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Components of Population growth and change

Population growth

Population growth is a significant aspect that impacts various aspects of society. Understanding the components of population growth helps us comprehend the dynamics of population change. The population of a country or region can change over time due to many factors. This includes birth, death, and migration.

Major Components of Population Growth:

- Natural Increase: Births and Deaths
- Net Migration: Immigration and Emigration
- Fertility Rate: Childbearing Patterns
- Mortality Rate: Patterns of Death
- Age Structure: Distribution of Age Groups

Natural increase: Births and deaths

Population growth is affected by the number of births and deaths in a population. The following indicators can help us analyze this component:

Birth rate

This is the number of live births per 1,000 people in a population in a year. It shows how fertile a population is and varies across different regions.

Death rate

This is the number of deaths per 1,000 people in a population in a year. It shows the overall health and mortality conditions in a society.

Infant mortality rate

This is the number of infant deaths under one year of age per 1,000 live births in a year. It is an important indicator of the healthcare and well-being of a population.

Life expectancy

This is the average number of years a person is expected to live. It shows the overall health and quality of life in a population.

Net Migration: Immigration and Emigration

Net migration is the difference between the number of people who immigrate to a region and the number of people who emigrate from it. The following components contribute to net migration:

Immigration

This is when people move to a country or region with the intention of settling there. It contributes to population growth by increasing the number of residents in a given area.

Emigration

This is when people move from a country or region to live elsewhere. It leads to a decrease in the population of the area of origin.

Net migration rate

This is the difference between the number of immigrants and emigrants per 1,000 people in a population in a year. It shows the overall impact of migration on population growth.

Fertility Rate: Childbearing Patterns

The fertility rate measures the average number of children born to women during their reproductive years. Two key factors associated with the fertility rate are:

Total fertility rate (TFR)

This is the average number of children a woman is expected to have in her lifetime. It provides insights into population replacement levels and future population growth.

Replacement level fertility

The fertility rate required for a population to replace itself without migration. It is typically estimated to be around 2.1 children per woman.

Mortality Rate: Patterns of Death

Mortality rate encompasses the occurrence of deaths within a population. It can be examined using the following indicators:

Crude death rate (CDR)

This is the number of deaths per 1,000 people in a population in a year. It provides an overall picture of mortality within a population.

Age-specific death rate (ASDR)

This is the number of deaths occurring in specific age groups per 1,000 people in a year. It helps identify variations in mortality patterns across different age groups.

Age Structure: Distribution of Age Groups

The age structure of a population plays a vital role in determining population growth and development. Key components include:

Dependency ratio

This measures the proportion of dependent individuals to the working-age population. It influences the social and economic dynamics of a society.

Median age

This represents the midpoint of a population's age distribution. It reflects the overall age composition and demographic profile.

Population growth

The term 'population change' signifies the fluctuation in the number of individuals within a specific time frame. The global population is constantly evolving, driven by factors such as birth rates, death rates, and migration patterns. Over the past few decades, the world population has significantly increased. Population change, broadly defined, refers to the variation in the size of a population from the commencement to the conclusion of a specified period, typically one year.

The alteration in population encompasses two main components:

- Natural population change, calculated as the disparity between the number of live births and deaths.
- Net migration, which involves the difference between the number of immigrants and emigrants, accompanied by a statistical adjustment. It is essential to note that in the context of population change statistics, net migration includes statistical adjustments within the annual population balance, serving the purpose of reconciling this balance.

Causes of Population Change

The following factors are primarily responsible for population change:

- High fertility rates
- Increasing aging population
- Human Migration

The global population increase is mainly attributed to the rapid rise in the natural growth rate, which is the difference between a country's birth rate and death rate.

Migration: Understanding Immigration and Emigration

- Migration, a significant cause behind population change, involves the movement of individuals into (immigration) or out of (emigration) a specific area or country.
- Countries such as the United States and Australia have experienced population growth due to immigration.
- Generally, international migrations occur from less developed nations to more developed ones, driven by the search for better job opportunities.
- Within countries, numerous individuals migrate from rural to urban areas seeking better employment, education, and healthcare facilities.

Four Major Factors Influencing Population Change

The following four factors play a crucial role in population change:

- Birth rate
- Death Rate
- Immigration
- Emigration

Calculating Population Change

The formula for calculating population change is as follows:

$$\text{Population change} = (\text{Births} + \text{Immigration}) - (\text{Deaths} + \text{Emigration})$$

Aspect	Population Growth	Population Change
Definition	Refers to the increase in the number of individuals in a population over time.	Encompasses both increases and decreases in population size due to various factors.
Direction	Unidirectional, focusing on the numerical increase of the population.	Bi-directional, accounting for both growth and decline in population numbers.
Measurement Period	Typically measured over a specified time period, often expressed as a percentage.	Encompasses both positive and negative changes in population size within a given timeframe.

Factors	Primarily influenced by birth rates, death rates, immigration, and emigration.	Influenced by birth rates, death rates, immigration, emigration, and other demographic factors.
Nature of Change	Indicates a positive numerical increase in population size.	Signifies a broader spectrum of changes, including growth, decline, or stability.
Example	If a population goes from 1,000 to 1,200 in a year, it demonstrates population growth.	If a population goes from 1,000 to 950 in a year, it reflects population change, which could be a decline.
Focus on Dynamics	Primarily focuses on the numerical dynamics of population increase.	Encompasses a holistic view, considering various factors influencing population size.
Measurement Precision	Often measured precisely with specific growth rates and percentages.	May be measured with greater flexibility, accounting for diverse demographic shifts.

Models of population growth:

There are two models of population growth

1. Exponential growth
2. Logistic growth

Exponential growth

Instead of assuming that the population by a constant amount, the exponential model assumes that the population is growing at a constant rate. The growth rate tends to be negative if the population is shrinking over time, which can also fit this model. A constant negative growth is described as exponential decay. For the purpose of projecting population forward or backward, one requires an estimate of its growth rate. A minimum of two estimates of the population by means of a linear regression of the log of population size on time. In this model,

$$P(t + n) = P(t) * e^{rn}$$

where r is the constant growth rate:

$$r = \log_e (P(t+n) / P(t)) / n$$

The exponential model can be further used to estimate the doubling time of a population with a constant growth rate, the time when the population takes to double its initial size. The general exponential model equation goes

$$P(t+n) = P(t) * e^{rn}$$

When the population is doubling every n years,

$$n = \log_e(2) / r = 0.693 / r$$

Ern-error-related negativity.

Logistic Growth

The logistic growth model of the population growth is applicable when the growth rate slows over time, eventually when it drops to zero, a point where the population stabilizes. The equation for logistic model goes

$$P(t)P(\infty)$$

where $P(\infty)$ represents the final size of the population growth and time is measured relative to point h, date at which the population reaches half of its final size, s determines the growth rate, r, at each time it reaches its final size.

$$r = s^t$$

Thus the growth rate declines over time to zero, equaling $s/2$ at time when the population reaches half its final size.

T	P(t)	R
-	0	S
H	$P(\infty)/2$	$s/2$
	$P(\infty)$	0

Methods of projection:

A population projection is an estimation of the number of people expected to be alive at a future date that is made based on assumptions of population structure, fertility, mortality and migration. It is an essential to assess the need for new jobs, schools, doctors and nurses, planning urban housing, foods, clothing and requirements of energy and resources. It is also needed for policy discourse i.e. helps to the policy-makers to understand the existing problems and finally supports to develop the suitable solutions.

Types of Population Projections

Population projection is empirically based on calculations of past or future, population numbers under specified assumptions about changes in population growth or its components. Basically, there are three techniques for population projection:

- Mathematical Method
- Economic Method and
- Cohort Component Method.

Mathematical method:

Mathematical methods are frequently used for the estimation of population. It is done for a short period i.e. less than 10 years. The major assumptions of these methods are: the socio-economic setting affecting to the population size is fairly unchanging, no allowance is made for the irregular fluctuations in the population growth and same growth rate continues for the projection period. Furthermore, mathematical methods are used for inter-censal, post-censal estimates and future population for shorter period and projection for sub-national population.

The mathematical method uses various statistical formulas where the population projection of these methods does not provide the population projection by age and sex as it does not assimilate the past and future trends of fertility, mortality and migration. Some basic techniques of these methods are as follows:

a) Linear Growth Model (Arithmetic Growth Model)

$$P_t = P_0(1 + rt)$$

b) Geometric Growth Model

$$P_t = P_0$$

c) Exponential Growth Model

$$P_t = P_0 e^{rt}$$

d) Gompertz Curve

$$P_t = ab^{e^t}$$

e) Modified Exponential Function

$$P_t = a + bc^t$$

f) Makeham's Curve

$$P_t = \log(a + bc^t)$$

g) Polynomial of Degree n:

$$P_t = a_0 t^0 + a_1 t^1 + a_2 t^2 + \dots + a_n t^n$$

h) Logistic Growth Model

$$p_t = K / (1 + a + bc^t)$$

where,

P_t = current year population

P_0 = base year population

r = growth rate

t = time interval (in years)

e = base of the natural logarithms

Cohort component methods:

The cohort-component technique is a complex method for the population projection. It is the most frequently used method for projecting the population of nations, states, and sometimes smaller units of geography (Shryok & Siegel, 1973). It is the preferred method of national and international statistical organizations for projecting national population. This method is also useful for sub-national projection. Moreover, it provides projections by age and sex, the method is equally applicable at national and sub-national levels, it makes sufficient use of accessible statistical information on the components of population change. Furthermore, it has immense analytical value in understanding developments and the relative contributions of growth from different sources. At the same time, the method is flexible: assumptions can be varied according

to expectations about future directions of change in specific components. Like most projection tools and techniques, there are some disadvantages in using the cohort component method. First, it is highly dependent on reliable birth, death and migration data. Thus, it is difficult to collect the information to apply this tool. Second, it assumes that survival, birth rates and estimations of net migration will remain the same during the projected period.

Economic Method

Mathematical Method and Cohort Component Method of population projections require basic information of annual population growth, birth, death and migration rate. However, the factors really affecting them are not taken into consideration so the projected statistical information remains dynamic. Consequently, this method tries to explain how economic factors influence the demographic factors i.e. birth, death and migration rates. Economic development is more significant to know the effects of migrations.

In most of the developing countries, people migrate from the backward areas to developed areas in search of jobs and opportunities. In addition, the rural, urban, age and sex-wise number of projected labors are to be forecasted. These deviations, their effects on urbanization and the consequent growth of towns, cities and urban centers and birth rate, death rate and growth rate of population in them are projected. This method is more essential for province-wise projections than for the entire country. Among the various methods, it is also an essential technique for national population projection but it is a less applicable method.

Stable population:

A closed population subject to constant age-specific birth and death rates eventually becomes stable, with a constant growth rate and a constant age-distribution. We have already encountered the idea of a stationary population, where death rates are constant and there is a steady stream of births. In a stable population the birth stream grows exponentially over time.

The Renewal Equation

Let (t) denote the number of female births at time tt , and let (aa,t) be the number of women age aa at time t . (These are both densities, so strictly speaking the number of births in a short interval of time is the product of (t) times the width of the interval.) Suppose that starting at time zero the age-specific birth and death rates become constant. Let (a) denote the maternity function at any time after zero. If the reproductive span runs from ages α to β the number of births at time t is

$$B(t) = \int_0^{\beta} N(\alpha, t) m(\alpha) d\alpha, t > 0$$

Between time zero and α the only women having children were already born at time zero, so they are products of whatever fertility and mortality regimes existed before. Between time α and β we have a mix of old timers and women who have been born in the new regime. But when we reach time β and beyond, all women in the reproductive ages have been born in the new regime; they are the product of the fertility and mortality schedules in the model.

Consider then $N(\alpha, t)$, the number of women aged α at time t for $t > \beta$. These are the survivors of the cohort born at time $t - \alpha$, which had initial size $B(t - \alpha)$. Let $p(\alpha)$ the probability of surviving to age α for someone born after time zero. We can then write

$$N(\alpha, t) = B(t - \alpha) p(\alpha), t > \beta$$

and the stream of births becomes

$$B(t) = \int_0^{\beta} B(t - \alpha) p(\alpha) m(\alpha) d\alpha,$$

This is an integral equation (an equation involving a function and its integral). We would like to solve it, by which we mean finding a function $B(t)$ that satisfies it. Lotka tried an exponential form, where

$$B(t) = Be^{rt}, \quad t > 0$$

For $t > \beta$ we can also write $B(t - \alpha) = Be^{r(t - \alpha)} = Be^{rt} e^{-r\alpha}$. If we substitute these results into the integral equation and cancel BBe^{rt} , which appears on the left and right hand sides, we get after β time

$$1 = \int_0^{\beta} e^{-r\alpha} p(\alpha) m(\alpha) d\alpha$$

This is Lotka's equation.

Decennial population census in India:

A decennial population census in India is a process that collects, analyzes, and publishes demographic, economic, and social data about a population. The census provides a detailed picture of the population and its characteristics, including age, gender, education, employment, income, and housing.

The census is a decennial publication of the Government of India. It provides basic statistics on the state of human resources, demography, culture, and economic structure at the local, regional, and national level.

- **Source of Information:** The Indian Census is the **largest single source of a variety of statistical information** on different **characteristics of the people of India**. Researchers and Demographers use census data to **analyze growth and trends of population and make projections**.
- **Good Governance:** The data collected through the census is **used for administration, planning and policy making** as well as **management and evaluation of various programmes** by the Government.
- **Demarcation:** Census data is also used for **demarcation of constituencies and allocation of representation to Parliament**, State legislative assemblies and the local bodies.
- **Better Access for Businesses:** The census data is also important for business houses and industries for **strengthening and planning their business for penetration into areas**, which had hitherto remained, uncovered.
- **Giving Grants:** Finance Commission **provides grants to the states on the basis of population figures** available from the Census data.

Major Events/Findings in India's Census:

- **First Census (1881):** It laid main emphasis on the classification of **demographic, economic and social characteristics** of the entire continent of British India (**except Kashmir and French and Portuguese colonies**).
- **Second Census (1891):** It was **conducted almost on the same pattern** as of the 1881 census. Efforts were made for 100% coverage and the Upper part of present-day **Burma, Kashmir and Sikkim were also included**.
- **Third Census (1901):** In this Census, Balochistan, Rajputana, Andaman Nicobar, Burma, Punjab and remote areas of Kashmir were also included.
- **Fifth Census (1921):** The decade of 1911-21 has been the only one till now to witness a decadal population decline of 0.31%. This was the decade that ended in

the flu pandemic of 1918 which cost at least 12 million lives. India's population was continuously increasing until Census 1921 and still has been doing so after the 1921 Census. Therefore, the census year of 1921 is called the year of "The Great Divide" in the demographic history of India.

- **Eleventh Census (1971):** It was the second Census after independence. It added a question for information on fertility for currently married women.
- **Thirteenth Census (1991):** It was the fifth Census of independent India. In this Census, the concept of literacy was changed and the children of the 7+ age group were considered literate (as compared to 1981 when children up to the age group of 4+ were treated as literate).
- **Fourteenth Census (2001):** It witnessed a quantum leap in the technology front. The schedules for the phases were scanned through high speed scanners and handwritten data from the schedules were converted into digitized form through Intelligent Character Reading (ICR). An ICR captures handwriting from image files. It is an advanced version of Optical Character Recognition (OCR) technology in which printed characters are captured.
- **Fifteenth Census (2011):** In the 2011 Census, significant fall in case of EAG States (Empowered action group states: UP, Uttarakhand, Bihar, Jharkhand, MP, Chhattisgarh, Rajasthan & Orissa) was noticed for the first time.
- **Sixteenth Census (2021):** Census 2021 was postponed owing to the outbreak of Covid-19 pandemic.

However, it will be the first digital Census, also with a provision for self-enumeration. It is for the first time that information of households headed by a person from the Transgender Community and members living in the family will be collected. Earlier there was a column for male and female only.

Implications of the delay in Census

Targeting the Right Beneficiaries:

- Outdated Census information (available from the last Census in 2011) often becomes unreliable and affects those who do and do not receive the benefits of welfare schemes.

- For Instance, **National Food Security Act, 2013** which provides subsidised food grains to poor & vulnerable uses the census data to identify the beneficiaries.
- Moreover, the **Finance Commission** uses census data while granting finances to the states. In absence of exact data allocation of funds to the states would be disproportionate.

Challenges for Research and Analysis:

- Researchers and policymakers may have to rely on outdated information or alternative data sources, which may not provide the same level of accuracy or granularity.
- Census data are critical for other sample surveys conducted in the country as they use the Census data as reference. For instance, the latest **National Family Health Survey (NFHS-5)** released last year used 2011 census data.

Impacts the Political Representation:

- The Census data is also used to demarcate constituencies and allocate seats in Parliament and State Assemblies. The delay in the Census means that the data from the 2011 Census would continue to be used. This may not reflect the rapid changes in the composition of the population over the last decade.
- Census data is used for delimitation of constituencies and for determining the quantum of reservation for **Scheduled Castes** and **Scheduled Tribes**. The delay means that either too many or too few seats are being reserved for SC/STs and women in different regions.

Compromises the Migration Data:

- The Covid pandemic has exposed the need for Migration Data. During lockdowns, the govt – in the absence of adequate data – was unable to target migrant laborers stranded in cities far from their homes.
- Missed Opportunities and Delayed Decision-making: Timely census data is essential for identifying emerging trends, assessing needs, and seizing

opportunities. A delay in the census can result in missed opportunities for targeted interventions, economic planning, and business decisions.

Nuptiality models:

Age distributions of first marriages are structurally similar in different populations. These distributions tend to be smooth, unimodal, skewed to the right and have density close to zero below age 15 and above age 50. In addition that the differences in age at first marriage distributions across female populations present differences in modes, standard deviations and tails. The age pattern of first marriage frequencies was virtually identical in populations characterized by widely different marriage customs when adjusting the vertical and horizontal scales and the origin of the distribution of first marriage frequencies.

In recent years a considerable variation is observed in the pattern of first-marriage in data sets for populations of several countries. At the early ages, in first marriage rates of Chinese women. The new pattern of age-specific first-marriage curves reflects heterogeneity in its behavior. The plausible hypothesis that observations may come from two different groups. This heterogeneity may be associated with many factors such as the educational level and the social status of the population as well as religion, or existence of population groups with different demographic characteristics regarding marriage but all these hypotheses need further investigation of the empirical evidence.

A variety of mathematical models have been proposed in the literature for fitting the first- marriage curve. However, not much work has been done in graduating it, when the bulge at early ages of the first-marriage curve is appeared.

Among the various models used for estimating the age-specific first-marriage pattern of populations several have been proved to provide accurate fits to the one-year specific first marriage rates. These are the Standard Coaled-McNeil model, the Coaled-McNeil model in his flexible form, the generalized log gamma model and the mixture Coale-McNeil model.

The Coale-McNeil (1972) model based on the standard schedule of first marriage frequencies using data from Sweden covering the period 1865-1869, proposed by Coale (1971) is expressed by,

$$f(a) = \frac{C}{k} g_1\left(\frac{a-a_0}{k}\right)$$

where,

$f(a)$ - is the first-marriage frequency at age a ;

C - denotes the proportion of people eventually married in the population;

a_0 - is the origin of the observed distribution or equivalently the youngest age at which an appreciable number of first marriages occurs and which approximately is the first percentile of the distribution;

k - is the inverse of the rate at which first marriages occur in the observed population relative.
