*Original Article*

# Population Age Structure and Socio-Economic Transformation: Challenges in India

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**Abstract:** *Economic and social transformations of a country depend heavily on population age-structure and its growth dynamics along with impact on policies adopted and generation of opportunities.The paper describes major socio-economic-demographic consequences of India based on changing demography with emphasis on measurement aspects of demographic dividends (DV) and suggests indices like active participation index (API), comprehensive e-participation index (CEPI), index of participation rate of females ($I_{FLFPR}$) combining relevant chosen indicators in ratio or ordinal scales. The proposed indices reflecting social, economic and political effectiveness of the country across time and space satisfy desired properties and enable parametric statistical analysis. Linear regression equation of $I_{FLFPR}$ on GDP of a country and regression of DV on $I_{FLFPR}$show effect of FLFPR on socio-economic growth. A country needs to focus on the factors that can foster the progress during transition from favourable working-age population (WAP) to increasing share of elderly population. WAP of India with rising trend of income, educational attainments empower the citizens to participate in e-participation and active participation in economic, social, and political effectiveness of the country. Attempts can be made to estimate the required net birth rate ensuring WAP is around 59% and initiate policies accordingly.*

**Keywords:** *Population Age-Structure, Demographic Dividend, Female Labour Force Participation Rate, Composite Index, Normal Distribution, Participations.*

## I. INTRODUCTION

Human population of the world has registered increasing trend since the World War II. From 2.5 billion in 1950 it has increased to 8.11 billion in 2024. Population of the world is projected to reach 9.8 billion by mid-2050 and 11.2 billion by 2100 despite decline of fertility in a number of countries. At the global level, number of persons over 64 years exceeded number of children less than 5 years in 2018 (UN WPP 2022). As per the medium vertion of World Population Prospects (WPP) 2019, US and eight developing countries viz. India, Indonesia, Egypt, Pakistan, Nigeria, Ethiopia, Congo, and Tanzania are expected to contribute over 50% of the increased population at global level between 2020 and 2050 (Oeppen and Vaupel, 2002). India ranks 1st in the world with 1.428 billion (2023) population contributing 17.8% to the world population (United Nations, 2019).

Life expectancy at birth at the global level increased to over 70 years against 32 years in 1900. It has risen significantly across all ages and regions (UN WPP 2022). For India, life expectancy at birth in 2023 was72.03 (female: 73.65 and male: 70.52). However, life expectancy based on period life-table may not reflect the mortality pattern, which can be calculated in a cohort life-table.

Rapid growth of population and industrialization/urbanization put increasing pressure on environment and natural resources (Khan et al.2022). Economic and social transformation depends heavily on distribution of population across age groups and thus, studies on evolution of population age-structure are important (Bai and Lei, 2020). Increasing percentage of elderly population, birth rates, mortality rates and associated social patterns are the major factors contributing to population structure of a country. While humans consume and destroy natural resources and energy, they also preserve and produce resources and renewable energy.

Population age-structure of a country gets changed with time due to influences of economic growth, urbanization, changes in living standard, social preferences, advances in medical and associated facilities, general revaluation of priorities in life, quality of life, etc.(Alders and Broer, 2005; Zbigniew and Piotr, 2014). Growth dynamics of age-category-wise population have consequences in social and economic aspects of a country in achieving the Sustainable Development Goals (SDGs) and other development goals.

The paper describes major socio-economic-demographic consequences of India based on the current and future trends in population age-structure with emphasis on measurement aspects of demographic dividends, and multidimensional indices like index of female labour force participation rate (FLFPR), active participation index (API), comprehensive e-participation index (CEPI). Desired properties satisfied by the indices and empirical relationships with socio-economic benefits discussed along with the challenges and possibilities in the Indian context.

## II. LITERATURE SURVEY

### A. Measures of population age structure

In addition to the median age, age-structure of a country is typically shown as percentage share of Children population (up to 14 years), Working-age population (WAP) (between 15 – 60 years) and elderly people. Such presentation helps to compute "demographic window" (window of opportunity) or demographic dividend of a country and is measured by Dependency Ratio (DR) defied as $\frac{\text{Child population+OldAge population}}{\text{WorkingAge population}}$ = Child DR + Old AgeDR (United Nations, 2004). The desirable window is open when proportion of Child population is $\leq$ 30%, proportion of people $\geq$60 years is below 15 % implying WAP $\geq$ 55%. Lower value of DR indicates more people in the workforce to support the dependent population which in turn implies higher per capita GDP. DR is inversely related to active workforce of an economy, measured by $\frac{\text{No.of people ages} \geq 16 \text{ who are employed or actively seeking employment}}{\text{Total non}-\text{institutionalized working}-\text{age population}}$ where non-institutionalized population excludes those in prisons, patients (in hospitals/nursing-homes or mental health cares) and people in defense force (US Bureau of Labor Statistics, 2023).

While reduction of birth rate, higher mortality of children and maternal mortality and morbidity lower the LFPR, introduction of more young women into the workforce increase LFPR. LFPR in India improved to 57.9 in 2022-23 against 55.2 in 2021-22 with significant increase in Female Labour Force Participation rate (FLFPR) from 27.2 in 2021-22 to 31.6 in 2022-23 (National Sample Survey Office (NSSO) (https://mospi.gov.in). Higher FLFPR and opportunities of decent works are positive signals for an inclusive development.

India's DR is projected to reach its lowest point at 31.2% by 2030 (EY estimate). As per projections of age-structure of India's population works favourably against the open window (Ladusingh and Narayana, 2012). However, DR does not consider variations in age category-wise earnings and consumptions. National Transfer Accounts (NTA) based on the economic life cycle approach overcomes the limitation (Mason et al. 2017).

DR is better than other indices which focus primarily on child population and elderly population like the Index of demographic longevity = $\frac{\text{Population}_{60+}}{\text{Population}_{0-14}}$, Index of demographic aging = $[PP_{(0-14)t} - PP_{(0-14)(t+n)}] - [PP_{(60+)(t+n)} - PP_{(60+)t}]$ where PP denotes percentage of population, (t+n) denotes period later to t-th time period. Longevity Governance Index (LGI) 2022 (www.dka.global ) is a composite index covering six dimensions viz. Demography (changing dynamics of population structure), Ecology (exposure to the impacts of a changing climate, sociological or biological hazards), Economy (availability of resources to alleviate the impact of ageing), Government Care (government activities and spending on healthcare, laws, policies, and plans for Longevity initiatives), Health Status (population health with reference to life expectancy, well-being, and mental health indicators), and Society (development of human capital within the society) obtained from large number of countries. Here, each feature is normalized by max-min function Z= $\frac{X-Min(X)}{Max(X)-Min(X)}$ and dimension score is obtained as

($\sum$ weighted indicator subgroups) x100 followed by LGI = (Demography) ⅙ + (Ecology) ⅙ + (Economy) ⅙ + (Government Care) ⅙ + (Health) ⅙ + (Society) ⅙ where $0 \leq$ LGI $\leq$ 100. LGI requires huge reliable data. Max-min normalization depending heavily on $X_{Max}$ and $X_{Min}$(could be outliers and unreliable) reflects relative performance of a country. Decline or increase in value of $X_{Min}$ can change *Z*-value of country even if *X*-value of the country remains unchanged, and also change ranks of the countries in terms of *Z*-values (Seth and Villar, 2017). Increase in Z per unit increase in X is different for different values of X. Method of selection of weights are not beyond criticism.

Considering extent of production and consumption i.e. per capita labour income and per capita consumption, Navaneetham and Dharmalingam (2009) computed Support Ratio (SR) as:

$$SR = \frac{\text{Working age population}}{0.9 * \text{Child population} + \text{OldAge population}}$$

Economic support ratio (ESR) as the ratio of economically active population (producers) to the economically inactive population (consumers) could be a better measure. Age-wise effective number of workers or consumers is computed as the population at each age weighted by the labour income or consumption profile (Mason et al., 2017).

**B. Demographic Dividends**

Percentage of working age population (WAP) in India increased from 64.76% in 2012 to 68% in 2023 and resulted in decreasing trend of DR(54.42% in 2012 and 47.06% in 2023. The favourable trend may continue till 2055 for India (United Nations, 2019) implying higher growth of per capita income, known as first demographic dividend (FDD) (Lee and Mason, 2006). People in WAP are aware of increasing life expectancy and increasing cost to support consumption and security at old-ages. Thus, they to tend to save and accumulate wealth during the working years. This in turn accelerates real output, higher economic growth and further generation of employment (Ribaj and Mexhuani, 2021). This is known as second demographic dividend (SDD)

Magnitude and duration of FDD and SDD varied for different countries (Mason, 2005). Ladusingh and Narayana, (2012) estimated demographic dividends considering per capita income, labor productivity and support ratio taken as $\frac{\text{Effective number of producers (L)}}{\text{Effective number of consumers (N)}}$.

Here, FDD is expressed as the ESR i.e.

$$\frac{L}{N} = \frac{\sum_{a=0}^{W} \gamma(a)P(a,t)}{\sum_{a=0}^{W} \phi(a)P(a,t)} \tag{1}$$

where, P(a,t) is the size of population with age a at t-th time period, $\gamma(a)$ is age pattern of labour income and $\phi(a)$ is the same for consumption. Denoting Income, total population and total number of workers by Y, N and L respectively, per capita income can be taken as

$\frac{Y}{N} = \frac{L}{N} \times \frac{Y}{L} \implies$ growth rate of $\frac{Y}{N} =$ growth rate of $\frac{L}{N} \times$ growth rate of $\frac{Y}{L}$ (Mason et al., 2017). In other words, per capita output may continue to grow when growth rate of workers > growth rate of total population irrespective of output per worker (Bhat, 2001).

Differentiation of $\frac{Y}{N} = \frac{L}{N} \times \frac{Y}{L}$ gives relationship of growth rate of per capita income $(g_y)$ with growth rate of income per worker $(g_z)$, growth rate of labour force $(g_l)$ and growth rate of total population $(g_n)$ as $g_y = g_z + (g_l - g_n)$ (2)

Capital accumulation by people in WAP-category is taken as wealth held by the population who are aged over 50 years and may be used for estimation of life cycle wealth and SDD (Mason, 2005). Thus, wealth accumulation in the t-th year by the people born on or before the b-th year can be expressed by

$$W_{\leq b,t} = \left[ \frac{C_{\text{Effective consumer}_t}}{Y_{\text{Effective labour}_t}} \right] \left[ \frac{PVN_{\leq b,t}}{N_t} \right] - \frac{PVL_{\leq b,t}}{L_t} \tag{3}$$

where $PVN_{\leq b,t}$ denotes present value of future lifetime years of consumption for all persons born in the b-th year or earlier $(\mathcal{P}_{\leq b})$per effective producer in t-th year and $PVL_{\leq b,t}$ denotes present value of future lifetime years of production of $\mathcal{P}_{\leq b}$ per effective producer in t-th year.

The equation (3) is difficult to estimate due to complex changes in reality. For example, $\frac{\text{Wealth}}{\text{Income}}$ for a country changes with time, life cycle wealth may not register continuous increasing trend, mismatch of employment generation and number of job seekers, etc. To realize the economic gains from FDD, growth of employment opportunities need to match with the numbers seeking new jobs. The SDD may be undermined by generous pension plans and also by poorly developed financial markets.

Favourable demographic dividend of India arising out of increasing share of WAP in population age-structure, services-orientations (highest GDP share by service sector), etc. is likely to reach maximum around 2041, when share of the WAP reaches to 59% and help India to unlock sustainable long-term economic growth. However, the following illustrative measures need to be accelerated: -
- Up skilling of workers (number of programmes already initiated)
- High priority on innovations and technology,

- Encouraging and supporting FLFPR along with initiatives for girls' education, skill development, entrepreneurship facilitation, workplace safety, advancing the agenda of 'women-led development' etc. to (i) enhance women's empowerment to promote equal economic rights, access to employment and economic activities (ii) reduce gender inequality to achieve the targets of SDG-5 which also emphasizes equal rights, ownership of all forms of property across genders, education and employment (Dugarova, 2018).
- Strong wave of financial inclusion and investments to build digital payments infrastructure, etc.
- Bringing the untapped labour to labour market.

**C. Female labour participation rate (FLFPR)**

A large proportion of Indian women in WAP are not involved in paid works and thus reduces human capital which in turn slows down socio-economic progress of the country (Sanghi, et al 2015). FLFPR increases income but lowers fertility (Bloom et al. 2007). Demographic dividend effort index (DDEI) to reflect national efforts to derive benefits of demographic dividend was approached by Rusatira et al. (2023) through sector-specific questionnaire where ordinal scores of 10-points items were averaged to get sectoral and dimension scores and country scores were obtained as weighted sum where sectoral weights ($S_w$)= $\frac{\text{No.of participants in the Sector}}{\text{Total no.of participants for each country}}$. Major limitations of DDEI are non-admissibility of arithmetic aggregation of scores of ordinal multi-point items (Bastien, et al. 2001) and controversial weighting scheme. In addition, computation of reliability of multi-dimensional questionnaire by Cronbach's alpha violating its assumptions like tau-equivalence does not appear to be justified (Teo and Fan, 2013).

To see how FLFPR is influenced by GDP, Tam (2011) considered equation of the form $FLFPR_{it} = \alpha + \beta_1 \log(GDP_{it}) + \beta_2 \log(GDP_{it})^2 + error_{it}$

Where positive values of $\beta_1$ and negative value of $\beta_2$ result in inverted U-shaped curve.

Major problem areas are:
- Interpretation of negative value of $\alpha$ is difficult
- $\log(GDP)$ impact *FLFPR* more strongly for extreme values.
- Value of $r_{GDP^2, GDP}$ is high which implies multicolinarity.
- The form of equation considered by Tam (2011) indicates $\log(GDP) = -\frac{\beta_1}{2\beta_2}$ at the point of inflection which has no theoretical justification.
- Logarithmic transformation changes value of $r_{XY}$. For example, Kovacevic, (2011) found $r_{Life\ expectancy, HDI} > r_{Life\ expectancy, GDP}$ but $r_{\ln(Life\ expectancy), HDI} < r_{\ln(Life\ expectancy), GDP}$. Chakravarty, (2003) showed that desired properties of aggregation like Translation Invariance and aggregation consistency are not ensured by logarithmic transformation. *FLFPR* was poorly correlated with $\log(GDP Per\ capita)$ )(Chaudhary and Verick, 2014),

Major factors of FLFPR are: education level (Vlasblom & Schippers, 2004), urbanization, unemployment rate, liberal socio-cultural attitudes (Tsani et al. 2023), wage differential, social/cultural norms (Mehrotra and Parida, 2017; Dildar, 2015), etc. However, declining fertility rate is an output of higher FLFPR (Fatima and Sultana, 2009).

### III. METHOD

Chakrabartty (2024) proposed an index of FLFPR by multiplicative aggregation of relevant causal indicators excluding the outputs of FLFPR. For a country, let $X_{1t}, X_{2t}, \ldots \ldots, X_{nt}$ are values of the chosen indicators at t-th year with corresponding values $X_{10}, X_{20}, \ldots \ldots, X_{n0}$ at the base period, where pre-adjustment of data confirms $X_{ij} > 0$ is positively related with FLFPR for i= 1, 2, ....., n and j = 0 or t.

Country specific and year specific index of FLFPR ($I_{FLFPR_t}$) may be taken as Geometric Mean i.e. $I_{FLFPR_t} = \sqrt[n]{\frac{X_{1t}.X_{2t}\ldots\ldots X_{nt}}{X_{10}.X_{20}\ldots X_{n0}}}$ or equivalently by $I_{FLFPR_t} = \prod_{i=1}^{n} \frac{X_{it}}{X_{i0}}$

**A. Results**
- The index $I_{FLFPR_t}$ facilitates:
- Assessment of changes by $\frac{I_{FLFPR_t}}{I_{FLFPR_{(t-1)}}}$ or by $[I_{FLFPR_t} - I_{FLFPR_{(t-1)}}]$.
- Indicator-wise changes by $\frac{X_{it}}{X_{i(t-1)}}$

- *i*-th indicator becomes critical if $\frac{X_{it}}{X_{i(t-1)}} < 1$ and requires managerial attention for necessary corrective action.

- Relative importance of *j*-th indicator can be computed by $\frac{\nabla(I_{FLFPR_t})}{\nabla X_j}$

- By taking log on both sides of $I_{FLFPR_t} = \prod_{i=1}^{n} \frac{X_{it}}{X_{i0}}$, mean and variance of $ln\, I_{FLFPR_t}$ are $e^{\mu_X + \frac{\sigma_X^2}{2}}$ and $e^{2\mu_X + \sigma_X^2}(e^{\sigma_X^2} - 1)$ respectively for a group of countries (Alf and Grossberg, 1979).

- -The index $I_{FLFPR_t}$ satisfies time-reversal test and helps formation of chain indices. Empirical relationship may be found between $GDP_t$ or per capita GDP as the dependent variable and $I_{FLFPR_t}$ as the independent variable for a country. Similarly, *(FDD+ SDD)* $= \alpha + \beta(FLFPR)$ can show influence of FLFPR on demographic dividend of a country.

**B. Benefits**

*a) Maternal mortality*

Maternal mortality and death rate in WAP reduce the size of WAP. For a developing country like India, death of a mother is beyond emotional crisis, and may give rise to long-term social and economic problems for the immediate family and wider community. Male children of the family may drop schools for earning and burden of female children may be solved by early marriage which results in early motherhood, both indicate renewal of poverty cycle for the next generation. Developing countries like India may go beyond the target of maternal mortality rate of 70 per 100000 live births as given in SDG 3.1 to derive demographic benefits.

*i) Social benefits*

GDP measure the quantitative value of goods and services and does not cover the non-monetary segment of society like free medical services, value of qualitative changes made in the consumption baskets, etc. Thus, GDP fails to measure social progress and wellbeing of a nation. Different frameworks have been developed to assess social progress in terms of quality of life, human development, sustainable development, etc. by conceptual approach (what progress means) or consultative approach (measuring chosen components/dimensions of progress through consultation), and different initiatives to measure progress require different frameworks. Such approaches are not mutually exclusive and can be combined. Illustrative emerging activities with implications to social progress are detailed below:

*b) Active participation*

Effectiveness of a country in economic, social, and political areas depends on how its citizens aged ≥18 years participate in the following four dimensions:

- Political dimension - rights and responsibilities
- Social dimension - behaviour of individuals with measure of loyalty and solidarity including enhancement of social skills and knowledge of social relations
- Cultural dimension- consciousness of a common cultural heritage and
- Economic dimension - relationship between individuals with labour and consumer market including the right to work and to minimum subsistence level (primarily by WAP)

Active citizenship is related to participation of adults in civil society, community and political life in accordance with human rights and democracy and is an important development objective (Hoskins and Mascherini, 2009). However, the multidimensional active participation index (API) lacks sound operational definition. OECD (2008) identified factors of API both at individual and national levels and found that countries with high-income and materialistic values, homogeneous distribution of income and heterogeneous religious climate enjoy higher Active Citizenship. Participation of disadvantaged people in the society become poor with increase of socio-economic inequalities (Donbavand and Hoskins 2021; Hoskins et al. 2021).

Educated youths with enhanced civic knowledge show higher level of political engagement and electoral participation (Chryssochoou & Barrett, 2017).

Chakrabartty (2023) proposed Active participation index (API) by aggregating chosen indicators distributed over a finite number of dimensions by arithmetic aggregation (Method 1) and geometric aggregation (Method 2). While Method 1 ensures normally distributed scores facilitating parametric statistical analysis, Method 2 offers a generalized approach and can take additive model with logarithm transformation. GDP of a country may be regressed on API or dimensions of API to find effect of API on economic growth. Similarly, effect of demographic structure, good governance and stability on growth of API may be investigated.

*c)  E-participation*

E-participation deals with participation of adult citizens in the governance process through Information and Communications Technologies (ICTs). It is a growing phenomenon for strengthening collaboration between governments and citizens. In line with the target 7 of SDG-16, E-participation involves adult citizens in policy decisions and governance in inclusive fashion (UN 2014).

Four levels of participation are:
- Information: One-way communication to people through newsletters, websites, brochures, etc. about services and decisions.
- Consultation: Two-way communication encouraging public to express their feedback for possible adjustments and decisions through surveys, message board, interviews, suggestion boxes, etc.
- Collaboration: Dialogue-based communication with citizens for making decisions collaboratively through forums, mapping, idea-collection, education events, volunteer activities, etc.
- Empowerment: Dialogue-based communication giving managerial power of decision-making to the public through citizen proposals, community-run committees, etc.

Numbers of internet users are increasing in India. However, there exists gender gap of internet accessibility due to several factors including economic and socio-cultural barriers. Increasing trend of median age of India's population and efforts towards digitalizing India would induce higher number of older adults to adopt new technologies in their daily activities and participate in e-participation.

The e-Participation Index (EPI) of a country indicates extent of use of online tools for interactions among Government-to-citizens (G2C), Government-to-business (G2B), Government-to-government (G2G) and people. Measures of e-participation using questionnaire of different formats and different scoring methods have methodological shortcomings. Chakrabartty (2024b) proposed normally distributed comprehensive e-participation index (CEPI) where each sub-indices and component indicators were transformed to normally distributed scores with different parameters. Normality of CEPI enables testing of equality of means of CEPI for two countries, significance of improvement of CEPI by a country from previous year, etc. The index helps in assessment of e-participation in expanded areas to cover broader political, administrative and other socio-economic contexts, with emphasis on inclusive design including e-inclusion. CEPI helps the policy makers to find empirical relationships for sustained social service delivery system, strengthening human capital and social values and social equality through democratic fashion.

## IV. DISCUSSION

Measurement issues of FDD, SDD and relationship between age-structure and socio-economic growth are described. Ways to augment the size of WAP could be encouraging more female to participate in labour force, matching job creation with people seeking jobs by up-skilling and training, improving quality of life of elderly population and implementation of robust support system in terms of better social security for old-aged people including widows with emphasis on the unorganized sector.

WAP of India with good educational background and rising trend of income, reduced DR is the main group taking part in e-participation and active participation in economic, social, and political effectiveness of the country.  A country may run the risk of transition from a favourable size of WAP to an aging population due to declining trend of birth rate, increasing trend of life expectancy and progression of large cohorts to older ages. Better understanding of evolutionary path of the age-structure ranging from the child population to WAP and to the aging population is felt needed. Demographic window period and FDD and SDD depend on policies based on demographic changes, current and anticipated phases of employment scenario, participation of citizens in policy formulations, etc.

The proposed indices like index of FLFPR ($I_{FLFPR_t}$), active participation index (API), comprehensive e-participation index (CEPI), can consider all relevant chosen indicators including those in percentages or ratios and facilitate better comparisons, plotting of progress-paths across time and parametric statistical inferences. Suitably designed index of governance can be developed in this line.

As India marches towards the *Amrit Kaal* (an auspicious period most conducive to achieving the country's potential), it will be critical for India to capture the emerging opportunities, enhance the factors fostering the progress. Major areas of challenge are:
- Simplifying and maintaining a business-friendly environment for a fast growth path

- Improving ease-of-doing-business by leveraging digital tools and lowering the regulatory burden, etc.
- Determining drivers of labor force participation by gender in rural and urban areas and improving LFPR
- Increasing uptake of consumer credit ecosystem and increased financial inclusion
- Arrest jobless growth. Reorient growth strategy to make the growth process more employment-intensive. Ensure growth of employment opportunities matches the numbers seeking jobs.
- Ensure continuation of rising productivity by appropriate institutional reforms and meet the challenges posed by older adults.

## V. CONCLUSIONS

For evaluation of measurement of demographic dividend, India need to:
- Update NTA data to capture the progress made. State-specific NTAs need to be calculated   and States need to be ranked for investing in the youth per annum.
- Ensure Health spending to keep pace with India's economic growth.
- Improve health and education parameters for better rank of the country in UNDP's Human Development Index,
- Coordination between States on emerging population issues like migration, ageing, skilling, FLFPR, urbanization, etc. and necessary corrective measures in areas showing poor performances.

Appropriate health-policy and strong Public Health Surveillance systems focusing on demographic changes, epidemiological transition, disease burden across the age and gender categories, vulnerable groups, causes of deaths, etc. Attempts can be made to estimate the required net birth rate which ensures that working-age population is around 59% and initiate policies accordingly.  Future studies may be undertaken with real life data pertaining to India for better estimation of changes in demographic dividend across time periods and empirical relationships among $FLFPR_t$, year-wise per capita GDP, $FDD_t$ and $SDD_t$, active participation index ($API_t$), comprehensive e-participation index ($CEPI_t$), showing impact of policies on various sections of society through National and State level programmes.

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