1.42%	0.97%
2010	1234.28	195.71	1.36%	0.94%
2011	1250.29	197.51	1.30%	0.92%
2012	1265.78	199.28	1.24%	0.90%
2013	1280.84	201.03	1.19%	0.88%
2014	1295.60	202.76	1.15%	0.86%
2015	1310.15	204.47	1.12%	0.84%
2016	1324.52	206.16	1.10%	0.83%
2017	1338.68	207.83	1.07%	0.81%
2018	1352.64	209.46	1.04%	0.79%
2019	1366.42	211.04	1.02%	0.75%
2020	1380.00	212.55	0.99%	0.72%
2021	1391.95	213.99	1.02%	0.67%

Table 1

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Projected population both of India and Brazil from 2000 to 2050 :

Year	Exponential Model		Logistic Model	
	India	Brazil	India	Brazil
2000	1056.58	174.79	1056.58	174.79
2001	1070.10	176.47	1072.44	176.49
2002	1084.10	178.17	1088.16	178.17
2003	1098.28	179.89	1103.72	179.84
2004	1112.65	181.63	1119.11	181.48
2005	1127.21	183.38	1134.32	183.11
2006	1141.96	185.15	1149.34	184.72
2007	1156.91	186.93	1164.17	186.32
2008	1172.04	188.74	1178.80	187.89
2009	1187.38	190.56	1193.22	189.44
2010	1202.92	192.40	1207.42	190.98
2011	1218.66	194.25	1221.41	192.50
2012	1234.60	196.13	1235.17	193.99
2013	1250.76	198.02	1248.69	195.47
2014	1267.12	199.93	1261.99	196.92
2015	1283.70	201.86	1275.04	198.35
2016	1300.50	203.80	1287.85	199.77
2017	1317.52	205.77	1300.42	201.16
2018	1334.76	207.76	1312.74	202.53
2019	1352.22	209.76	1324.81	203.88
2020	1369.92	211.78	1336.63	205.20
2021	1387.84	213.83	1348.20	206.51
2022	1406.00	215.89	1359.51	207.80
2023	1424.40	217.97	1370.58	209.06
2024	1443.04	220.07	1381.39	210.30
2025	1461.92	222.20	1391.95	211.52
2030	1560.10	233.12	1441.03	217.59
2035	1664.88	244.59	1484.09	227.36
2040	1776.69	256.61	1521.50	231.65
2045	1896.01	269.23	1553.72	235.50
2050	2023.34	282.47	1581.28	238.94

Table -2

- Population Growth in India from 2000 to 2050

___ -Actual   — - Exponential Modal   ___ - Logistic Modal
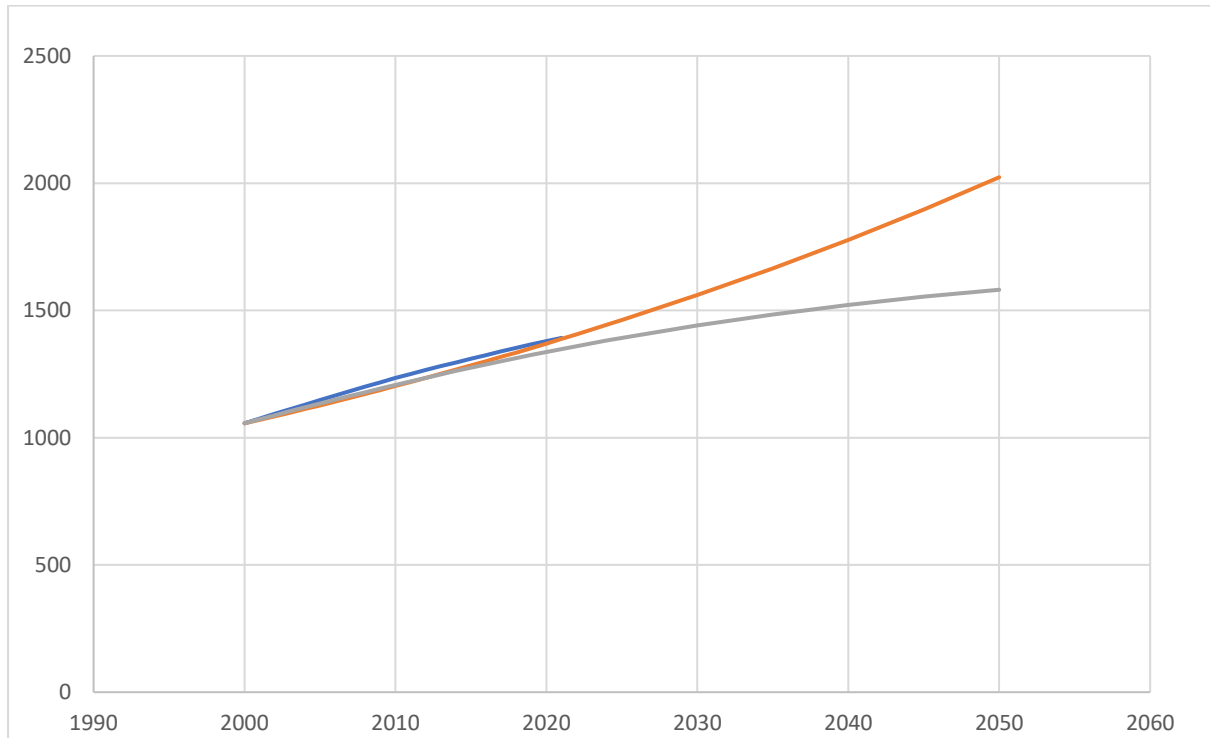
- Population Growth in Brazil from 2000 to 2050

___ -Actual   ___ - Exponential Modal   ___ - Logistic Modal