An Empirical Study on Female Population Projection in India

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ABSTRACT

Since 1952, India has undergone demographic as well as economic changes of historic proportions. Demographically, India has transformed itself from a "demographic transitional" society, where reductions in mortality led to rapid population growth and subsequent decreases in fertility led to a slower population growth, to a "post-transitional" society, where life expectancy has reached new heights, fertility has declined gradually, and rapid population ageing is on the horizon. In the not-too-distant future—in a matter of a few decades—India's population will start to shrink, an unprecedented demographic turn in Indian history in the absence of major wars, epidemics, or famines.

The article delineates projected demographic changes in the age structure of India's population and points to the impact these changes will have on India's economy. The empirical methods used in this study show that a continuous decline in fertility has a positive impact on the economic growth of India as this result will not only lower the population growth but also be a benchmark for the development of women and children of India. The result concludes that – economically, India has completed its transition from a socialist centrally planned economy to a market-based economy. This study is based on the secondary data of the Census of India, U.N. Medium of Population Projection and other reading materials and Journals reflecting the recent trends in population.

Keywords Demography, Population Projection and UN Medium Population Projection

INTRODUCTION

Population projection is a process to estimate the population size and structure from one period to another using a technique of information technology. A population projection, therefore, gives a variety of results like describing the pattern and causes of the change which took place during the interim period. In general, a population forecast of longer-term is called projection. However, the prospects of success of the population forecast can't always be held as there can be times when the results of past projections don't match with the population changes that have taken place and hence the population projection may fail to portray the accuracy of past the results. One can say that it is quite similar to the concept of weather forecasting. Even the population experts or the meteorologists know that they cannot present a precise 'forecast,' 'foretell,' or 'predict' the future.

The strategies of Population Projection involve two contrasting approaches, as stated

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below:

Strategies of Population Projection

1. Total methods (Ratio method of projection) 2. Cohort component method

Uses a mathematical model of Population Projection	Measures the parameter like age group, sex and other categories
Calculates the overall trends in the size of the population	All these parameters are projected separately for each of them as per the interest of the demographer
Population is distributed into different sub - groups in ratio	Final result is then aggregated to obtain the total population
Final result presents the structure o f the population	The term cohort is used to with a purpose to emphasise on the characteristics of a particular age group who are born during the same period and undergoes their own life in the coming time intervals together
Extrapolates the forecast of t he age structure	The size of a cohort at one age (and date) is strongly predictive of its size at other ages (and date)

Figure 1 1.

Both the above approaches are often seen combined while studying population projections. However, the cohort component approach is a commonly used method for Population Projection, even as this method requires many more input data and assumptions as compared to the total methods and can be easily computed using computer software.

This method can be used manually as well as on computer to project the population projection for any country. This method is used in this research paper to understand the views of a demographer in working towards the age structure projections of India's population for the future.

COHORT-COMPONENT METHOD OF POPULATION PROJECTIONS

The cohort-component method of population projection models various vital rates, some of which are stated below:

- size and structure ranging from age-sex in a population

- population growth and the components of demographic change which are fertility, mortality, and migration

Whelpton introduced the cohort-component method of population projection in the 1930s. Mathematically, the estimation is done using the following demographic balancing equation:

$$P_{t+n} = P_t + B_t - D_t + I_t - E_t \qquad \textbf{(1.1)}$$

Where;

P_t is the population at time *t*;

B_t and D_t are number of births and deaths occurring between *t* and (*t*+*n*) respectively;

I_t and E_t are the number of immigrants and emigrants from the country during the period *t* to *(t+n)* respectively.

Equation (**1.1**) gives an idea that one can join a population either by having been born into it or by migrating into it. Reversely, if one wants to leave a population, one has to emigrate or die. Globally, none of the human population has ever immigrated, but there are cases where some of unfortunate astronauts have emigrated and never returned. This concept is extended to individual age groups by using the obvious fact that each individual in a population becomes a year older every year. Therefore, after ten years the survivors of the cohort aged 0-5 at some baseline date will be 10-15 years old, and if one moves five years ahead, they will be aged 15-20, and so on. This basis concept is then applied in the cohort-component method population projection.

Below are the steps involved in a cohort-component projection:

Step 1	Each age group is projected for a single projection interval at a specified time
Step 2	During this specified time, the births are calculated and then added in the data of the newly born children
Step 3	The data on migration is then adjusted

Figure 1 2.

These three steps are repeated unless the next population projection begins and continues until the end of the next interval. A data set on n-year age groups is used to project a population of n years of time intervals. Basically, population projection for a single-year age group is made by using data per one year time, and population projection for five-year age groups is done by using data per five-years at a time.

DATA REQUIRED FOR COHORT-COMPONENT PROJECTIONS

The cohort-component projection method requires a detailed assumption on the size and structure of the baseline population and also on each component of population growth during the interim period of the projection. To sum up, the following are the four essential data that are required before applying the cohort-component method of population projection on the data set:

i. The subdivided data set on the age and sex for the base year population,

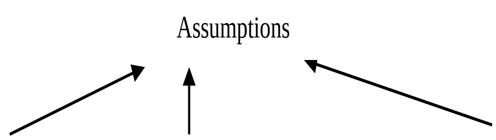
ii. The mortality rate for the defined sex for each projection interval in the projection period,

iii. The fertility rates for the defined age for each projection interval in the projection period,

iv. The net migration for the specified age and sex for each interval in the projection period (this can be ignored if migration did not happen in the population)

Table 1.1 (see below) presents data on the female population of a country named 'X' from 2015 to 2020:

Table 1.1. Projection of the female population of a country named 'X' from 2015 to 2020



Age group	Female population in 2015 ('000s)	Life Table person-years:	Net migrants ('000s)	Female population in 2020 ('000s)	Age-specific fertility rates	Births by age of mother
0–4	904	487813	-1.5	904		
5–9	982	485432	-1.4	899		
10–14	863	485236	-1.9	980		
15–19	781	484692	-2.9	860	0.0281	115.2
20–24	759	483921	-3.9	776	0.1548	594
25–29	842	482898	-3.8	754	0.2676	1067.7
30–34	895	481542	-3.6	836	0.1979	856.4
35–39	832	479694	-2.6	889	0.1895	815.3
40–44	705	476983	-0.4	826	0.1899	726.8

Age group	Female population in 2015 ('000s)	Life Table person-years:	Net migrants ('000s)	Female population in 2020 ('000s)	Age-specific fertility rates	Births by age of mother
45–49	743	472896	-0.8	699	0.0175	63
50–54	689	466601	-0.7	733		
55–59	673	456793	-0.6	674		
60–64	543	441397	-0.2	651		
65–69	456	416532	-0.4	512		
70–74	332	377078	-0.2	413		
75–79	289	319916	-0.1	282		
80–84	129	242595	0	220		
85+	95	257642	0	137		
Total	**11512**		**-25**	**12045**	**1.04**	**4238.4**
Female births						**2,067.5**

The data set for projecting population of this country called ‘X’ from 2015-2020 is taken into consideration. The figures in Column 2 forms the basis of the calculations, which gives the data on the age structure of the female population of ‘X,’ and the calculations are done using the Cohort-component method of population projection, which is based on certain assumptions. The figures in Column 5 are the projected data on the age structure of the female population of ‘X’ for the future year 2020.

We undertake the following assumptions in projecting a population forward by based on years with data on women in this country:

1. For the period 2015-2020, the projection uses a life table with a life expectancy at birth of 78 years (column 3)
2. Total fertility is 2.10 children per women (column 6)
3. Net emigration of 20,000 women occurs (column 4) during the period.

Using these assumptions, we now start to calculate the projected female population of ‘X’ forward another five years to 2020 step by step as stated below the table.

<u>Step 1</u>. We first calculate how many members of each living age cohort will survive the

current projection interval

In Table 1.1, column 3 represents the abridged life table, which measures the number of survived persons in that year in each age group relative to the radix of the life table. Thus, the ratio of two adjoining values measures the number of people in the young cohort who will survive until the old age group based on the age-specific mortality rates, which are used to construct the life table. These ratios are known as survivorship ratios:

$$S(x+n, t) = \frac{{}_nL_{x+n}(t)}{{}_nL_x(t)} \qquad (1.2)$$

Where;

S($x+n,t$) is the survivorship ratio of persons who are aged x to $x+n$ at the start of projection interval *t to t+n.*

Multiplying the number of young cohorts in a population at the start of the projection interval by these life table measures the survivorship into the next old age group, which again gives the projected population surviving to the next older age group at the end of the interval. Mathematically, it can be represented as:

$$P(x+n, t+n) = P(x, t) \times S(x+n, t) \qquad (1.3)$$

Now, using Equation (1.3), we calculate the projection for the women aged 5-9 by calculating the value of P(5, 2020) from table 1.1:

From the table, x= 5 (min age), n=4 (age difference interval), t=2015 (initial yr)

Here, for aged 0-4: P(5, 2015) = P (0, 2015) × S (10, 2015) {using Equation 1.3}

$$= 873 \times \frac{{}_nL_{x+n}(t)}{{}_nL_x(t)}$$

$$= 873 \times (485794/\ 487866) = 869.2$$

Step 2. Adjusting the migration: add all the immigrants to each age group and then subtract the emigrants or add net migrants to each age cohort.

Migration flows can be merged into population projections using several methods that can be chosen based on the nature of the available data on migration. As it can be quite challenging to measure the data on immigration and emigration because of its sharp and erratic fluctuating data, it is better to adopt a simple method rather than choosing a complex one. For example, to forecast age-specific emigration rates, a simple method on emigration can be used just like we used the previous method on mortality rates using the life table probabilities of not emigrating to each age group.

On a national level, the data on immigration is not that complicated and can be handled easily, which is, however, not possible if the data is global data. So, the easiest step is to add an estimate of the number of immigrants in each age group to the projected population at the end of the interval. In some projections which involved a detailed study on immigration, the estimates of net migrants are added simply to the projected population to get the result, and misconception of trying to model the larger gross flows of emigrants and immigrants should be avoided.

Then, incorporate migration into the projection calculated in step 1:

The final projected number of women aged 5-9 years in India is calculated by subtracting net emigrants from the survivors at the end of the interval (calculated as 869.2 on the previous page):

The Net Migrants (NM) is subtracted from the final projected result:

P(9, 2020) = P (0, 2015) × S(10, 2015) -NM (5, 2015) = 869.2- 1.7= 867.5= 868 (approx)

Similarly, we can calculate the projection for the women aged 10-14 by finding P(10, 2020) from the table and following the above two steps as calculated below:

From the table, x= 10 (min age),n=4 (age difference interval), t=2015 (initial yr)

<u>Step 1</u>. Here, for aged 5-9: P(10, 2020) = P (5, 2015) × S(10, 2015)

$$= 922 \times \frac{{}_nL_{x+n}(t)}{{}_nL_x(t)}$$

$$= 922 \times 485235 / 485794 = 920.9$$

<u>Step 2</u>. Let use incorporate migration into projections:

So, P(10, 2020) = P (5, 2015) × S(10, 2015) -NM (10,2015) = 920.9- 1.5= 919.4

A slightly different calculation is required for the open-ended age group. It is based on T_x, which is the person years lived above age x in the life table, rather than ${}_{10}T_x$, the person years lived between ages *x* and *x+10:*

$$P(x+,\ t+n) = \{\ P(x\text{-}5,\ t) + P(x+,\ t)\ \} \times \frac{T_x}{T_{x-5}} \qquad (1.4)$$

The process continues to get all the results, and these results are projected in column 5 in Table 1.1. We then do the total of all the projected values of female population in 2020, which comes out to be 11619 as shown in the table.

Step3: Calculate the numbers of birth that occurs during the present projection interval and then divide the result into male and female born.

Step 1	Calculate the average number of women in each fertile age group by averaging the number of women in the age group at the start of the projection interval
Step 2	Calculate the number of women in the same age group at the end of the interval
Step 3	Add the above two results
Step 4	Multiply the final result in step 3 by the age-specific fertility rate for that age group
Step 5	Multiply the result in step 5 by the number of years in the projection intervals to estimate the number of births to women in that age group over the entire interval *t* to *t+n*
Step 6	Sum these counts of births over all the fertile age groups to get the total number of births occurring between t and t+n.

Figure 1.4. Steps involved in calculating the births

Mathematically, the above steps can be summarized as:

$$B(t) = \sum_{x=n}^{x+n} f(x,t) \times \frac{n}{2}\{P^f(x,t) + P^f(x,t+n)\} \qquad (1.5)$$

We calculate the births to women aged 15–19 in the country 'X' between 2015 and 2020 from Table 1.1:

$$B(t,n) = \sum_{x=15}^{49} f(x,t) \times \frac{n}{2}\{P^f(x,t) + P^f(x,t+n)\}$$

Here, $n = 5$

$P^f(x,t)$ = $P^f(20{,}2015)$ = 761 (Female population in 2015)

$P^f(x,t+n)$ = $P^f(20{,}2020)$ = 850 (Female population in 2020)

$\sum_{x=15}^{49} f(x,t)$ = Σ *f*(20, 2015) =0.0207 (Age-specific fertility rates)

So, B(15, 2015) = 0.0207 × 5 × (761 + 850) ⁄ 2 = 0.1035 × (761 + 850) ⁄ 2 = 0.1035 × 805.5= 83.4 (approx)

Similarly, we calculate the births to women aged 20–24, 25-29, 30-34, 35-39, 40-44 and 45-49 in this county between 2015 and 2020*: the results are in column 7 of Table 1.1.*

Summing up all the births across all the fertile age groups gives a total of 1694.6, which is the total Births by the age of mother (Column 7).

Now the births are divided into the groups of boys and girls, which is done by considering an assumption on the estimates of sex ratio at birth. In general, this is approximately 105 boys for every 100 girls. Hence, this estimate is used to calculate the number of female and male births, respectively using the following two equations:

Female Births: $B^f(t) = \frac{1}{(1+1.05)} \times B(t)$

Male Births: $B^m(t) = \frac{1.05}{(1+1.05)} \times B(t)$ (1.6)

In the country 'X' this Equation (5.10) gives an estimate of the girls born between 2015 and 2020 as:

$B^f(t) = \frac{1}{(1+1.05)} \times B(t)$ = {1/ (2.05)} × B (t) = B(t) / 2.05

Here, B(t) = B(2015) = 1694.6 (total Births by age of mother)

So, the estimate of the girls born between 2015 and 2020:

Bf (2015) /2.05= 1694.6 / 2.05 = 826.6

This result can be seen in the last column and row of table 1.1

After all these calculations, the result is then presented in column 5 and 7 of Table 1.1.[1]

A ‘male dominant projection’ cannot be worked out because reliable age-specific data on men’s fertility rates are very rare. The number of boys and girls that are born remains at an assumed ratio (or a series of ratios) throughout the projection, whether one uses a female or male dominant projection. And thus, the male and female populations grow at the same rate in the long run. One can even calculate an independent projection of the male and female population and this wouldn’t make any changes in the computational procedure, and the size of both male and female would diverge as naturally as it would be and hence it won’t affect the biological data.

Table 1.1 shows the relevant projections required for the year 2015. The main changes in the projected population between 2015 and 2020 are;

1. The female population of the country ‘X’ increases from 11.1 million to 11.6 million which represents a growth rate of ln (11619 ⁄ 11104) ⁄ 5 = In (1.946) / 5 = 0.044/5= 8.99 i.e. 0.8 per cent per year.
2. The elderly population is growing much faster than the population as a whole but the number of girls aged less than ten shrinks.
3. Thus, the assumptions made about vital rates lead to ageing of the projected population.

Cohort-component models can be done in a spreadsheet but are usually undertaken using computer software developed specifically for the purpose.

FUTURE PROJECTIONS OF DEMOGRAPHIC DIVIDEND FOR INDIA

The above population projection process of Cohort Component Method can be applied to any data set for any country to project its further data. Now, we present the data set projecting population of India from 2011-2021, as depicted in table 1.2. The figure in column 2 is taken from the Office of the Registrar General of India, and the calculation is done using the Cohort-Component Method of population projection, which is based on certain assumptions.

[1] Note that the cohort method for projecting population, specially projecting babies born for some future year, give rise to a term called ‘female dominant projection’ The reason for highlighting this terminology is that the age-specific fertility rates for women are the main and only information used to calculate the initial size of each age cohort of both girls and boys and hence provides the data on the projected population of women.

Table1.2. Projection of the female population of India from 2011 to 2021

Age group	Female population in 2011 ('000s)	Female population in 2021 ('000s)
0–4	54175	65535
5–9	60628	64265
10–14	63290	66209
15–19	56544	66630
20–24	53840	64793
25–29	50070	61835
30–34	43934	58531
35–39	42221	54119
40–44	34893	47255
45–49	30180	41337
50–54	23226	35733
55–59	19690	30560
60–64	18962	25028
65–69	13511	19403
70–74	9557	12096
75–79	4742	7169
80+	6005	6544
Total	**585468**	**727042**

Source: Report of 2017, Office of the Registrar General, India for the year 2011 and Population Projection for 2012 by World Bank

We undertake the following assumptions in projecting a population forward by ten years with data on women in India:

1. For the period 2011-2021, the projection uses a life table with a life expectancy at birth of 77 years
2. Total fertility is 2.10 children per women.
3. Net emigration of 20,000 women occurs during the period.

Using these assumptions and following all the steps involved in the cohort component methods, one can calculate the projected population step by step as worked in the above sections. Though this method is complex and time-consuming, it presents an accurate estimate of the population projections. Earlier, we calculated all the projected figures in a spreadsheet, but for India, we print the projected data from the 2017 Report of the Office of the Registrar General of India, which was undertaken using computer software developed specifically for the purpose. As our primary objective has already been performed (which was to understand the population projection methods) by using an illustrative example of the country 'X,' the same process was not repeated for India. The main focus of this research is to understand the projected population of demographic dividend of India, and hence we use the authentic source of data for this purpose, which is the Report from the Office of the Registrar General, India.

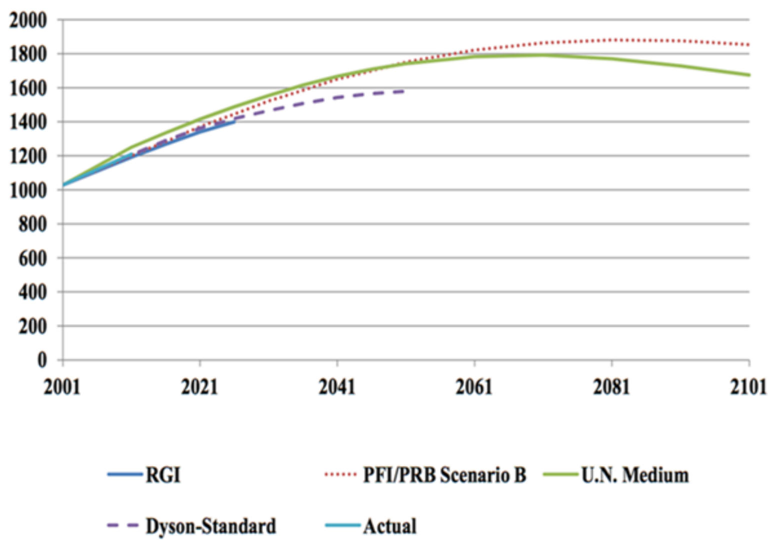
The main changes in the projected population between 2011 and 2021 are:

1. The female population of India increases from 58.5 million to 72.7 million.
2. This represents a growth rate of ln (727042 ⁄ 585468) ⁄ 10 = In (1.2418) / 10 = 0.2165/10 = 2.165 i.e. 0.021 per cent per year.
3. The elderly population is growing much faster than the population as a whole.
4. Thus, the assumptions made about vital rates lead to ageing of the projected population.

Next, I will focus on vital information taken from the 2014 Census Data of India projecting the population growth in the forms of graphs and pyramids. Firstly, Graph 1.1 portrays the population prospects of India from 2001 to 2101 as predicted by various organization and agencies worldwide. Some of these organizations, as listed in the graphs, are RGI, PFI/PRB Scenario B, UN Medium, Dyson-standard and Actual.[2]

However, in this thesis, the results rely entirely on the UN Medium. (As seen in Medium of population projection in the earlier chapters, most of the graphs and tables used are from the UN)

[2] RGI: Registrar General and Census Commissioner of India, PFI/PRB Scenario B: Population Foundation of India/Population Reference Bureau named as Scenario B, U.N. Medium: United Nations Medium of Population Projection, Dyson-standard: Standard medium of Population Projection of India projected by Tim Dyson, (Tim Dyson is Professor of Population Studies at LSE. He has worked a lot on the demography of India), Actual: Actual Population Projection of India



Graph 1.1. Population Prospects of India from 2001 to 2101 *Source:* 2014 Census Report, Office of Registrar General of India

The graph above shows that the population of India varies between 1.5 and 1.8 billion from 2001 to 2051 using the various projections methods.

Secondly, I will analyze the demographic dividend of India for the present decade, followed by the early era of 1971 until the coming decades in the form of some pyramids.

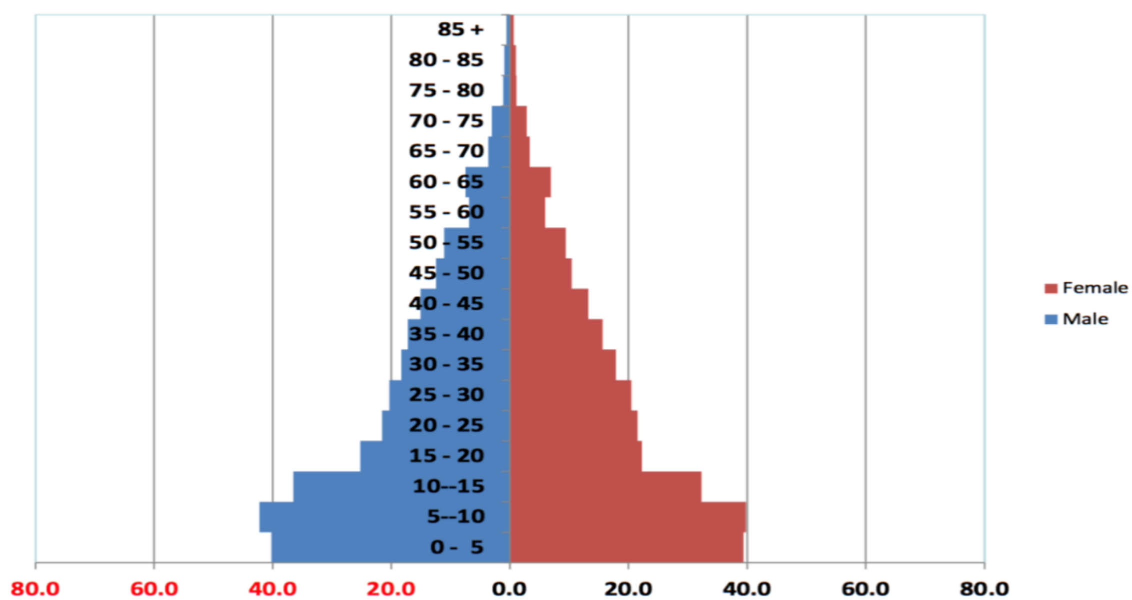


Figure 1.5. Population Pyramid of India (1971) *Source* 2014 Census Report, Office of Registrar General of India

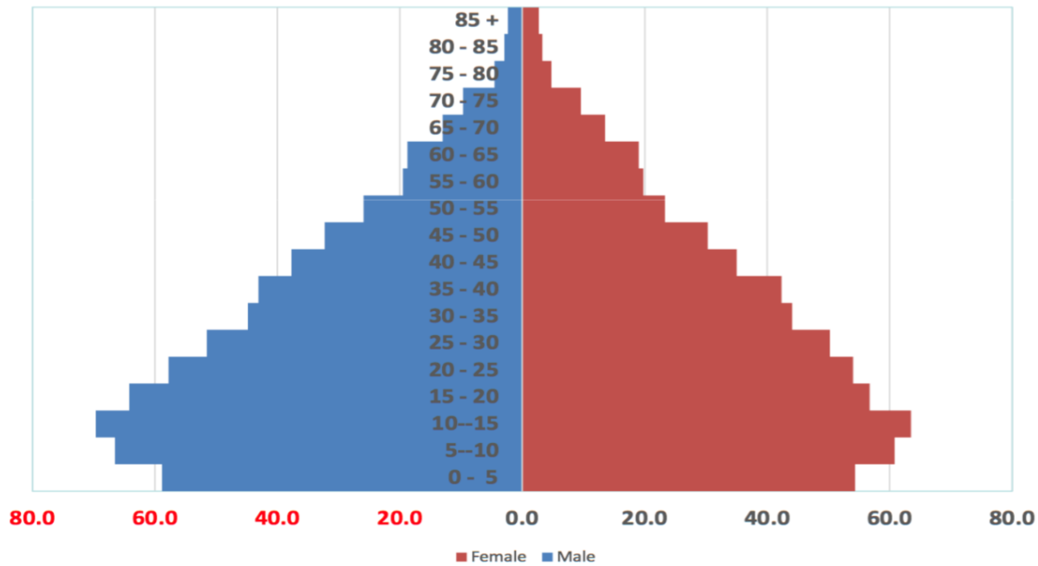


Figure 1.6. Population Pyramid of India (2011) *Source:* 2014 Census Report, Office of Registrar General of India

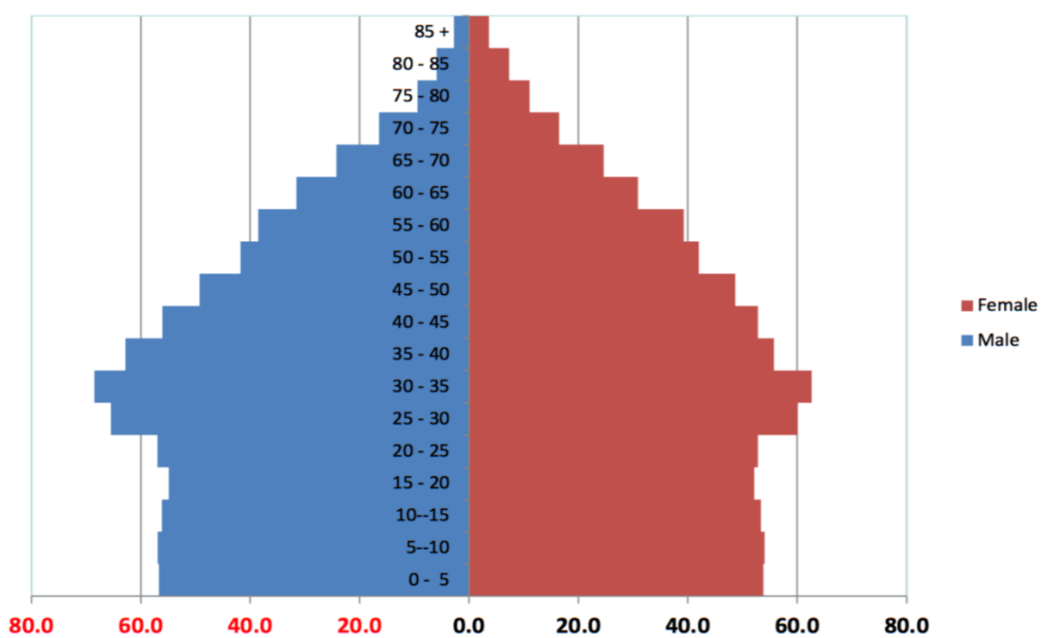


Figure 1.7. Population Pyramid of India (2031) *Source:* 2014 Census Report, Office of Registrar General of India

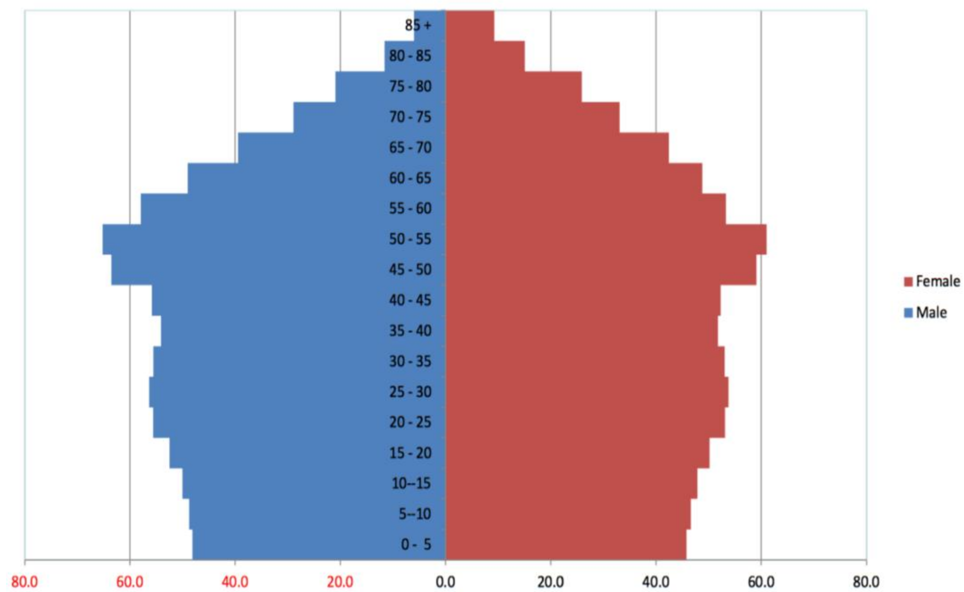


Figure 1.8. Population Pyramid of India (2051) *Source:* 2014 Census Report, Office of Registrar General of India

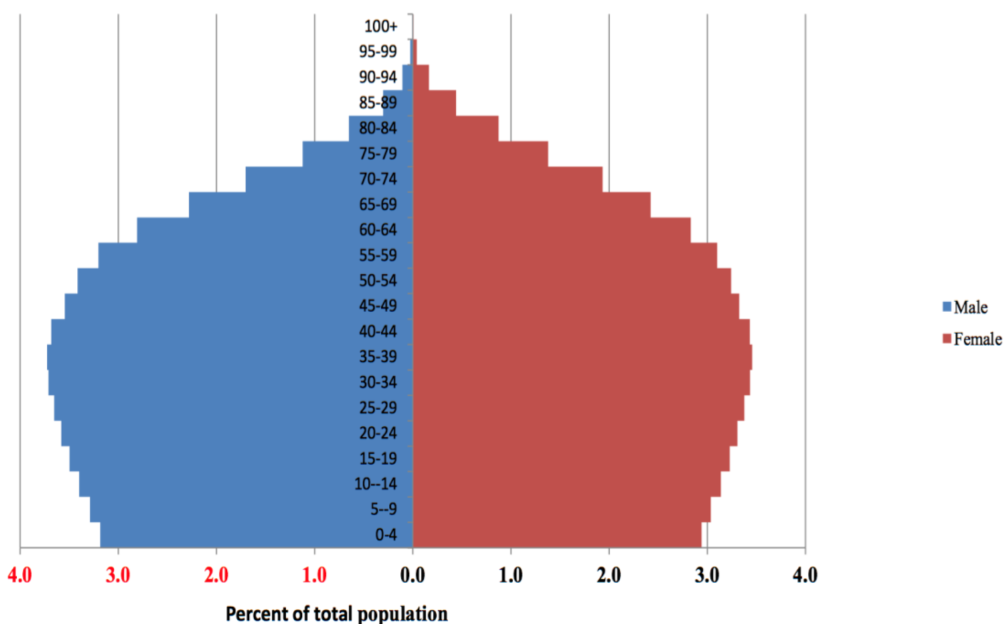


Figure 1.9. Population Projection of India, based on UN medium projection *Source:* 2014 Census Report, Office of Registrar General of India

After analyzing the above pyramids, one can conclude that:

1. There wasn't any awareness of a Demographic Dividend in India in the year 1971, as shown in Figure 1.5.
2. Figure 1.6 shows that the Demographic Dividend has just started emerging over the age structure in India in the year 2011.
3. The pyramid showed in Figure 1.7 states that a high Demographic Dividend in India is predicted to happen in the year 2031.
4. The pyramid showed in Figure 1.8 indicates that the Demographic Dividend in India is predicted to phase-out starting from in the year 2051.

CONCLUSION

The following crucial points are extracted from the Empirical Estimation of population projection and the depicted pyramids of India:

1. The demographic transition process has overshadowed India with the phenomenon of decreasing fertility rates, which is resulting in the reduction of its natural growth and the estimations on the fertility rates show that it will continue to decline to its lowest level with a mortality replacement level in the coming decades.
2. India is seen almost coming out of the issue of uncontrolled population growth. The population of India in the coming years will be much higher than what is today.
3. India will overtake China and hence would be counted as one of the most populated countries before 2030.
4. The future growth is not expected to be that large at the national level, but some states which haven't yet experienced the phenomenon of demographic transition like the north-central states of India would probably expand its population size and get doubled in the next 50 years.
5. Such a rapid population growth may generate a sizeable regional growth imbalance which may also impact on the socio-political consequences.

Status of Fertility and Mortality Rates:

The continuous decline in fertility has a positive impact on the economic growth of India, as this result will not only lower the population growth but also be a benchmark for the development of women and children of India.

Demographic dividend and Ageing:

1. India is ready to reap the benefits of the demographic dividend and will continue grabbing this window of opportunity in the coming decades.

2. The potential of India to capitalize on the demographic dividend, however, depends on how well the working-age cohorts can be employed. This issue then gives rise to the importance of the parameters of the quality of labor force and capacity of India's economy to harvest the potential dividend into a real benefit.

3. As time pass, a large bulge of India's population will shift from working ages to old ages, which brings an issue of old-age dependency. This would matter at the level of the society, be it the macro-level, the micro-level or the household level.

4. India's culture and tradition, if one has seen, is that it is usually the responsibility of the young working members of a family to support their elderly parents, but the recent pattern in the low fertility rates can try to break this tradition as in small families, having fewer members would create difficulty in supporting elderly parents. This would then urge the government to develop a mechanism to support the old age group. This matter is not seen growing much at the national level but can be seen in some leader states as the fertility transition continues over there.

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