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Mortality Transition in India: 1998-2017

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Abstract

This paper analyses mortality transition India in terms of life expectancy at birth during 1998-2017. The analysis reveals considerable volatility in the increase in the life expectancy at birth in the country. There is considerable deceleration in the increase in the life expectancy at birth in the country because of the deceleration in the increase in female life expectancy at birth. Most of the increase in life expectancy at birth is attributed to the improvement in the person-years lived in the first five years of life. The recent deceleration in the increase in female life expectancy at birth may be attributed to the decrease in the person-years lived in the age group 40-65 years.

Introduction

The abridged life tables prepared by the Registrar General and Census Commissioner of India suggest that the life expectancy at birth (e_0) in India increased by more than 6 years from 62.9 years during 1998-2002 to around 69 years during 2013-17 (Government of India, 2019). The increase has more rapid in females (6.4 years) than in males (5.9 years). When compared with the United Nations model mortality improvement schedules (United Nations 2004), male mortality improvement in India has been somewhere between slow to medium model mortality improvement schedules female mortality improvement has been somewhere between medium to fast model mortality improvement schedules. Among states, e_0 ranged from more than 75 years in Kerala to 65 years in Uttar Pradesh during 2013-17. There are only six states, besides Kerala, where e_0 was more than 70 years. The gap in the highest and the lowest e_0 across states has, however, decreased from around 13.9 years during 1998-2002 to around 10.2 years during 2013-2017.

India was one of the signatories of The Programme of Action adopted at the 1994 International Conference on Population and Development at Cairo (United Nations, 1994). The Programme of Action envisaged that every country would take appropriate steps to increase e_0 to more than 70 years by the year 2005 and to more than 75 years by the year 2015. Viewed from this perspective, mortality improvement in India has fallen substantially short of what was committed way back in 1994. India's latest National Health Policy 2017 now aims at increasing e_0 to 70 years by the year 2025 (Government of India, 2017).

The life expectancy at birth is an indicator of population health (Wilmoth, 2000) and the most widely used summary measure of the survival experience of the population. The relationship between survival and e_0, although reciprocal, is more complicated (Pollard, 1982). Improvement in survival probability at different ages of the life has different impact on the improvement in e_0. The relevance of e_0, essentially, lies in the fact that the increase in the length of life of the people is one of the key health and development agenda throughout the world. Improvement in the health status of the people and reduction in mortality are widely recognised as the most proximate approaches of increasing the length of the life.

Despite the slow mortality transition and despite marked within country variation in longevity in India, there is virtually no study, to the best of our knowledge, that has analysed the temporal patterns and regional variations in e_0 in India in recent years. There have been many studies in the past that have analysed mortality transition in India (Chaurasia, 2010; Mari Bhat, 1987) but recent studies on mortality transition in India, especially, after 2000, are rare. Such an analysis is relevant as India announced a new population policy in 2000 (Government of India, 2000) and a new health policy in 2002 (Government of India, 2002). The National Rural Health Mission was launched in the year 2005 with a focus on establishing a fully functional, community-owned, decentralized health care delivery system (Government of India, 2005). In 2013, the National Urban Health Mission was launched (Government of India, 2013). The two Missions were clubbed into National Health Mission in 2013 which envisages achievement of universal access to equitable, affordable, and quality health care services that are accountable and responsive to health and family welfare needs of the people (Government of India, 2013). India has also recorded an unprecedented economic growth in the recent past. During 2001-2011, the country recorded an average annual growth rate of almost 7.7 per cent per year in the gross domestic product (Government of India, 2018). Although, economic growth in India slowed down after 2011, yet it remained amongst the highest in the world. It is expected that population and health related policy measures and rapid economic growth during 2000-2015 would have contributed to an accelerated improvement in the survival experience of Indian population and would have an impact on the health of the population of the country. It is in the above context, that this paper analyses temporal patterns and regional variations in the life expectancy at birth in India during 1998-2017.

The paper is organised as follows. The next section describes the data source. We have used abridged life tables based on India's official Sample Registration System. The third section outlines the methodology. We first analyse the trend in e_0 during 1998-2002 through 2013-2017 and then decompose the change in e_0 to the change in person-years lived in different ages. Results of the analysis of the trend in e_0 are presented in four. Section five analyses the contribution of the change in person-years lived in different ages to the change in e_0. Findings of the analysis are summarised and discussed in the last section of the paper.

Data Source

The analysis is based on the abridged life tables prepared by the Registrar General and Census Commissioner of India based on age specific death rates available through official Sample Registration System (SRS). SRS is a large-scale demographic sample survey based on the mechanism of a dual record system which was launched in 1964-65 to provide reliable estimates of fertility and mortality indicators. Since 1969-70, SRS covers the entire country (Government of India, 1971). Reporting of births and deaths in SRS has been found to be fairly reliable, although, there is some under-reporting (Government of India, 1983; Government of India, 1988; Mari Bhat, 2002; Mahapatra, 2010; 2017). Abridged life tables, based on SRS are available for the country and for states having least 10 million population. Five years average age-specific death rates are used for the construction of life tables to adjust for sampling fluctuations and to augment the sample size (Government of India, 2019) so that the average mortality experience of the population over five years period and it is assumed that the average mortality experience refers to the mid-year of the five-year period. Thus, abridged life table for the period 1998-2002 is assumed to reflect the mortality situation that prevailed in the year 2000. In situation where no death is reported under the system in an age-group, the age-specific death rate for that age group is imputed based on a geographic approach (Government of India, 2019). These abridged life tables are available for concurrent five-year periods since 1986-90 and are the only source to analyse temporal patterns of the life expectancy at birth in the country.

Methods

The analysis has been carried out in two parts. The first part of the analysis focusses on characterising the trend in e_0 while the second part dwells upon analysing the contribution of the change in person-years lived in different age groups to the change in e_0. To analyse the trend, we first identify the year(s) when the trend has changed. This is important as the trend in e_0 may be influenced by policies and programmes directed towards improving the health of the people and by improvements in the standard of living. The trend analysis is then carried out separately for different temporal segments in which the trend has remained unchanged. Different methods are available for identifying the year(s) when the trend has changed. These include permutation test (Kim et al, (2000), Bayesian Information Criterion (BIC) (Kim et al, 2009), BIC3 (Kim and Kim (2016) and Modified BIC (Zhang and Siegmund (2007). The permutation test is the gold standard but is computationally very intensive. BIC performs well to detect a change with a small effect size but has a tendency of over-estimating the number of joinpoints. The Modified BIC is the most conservative method, but it performs well to detect a change with a large effect size. The performance of BIC3 is comparable to that of the permutation test.

When there is a change in trend, the trend analysis may be carried out through joinpoint regression analysis. Let y_i denotes e_0 for the year t_i such that $t_1<t_2<...<t_n$. Then the joinpoint regression model is defined as

$$\ln(y_i) = \alpha + \beta_1 t_1 + \beta_1 u_1 + \beta_2 u_2 + \cdots . + + \beta_j u_j + \varepsilon_i \quad (1)$$

where

$$u_j = \begin{cases} (t_j - k_j), & if\ t_j > k_j \\ 0 & otherwise \end{cases}$$

and $k_1<k_2.......<k_j$ are the years when the trend has changed or joinpoints. Details of joinpoint regression are given elsewhere (Kim et al, 2000; Kim et al, 2004). Assuming that the trend is linear on a log scale in a temporal segment or between two joinpoints or

$$\ln(y_t) = \alpha_0 + \beta(t) \quad (2)$$

then the annual per cent change (APC) in e_0 between two joinpoints or in a temporal segment is estimated as

$$APC = \frac{e_{0(t+1)} - e_{0t}}{e_{0t}} \times 100 = (e^{\beta} - 1) \times 100 \quad (3)$$

The average annual per cent change (AAPC) during the entire reference period is then obtained as the weighted average of APCs in different temporal segments with weights equal to the length of different temporal segments. The AAPC is argued to be a better approach to describe the long-term trend when the trend changes over time in comparison to the commonly used approach in which a single regression line on a log scale is fitted for the entire reference period and the average annual per cent change is calculated from the slope of the regression line (Clegg et al, 2009). AAPC permits comparison of trend in different temporal segments.

Actual calculations are carried out using Joinpoint Regression Program (National Institute of Cancer, 2013). The software requires specification of minimum (0) and maximum number of joinpoints (>0) up to a maximum of 9 in advance. The programme starts with 0 or minimum number of joinpoints, which means a straight line fit on a log scale and tests whether more joinpoints must be added to the model to better describe the trend in the data. The statistical significance of the change in trend is tested based on a Monte Carlo permutation method (Kim et al, 2000). The number of joinpoint(s) are identified using the grid search method (Lerman, 1980) which allows a joinpoint to occur exactly at the year t. A grid is created for all possible positions of the joinpoint(s) or combination of joinpoint(s), the model is fitted for each possible position and that position is selected which minimises the sum of squared errors (SSE). In the present analysis, the minimum number of joinpoint(s) has been set to 0 while the maximum number of joinpoint(s) is set to 4.

Joinpoint regression analysis has frequently been used for analysing trend in mortality and morbidity from specific causes (Tyczynski and Berkel, 2005; Doucet, Rochette and Hamel, 2016; John and Hanke, 2015; Akinyede and Soyemi, 2016; Mogos et al, 2016; Chatenoud et al, 2015; Missikpode et al, 2015; Rea et al, 2017; Qiu et al, 2008; Puzo, Qin and Mehlum, 2016). It has also been used for estimating population parameters under changing population structure (Gillis and Edwards, 2019). It has also been used to analyse long-term trend in infant mortality and marital fertility in India (Chaurasia, 2020a; 2020b) and in understanding the rapid increase in life expectancy in Shanghai, China (Chen et al, 2018). Jointpoint regression analysis has also been used to analyse patterns and changes in life expectancy at birth in China during 1990-2016 (Chen et al, 2020).

The second part of the paper analyses the contribution of the change in person-years lived in different ages to the change in e_0. Let the radix of the life table is l_0 or there are l_0 persons at age 0. If there is no death, at any age, then the total number of person-years lived up to the age N will be N^*l_0. If there is no death in the first year of life, then the survival probability in the first year of life, ${}_1p_0=1$, and the total number of person-years lived in the first year of life will be ${}_1L_0=l_0$. If ${}_1p_0<1$, then ${}_1L_0<l_0$ and person-years lost in the first year of life is

$${}_1D_0 = l_0 - {}_1L_0 \quad (4)$$

The persons years lost through all ages as the result of mortality in the first year of life, therefore, is given by

$$D_1 = \sum_1^N {}_1D_0 = N * {}_1D_0 \quad (5)$$

Similarly, the person years lost in the second year of life is given by

$${}_1D_1 = {}_1L_0 - {}_1L_1 \quad (6)$$

and the number of person years lost through all ages as the result of the mortality in the second year of life is given by

$$D_2 = \sum_2^N {}_1D_1 = (N-1) * {}_1D_1 \quad (7)$$

Total person-years of life lost due to mortality in different ages is, therefore

$${}_ND_0 = \sum_N D_i \quad (8)$$

The life expectancy at birth, e_0 may now be computed as

$$e_0 = \frac{N*l_0 - {}_ND_0}{l_0} = N - \frac{{}_ND_0}{l_0} \quad (9)$$

The change in e_0 between two points in time, 1 and 2 may now be decomposed as

$$e_0^2 - e_0^1 = \frac{{}_ND_0^1 - {}_ND_0^2}{l_0} = \frac{1}{l_0}\sum_N D_i^1 - D_i^2 \quad (10)$$

Temporal Patterns

Results of the joinpoint regression analysis of the trend in e_0 are presented in table 1. The joinpoint regression analysis suggests that the trend in e_0 in India changed three times during 2000 (1998-2000) through 2015 (2013-2017). The annual percent increase (APC) decreased considerably during 2002-2009 relative to 2000-2002; increased during 2009-2012 relative to 2002-2009 but again decreased during 2012-2015 relative to 2009-2012. As a result, e_0 increased, on average, by around 0.35 years per year during 2000-2002; by 0.32 years per year during 2002-2009; by 0.36 years per year during 2009-2012; and by only about 0.28 years per year during 2012-2015 (Table 1). If the increase in e_0 in the country, observed during 2000-2002, would have been sustained after 2002, the e_0 in India would have increased to more than 7.1 years by 2015. The deceleration in the increase in e_0 during 2002-2009 and again during 2012-2015, as reflected through APC, has resulted in a loss of more than two years in e_0 in the country during 2000-2015.

The increase in male e_0 has been different from that in female e_0. The trend in male e_0 changed two times during the period under reference but the trend in female e_0 changed three times. The increase in male e_0 accelerated during 2009-2015 but the increase in female e_0 decelerated considerably during 2011-2015. If the APC in female e_0 would have not decreased after 2002, the female e_0 would have increased to almost 73.9 years by 2015 which means that deceleration in the increase in female e_0 resulted in a loss of around 3.4 years in female e_0 during 2000-2015. Because of the deceleration in the increase in female e_0 during 2011-2015, the female-male gap in e_0 narrowed down substantially after 2011.

The increase in e_0 has also been comparatively faster in rural than in the urban areas of the country. The trend in both rural and urban e_0, however, changed three times, although the years of change in trend or the joinpoints have been different. The increase in urban e_0 has been slower than the increase in rural e_0 largely because the increase in urban e_0 almost stagnated during 2004-2007. The increase in e_0 decelerated in both rural and urban areas of the country during 2012-2015, although the deceleration has been more pronounced in the urban areas than in the rural areas. As a result of the stagnation in the increase in urban e_0, the urban-rural gap in e_0 was the lowest in 2007 (2005-2009).

Among different mutually exclusive population groups, the increase in e_0 has been the fastest in rural females but the slowest in urban females. The increase in e_0 accelerated substantially in rural females during 2009-2015 but decelerated considerably in urban females during 2012-2015 so that the urban-rural gap in female e_0 has narrowed down substantially. The trend in rural and urban male e_0 has, however, been more volatile so that the rural-urban gap in male e_0 has been the lowest in 2007 (2005-09). Table 1 also suggests that there has been substantial deceleration in the increase in female e_0 compared to the increase in male e_0 in recent years.

Table 1: Trend in e_0 in India and different population groups, 1998-2002 (2000) to 2013-2017 (2015).

<table>
<tr><th rowspan="2">Population groups</th><th rowspan="2">Total increase (years)</th><th rowspan="2">AAPC</th><th colspan="16">APC in different time-segments</th></tr>
<tr><th>2000</th><th>2001</th><th>2002</th><th>2003</th><th>2004</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th></tr>
<tr><td>Person</td><td>6.1</td><td>0.622*</td><td colspan="2">0.823*</td><td></td><td colspan="6">0.558*</td><td></td><td colspan="2">0.738*</td><td></td><td colspan="3">0.534*</td></tr>
<tr><td>Male</td><td>5.9</td><td>0.613*</td><td colspan="3">0.670*</td><td></td><td colspan="5">0.448*</td><td></td><td colspan="6">0.750*</td></tr>
<tr><td>Female</td><td>6.4</td><td>0.643*</td><td colspan="2">0.962*</td><td></td><td colspan="5">0.618*</td><td></td><td colspan="2">0.800*</td><td></td><td colspan="4">0.606*</td></tr>
<tr><td>Rural</td><td>6.1</td><td>0.631*</td><td colspan="2">0.884*</td><td></td><td colspan="5">0.573*</td><td></td><td colspan="3">0.696*</td><td></td><td colspan="3">0.491*</td></tr>
<tr><td>Rural male</td><td>6.6</td><td>0.601*</td><td colspan="4">0.653*</td><td></td><td colspan="4">0.460*</td><td></td><td colspan="6">0.683*</td></tr>
<tr><td>Rural female</td><td>4.8</td><td>0.662*</td><td colspan="2">1.002*</td><td></td><td colspan="9">0.717*</td><td></td><td colspan="3">0.256*</td></tr>
<tr><td>Urban</td><td>5.7</td><td>0.455*</td><td colspan="4">0.464*</td><td></td><td colspan="2">0.099</td><td></td><td colspan="4">0.705*</td><td></td><td colspan="3">0.385*</td></tr>
<tr><td>Urban male</td><td>5.1</td><td>0.498*</td><td colspan="3">0.592*</td><td></td><td colspan="3">0.100</td><td></td><td colspan="5">0.715*</td><td></td><td colspan="2">0.506*</td></tr>
<tr><td>Urban female</td><td>4.5</td><td>0.416*</td><td colspan="4">0.480*</td><td></td><td colspan="2">0.143</td><td></td><td colspan="3">0.716*</td><td></td><td colspan="4">0.256*</td></tr>
</table>

Source: Author

Remarks: * indicates that APC and AAPC are statistically different from zero. Dark shaded cells are jointpoints

Table 2: Trend in e_0 in selected states, 1998-2002 (circa 2000) through 2013-17 (circa 2015).

State	Net increase (years)	AAPC	APC in different time-segments															
			2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Andhra Pradesh	6.3	0.645*	0.987*				0.495		0.065				1.029*					0.440
Assam	8.2	0.887*						0.807*									1.208*	
Bihar	5.9	0.589*	0.848*				0.081				1.015*					0.436*		
Gujarat	4.9	0.457*				0.373*									0.640*			
Haryana	4.6	0.450*			0.708*				0.037					0.725*				0.419*
Himachal Pradesh	4.3	0.416*	0.811*					0.124*							0.625*			
Jammu and Kashmir	8.2	0.843*			1.554*				0.159						0.830*			
Karnataka	4.2	0.417*			0.567*			0.129				0.616*					0.126*	
Kerala	3.3	0.299*	0.930*				0.445*		0.030				0.240*					0.002
Madhya Pradesh	7.9	0.828*								0.828*								
Maharashtra	6.3	0.607*			0.886*				0.330				0.648*				0.366*	
Odisha	9.3	0.990*	1.080*					0.712*				1.020*				1.342*		
Punjab	5.2	0.511*		0.835*				0.128					0.826*					0.204
Rajasthan	5.2	0.532*				0.626*									0.424*			
Tamil Nadu	6.0	0.580*		0.732*								0.553*						
Uttar Pradesh	5.3	0.567*						0.599*									0.439*	
West Bengal	5.6	0.538*			0.788*								0.447*					

Source: Author's calculations

Remarks: The shaded cell indicates joinpoint.

* Indicates APC or AAPC are statistically significantly different from zero.

Table 3: Trend in male e_0 in selected states, 1998-2002 (circa 2000) through 2013-17 (circa 2015).

<table>
<tr><th rowspan="2">Country/State</th><th rowspan="2">Net increase (years)</th><th rowspan="2">AAPC</th><th colspan="16">APC in different time-segments</th></tr>
<tr><th>2000</th><th>2001</th><th>2002</th><th>2003</th><th>2004</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th></tr>
<tr><td>Andhra Pradesh</td><td>7.0</td><td>0.749</td><td colspan="3">0.872*</td><td></td><td colspan="4">0.199</td><td></td><td colspan="7">1.090*</td></tr>
<tr><td>Assam</td><td>8.0</td><td>0.838</td><td colspan="11">0.668*</td><td></td><td colspan="4">1.309*</td></tr>
<tr><td>Bihar</td><td>5.8</td><td>0.545</td><td colspan="6">0.118</td><td></td><td colspan="9">0.831*</td></tr>
<tr><td>Gujarat</td><td>4.6</td><td>0.479</td><td colspan="7">0.320*</td><td></td><td colspan="8">0.619*</td></tr>
<tr><td>Haryana</td><td>3.2</td><td>0.282</td><td colspan="16">0.282*</td></tr>
<tr><td>Himachal Pradesh</td><td>3.2</td><td>0.287</td><td colspan="9">0.192*</td><td></td><td colspan="6">0.430*</td></tr>
<tr><td>Jammu and Kashmir</td><td>7.4</td><td>0.764</td><td colspan="4">1.596*</td><td></td><td colspan="11">0.463*</td></tr>
<tr><td>Karnataka</td><td>5.1</td><td>0.536</td><td colspan="4">0.690*</td><td></td><td colspan="3">0.165</td><td></td><td colspan="3">0.833*</td><td></td><td colspan="3">0.430*</td></tr>
<tr><td>Kerala</td><td>3.5</td><td>0.319</td><td colspan="2">0.933*</td><td></td><td colspan="2">0.348</td><td></td><td colspan="10">0.187*</td></tr>
<tr><td>Madhya Pradesh</td><td>6.7</td><td>0.706</td><td colspan="16">0.706*</td></tr>
<tr><td>Maharashtra</td><td>6.7</td><td>0.667</td><td colspan="5">0.884*</td><td></td><td colspan="2">0.314</td><td></td><td colspan="7">0.707*</td></tr>
<tr><td>Odisha</td><td>8.7</td><td>0.913</td><td colspan="16">0.913*</td></tr>
<tr><td>Punjab</td><td>5.0</td><td>0.526</td><td colspan="3">0.840*</td><td></td><td colspan="4">-0.101</td><td></td><td colspan="7">0.840*</td></tr>
<tr><td>Rajasthan</td><td>4.4</td><td>0.457</td><td colspan="7">0.606*</td><td></td><td colspan="8">0.328*</td></tr>
<tr><td>Tamil Nadu</td><td>5.7</td><td>0.570</td><td colspan="2">0.849*</td><td></td><td colspan="8">0.478*</td><td></td><td colspan="4">0.637*</td></tr>
<tr><td>Uttar Pradesh</td><td>4.4</td><td>0.476</td><td colspan="11">0.392*</td><td></td><td colspan="4">0.708*</td></tr>
<tr><td>West Bengal</td><td>6.1</td><td>0.599</td><td colspan="3">0.717*</td><td></td><td colspan="7">0.503*</td><td></td><td colspan="4">0.700*</td></tr>
</table>

Source: Author's calculations

Remarks: The shaded cell indicates the joinpoint.

* Indicates APC or AAPC are statistically significantly different from zero.

Table 4: Trend in female e_0 in selected states, 1998-2002 (circa 2000) through 2013-17 (circa 2015).

<table>
<tr><th rowspan="2">Country/State</th><th rowspan="2">Net increase (years)</th><th rowspan="2">AAPC</th><th colspan="16">APC in different time-segments</th></tr>
<tr><th>2000</th><th>2001</th><th>2002</th><th>2003</th><th>2004</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th></tr>
<tr><td>Andhra Pradesh</td><td>5.6</td><td>0.559</td><td colspan="3">1.043*</td><td></td><td colspan="4">0.119</td><td></td><td colspan="2">1.029*</td><td></td><td colspan="4">0.188</td></tr>
<tr><td>Assam</td><td>8.4</td><td>0.924</td><td colspan="16">0.924*</td></tr>
<tr><td>Bihar</td><td>6.1</td><td>0.614</td><td colspan="2">1.082*</td><td></td><td colspan="3">0.289*</td><td></td><td colspan="4">1.073*</td><td></td><td colspan="4">0.133</td></tr>
<tr><td>Gujarat</td><td>5.3</td><td>0.509</td><td colspan="2">0.642*</td><td></td><td colspan="5">0.358*</td><td></td><td colspan="4">0.722*</td><td></td><td colspan="2">0.298</td></tr>
<tr><td>Haryana</td><td>6.4</td><td>0.605</td><td colspan="2">1.396</td><td></td><td colspan="2">0.624</td><td></td><td colspan="2">0.063</td><td></td><td colspan="4">0.723*</td><td></td><td colspan="2">0.308</td></tr>
<tr><td>Himachal Pradesh</td><td>5.4</td><td>0.513</td><td colspan="2">1.158</td><td></td><td colspan="6">0.054</td><td></td><td colspan="6">0.836*</td></tr>
<tr><td>Jammu and Kashmir</td><td>9.4</td><td>0.883</td><td colspan="4">1.327*</td><td></td><td colspan="3">0.029</td><td></td><td colspan="4">1.366*</td><td></td><td colspan="2">0.506</td></tr>
<tr><td>Karnataka</td><td>3.1</td><td>0.302</td><td colspan="2">0.605*</td><td></td><td colspan="4">0.230*</td><td></td><td colspan="3">0.541*</td><td></td><td colspan="4">0.001</td></tr>
<tr><td>Kerala</td><td>2.9</td><td>0.286</td><td colspan="13">0.872*</td><td></td><td colspan="2">0.141*</td></tr>
<tr><td>Madhya Pradesh</td><td>9.3</td><td>0.968</td><td colspan="8">1.062*</td><td></td><td colspan="7">0.860*</td></tr>
<tr><td>Maharashtra</td><td>5.8</td><td>0.543</td><td colspan="6">0.828*</td><td></td><td colspan="6">0.464*</td><td></td><td colspan="2">-0.034</td></tr>
<tr><td>Odisha</td><td>10.0</td><td>1.046</td><td colspan="2">1.405*</td><td></td><td colspan="6">0.623*</td><td></td><td colspan="6">1.422*</td></tr>
<tr><td>Punjab</td><td>5.7</td><td>0.540</td><td colspan="3">0.950*</td><td></td><td colspan="4">0.424*</td><td></td><td colspan="4">0.716*</td><td></td><td colspan="2">-0.218</td></tr>
<tr><td>Rajasthan</td><td>6.0</td><td>0.592</td><td colspan="8">0.627*</td><td></td><td colspan="2">0.844*</td><td></td><td colspan="4">0.332*</td></tr>
<tr><td>Tamil Nadu</td><td>6.5</td><td>0.686</td><td colspan="16">0.686*</td></tr>
<tr><td>Uttar Pradesh</td><td>6.2</td><td>0.650</td><td colspan="11">0.838*</td><td></td><td colspan="4">0.135</td></tr>
<tr><td>West Bengal</td><td>5.2</td><td>0.487</td><td colspan="2">1.091*</td><td></td><td colspan="2">0.732*</td><td></td><td colspan="3">0.449*</td><td></td><td colspan="6">0.189*</td></tr>
</table>

Source: Author’s calculations

Remarks: The shaded cell indicates the joinpoint.

* Indicates APC or AAPC are statistically significantly different from zero.

Table 5: Contribution of different age groups to the increase in e_0 in India between 2000(1998-2000) and 2015 (2013-2017).

Age	Combined			Rural			Urban		
Years	Person	Male	Female	Person	Male	Female	Person	Male	Female
0-1	1.72	1.77	1.61	1.72	1.75	1.63	1.22	1.38	1.01
1-4	1.86	1.70	2.10	2.08	1.90	2.35	0.89	0.83	0.99
5-9	0.70	0.58	0.82	0.76	0.63	0.89	0.41	0.34	0.47
10-14	0.30	0.26	0.33	0.33	0.29	0.37	0.15	0.13	0.17
15-19	0.21	0.18	0.25	0.24	0.20	0.29	0.10	0.09	0.12
20-24	0.29	0.21	0.37	0.33	0.24	0.44	0.14	0.11	0.18
25-29	0.31	0.24	0.38	0.33	0.26	0.41	0.22	0.17	0.27
30-34	0.26	0.24	0.29	0.25	0.22	0.29	0.24	0.26	0.21
35-39	0.21	0.20	0.22	0.20	0.18	0.22	0.19	0.23	0.14
40-44	0.15	0.17	0.14	0.12	0.13	0.11	0.18	0.20	0.15
45-49	0.13	0.13	0.13	0.09	0.09	0.09	0.18	0.20	0.15
50-54	0.11	0.18	0.04	0.03	0.12	-0.06	0.24	0.27	0.18
55-59	0.13	0.19	0.05	0.01	0.07	-0.07	0.34	0.38	0.26
60-64	0.20	0.24	0.17	0.10	0.10	0.10	0.39	0.47	0.30
65-69	0.29	0.38	0.21	0.21	0.30	0.15	0.45	0.56	0.36
70-74	0.13	0.11	0.15	0.10	0.08	0.13	0.20	0.19	0.22
75-79	-0.10	-0.16	-0.03	-0.09	-0.15	-0.03	-0.09	-0.19	0.02
80-84	-0.35	-0.38	-0.33	-0.36	-0.37	-0.34	-0.29	-0.31	-0.26
85+	-0.40	-0.36	-0.44	-0.42	-0.38	-0.46	-0.29	-0.21	-0.40
Increase in e_0	6.15	5.89	6.44	6.05	5.65	6.50	4.85	5.10	4.53

Source: Author's calculations.

Table 6: Contribution of different age groups to the increase in e_0 in states between 2000(1998-2000) and 2015 (2013-2017).

Age	AP	AS	BI	GU	HA	HP	JA	KA	KE	MP	MS	OD	PU	RA	TN	UP	WB
0-1	1.90	1.87	1.57	1.09	1.78	1.47	0.93	2.06	0.07	2.14	2.05	2.52	2.17	1.73	1.76	1.08	1.76
1-4	1.30	2.18	1.89	1.41	1.85	0.84	0.85	1.41	0.15	3.19	0.99	2.68	1.29	2.46	0.85	2.51	1.22
5-9	0.36	0.90	0.93	0.61	0.57	0.19	2.08	0.37	0.41	0.80	0.30	0.60	0.35	0.72	0.26	1.06	0.48
10-14	0.23	0.54	0.48	0.19	0.14	0.09	1.76	0.11	0.33	0.31	0.16	0.32	0.11	0.20	0.12	0.39	0.23
15-19	0.26	0.36	0.35	0.11	0.09	0.08	0.05	0.13	0.05	0.20	0.18	0.32	0.06	0.14	0.20	0.27	0.17
20-24	0.33	0.49	0.38	0.18	0.25	0.15	0.08	0.20	0.05	0.29	0.19	0.45	0.10	0.21	0.37	0.44	0.21
25-29	0.30	0.46	0.41	0.24	0.31	0.18	0.23	0.21	0.07	0.23	0.22	0.35	0.23	0.26	0.34	0.49	0.18
30-34	0.29	0.34	0.35	0.27	0.14	0.24	0.15	0.22	0.12	0.18	0.28	0.24	0.24	0.19	0.26	0.34	0.13
35-39	0.22	0.27	0.28	0.18	0.12	0.09	0.11	0.17	0.14	0.18	0.23	0.31	0.13	0.06	0.18	0.24	0.15
40-44	0.11	0.28	0.21	0.14	0.07	0.07	0.02	0.07	0.15	0.24	0.22	0.27	0.04	-0.01	0.19	0.07	0.12
45-49	0.10	0.39	0.31	0.19	-0.02	0.07	-0.07	0.09	0.14	0.19	0.28	0.14	-0.05	-0.03	0.13	-0.06	0.17
50-54	0.20	0.32	0.35	0.01	0.13	-0.01	0.12	0.22	0.12	0.17	0.19	0.18	-0.06	-0.16	0.11	-0.26	0.17
55-59	0.30	0.39	0.16	-0.11	0.14	-0.01	0.29	0.17	0.17	0.21	0.14	0.40	0.12	-0.21	0.35	-0.41	0.26
60-64	0.37	0.44	0.29	0.11	-0.33	0.19	0.27	-0.01	0.35	0.21	0.38	0.44	0.13	-0.07	0.50	-0.21	0.47
65-69	0.30	0.16	0.47	0.36	-0.48	0.48	0.37	0.07	0.37	0.33	0.50	0.16	0.01	0.11	0.51	0.12	0.50
70-74	0.15	-0.07	-0.18	0.18	-0.21	0.25	0.42	-0.09	0.34	0.07	0.48	0.11	0.12	0.13	0.35	0.13	0.19
75-79	-0.08	-0.25	-0.52	-0.04	-0.02	-0.09	0.12	-0.11	0.34	-0.31	0.22	-0.19	0.16	-0.07	0.08	-0.02	-0.13
80-84	-0.26	-0.47	-0.83	-0.17	-0.02	-0.13	-0.08	-0.41	-0.02	-0.46	-0.35	-0.29	-0.01	-0.22	-0.28	-0.36	-0.35
85+	-0.06	-0.36	-0.96	-0.11	0.05	0.10	0.49	-0.62	-0.03	-0.29	-0.45	0.20	0.11	-0.26	-0.18	-0.52	-0.29
Increase in e_0	6.31	8.24	5.93	4.85	4.59	4.25	8.18	4.26	3.32	7.90	6.24	9.21	5.26	5.18	6.08	5.29	5.63

Source: Author's calculations.

Table 7: Contribution of different age groups to the increase in e_0 in India in different time segments of the period 2000-2015 identified through joinpoint regression analysis.

Age	Time-segment				
	2000-02	2002-09	2009-12	2012-15	2000-15
0-1	0.10	0.89	0.45	0.28	1.72
1-4	0.26	0.87	0.41	0.32	1.86
5-9	0.14	0.25	0.15	0.16	0.70
10-14	0.06	0.12	0.06	0.05	0.30
15-19	0.03	0.09	0.05	0.05	0.21
20-24	0.05	0.09	0.06	0.09	0.29
25-29	0.05	0.11	0.05	0.10	0.31
30-34	0.03	0.10	0.06	0.07	0.26
35-39	0.03	0.06	0.07	0.04	0.21
40-44	0.04	0.04	0.04	0.03	0.15
45-49	0.03	0.03	0.03	0.04	0.13
50-54	0.06	0.05	0.00	0.00	0.11
55-59	0.09	0.16	-0.03	-0.08	0.13
60-64	0.07	0.12	0.04	-0.02	0.20
65-69	0.06	0.01	0.10	0.11	0.29
70-74	0.03	-0.11	0.09	0.11	0.13
75-79	-0.03	-0.15	0.05	0.03	-0.10
80-84	-0.05	-0.11	-0.09	-0.10	-0.35
85+	-0.01	-0.08	-0.14	-0.16	-0.40
Increase in e_0	1.04	2.52	1.46	1.12	6.15

Source: Author's calculations.

The trend in e_0 has varied across the states in terms of both volatility and magnitude of change (Table 2). In Andhra Pradesh and Kerala, the trend in e_0 changed four times whereas Madhya Pradesh is the only state where there has been no change in the trend during 2000-2015 or e_0 increased linearly on a log scale during the period under reference. In majority of the states, however, the trend in e_0 changed three times during the period under reference reflecting the volatility in the trend. The increase in e_0 has been the fastest in Odisha but the slowest in Kerala. Odisha is the only state where female e_0 increased by more than nine years during 2000-2015 or by more than 0.5 years per year, on average. Kerala, on the other hand, is the only state where e_0 increased by less than four years or by just 0.2 years per year. Inter-state variance in e_0, however, decreased over time which indicates sigma-convergence in e_0 across states. There are seven states where APC has not been found to be statistically significantly different from zero during at least one time-segment of the period under reference which suggests that the increase in e_0 stagnated during these time segments. In Andhra Pradesh, the increase in e_0 stagnated in three of the five time-segments. In Kerala and Punjab, increase in e_0 stagnated in two time-segments while it stagnated in one time segment in Bihar, Haryana, Jammu and Kashmir and Maharashtra.

Table 8: Contribution of different age groups to the increase in male e_0 in India in different time segments of the period 2000-2015 identified through joinpoint regression analysis.

Age	Time-segment			
	2000-2004	2004-2009	2009-2015	2000-2015
0-1	0.20	0.81	0.76	1.77
1-4	0.30	0.76	0.64	1.70
5-9	0.11	0.21	0.26	0.58
10-14	0.04	0.11	0.11	0.26
15-19	0.03	0.07	0.08	0.18
20-24	0.05	0.03	0.13	0.21
25-29	0.06	0.03	0.15	0.24
30-34	0.04	0.04	0.16	0.24
35-39	0.05	0.00	0.16	0.20
40-44	0.05	-0.03	0.15	0.17
45-49	0.05	-0.04	0.12	0.13
50-54	0.08	-0.01	0.12	0.18
55-59	0.13	0.08	-0.02	0.19
60-64	0.13	0.04	0.06	0.24
65-69	0.08	-0.01	0.31	0.38
70-74	-0.01	-0.10	0.22	0.11
75-79	-0.06	-0.11	0.01	-0.16
80-84	-0.08	-0.06	-0.24	-0.38
85+	0.08	-0.17	-0.27	-0.36
Increase in e_0	1.34	1.64	2.91	5.89

Source: Author's calculations.

Across different states and different time segments, APC was the fastest in Jammu and Kashmir during 2000-2004 but the slowest in Kerala during 2013-2015. In most states of the country, the increase in e_0 decelerated during the later years or the period 2000-15 as compared to earlier years of the period 2000-2015, with the exception of only two states - Assam and Odisha. The trend in e_0 in Kerala, the state with the highest e_0 in the country throughout the period under reference is typical. currently and in the past has been the most remarkable with the increase in e_0 stagnating during the period 2013-2015.

The deceleration in the increase in e_0 has particularly been marked in female e_0. Odisha is the only state where increase in female e_0 did not decelerate during the period under reference whereas in Maharashtra and Punjab, female e_0 appears to have decreased in recent years. By comparison, there is no state where APC in male e_0 has been negative in recent years. By contrast, male e_0 decreased in only Punjab during 2003-2008. In many states, increase in male e_0 accelerated in recent years compared to that in the past. In all states, the volatility in the trend has also been found to be less in male e_0 compared to females. There is no state where number of joinpoints in male e_0 is four and, in three states, there is no joinpoint indicating a linear trend on a log scale. By comparison, number of joinpoints in female e_0 has been four in one state and three in seven states. There is only one state where there is no joinpoint in the trend in female e_0.

Table 9: Contribution of different age groups (years) to the increase in female e_0 in India in different time segments of the period 2000-2015 identified through joinpoint regression analysis.

Age	Time-segment				
	2000-2002	2002-2008	2008-2011	2011-2015	2000-2015
0-1	0.07	0.78	0.37	0.39	1.61
1-4	0.30	0.81	0.42	0.56	2.10
5-9	0.18	0.21	0.17	0.25	0.82
10-14	0.08	0.11	0.08	0.06	0.33
15-19	0.03	0.09	0.06	0.07	0.25
20-24	0.05	0.13	0.06	0.13	0.37
25-29	0.07	0.14	0.06	0.11	0.38
30-34	0.04	0.12	0.06	0.07	0.29
35-39	0.03	0.08	0.08	0.03	0.22
40-44	0.04	0.11	0.00	-0.02	0.14
45-49	0.04	0.06	0.04	-0.01	0.13
50-54	0.07	0.03	0.07	-0.13	0.04
55-59	0.09	0.18	0.00	-0.23	0.05
60-64	0.06	0.11	0.06	-0.07	0.17
65-69	0.07	0.01	0.01	0.11	0.21
70-74	0.07	-0.11	0.03	0.17	0.15
75-79	-0.01	-0.16	0.03	0.10	-0.03
80-84	-0.05	-0.12	-0.04	-0.12	-0.33
85+	0.04	-0.02	0.00	-0.46	-0.44
Increase in e_0	1.28	2.58	1.58	1.00	6.44

Source: Author's calculations.

Decomposition of the Increase in e_0

The increase in e_0 in India was around 6.1 years between 1998-2002 and 2013-2017. The increase in the person-years lived in the first year of life accounted for an increase of around 1.72 years in e_0 while increase in person-years lived in 1-5 years of life accounted for an increase of 1.86 years so that increase in person-years lived in the first five years of life accounted for an increase of 3.58 years or more than 58 per cent of the increase in e_0. Increase in person-years lived in 15-60 years of age accounted for an increase of 1.8 years or 30 per cent increase in e_0. Increase in person-years lived in 60-

75 years of age accounted for an increase of around 0.62 years or 10 per cent increase in e_0 but the decrease in the person-years lived in the age group 75 years and above resulted in a decrease of around 0.85 years or 14 per cent decrease in e_0. The average annual gain in e_0 was the highest during 2009-2012 but the lowest during 2012-2015 because the person-years lived in the age group 50-65 years decreased during 2012-2015 compared to 2009-2012. Another reason behind low average annual gain in e_0 during 2012-2015 appears to be very slow increase in the survival probability in the first five years of life leading to only a marginal increase in the person-years lived in this age group.

The relative contribution of the change in age-specific survival probabilities to the change in e_0 has been different in different states of the country. In most of the states, however, the increase in e_0 has primarily been attributed to the improvement in person-years lived in the first five years of life. Notable exceptions to this general pattern are Jammu and Kashmir and Kerala. Similarly, decrease in person-years lived in the age group 75 years and above has accounted for the decrease in e_0 in most of the states. There are only four states - Haryana, Jammu and Kashmir, Kerala, and Punjab - where person-years lived in the age group 75 years and above increased during the period under reference and, therefore, contributed to the increase in e_0. In Haryana, person-years lived in the age group 60-75 years decreased in 2015 compared to 2000. Similarly, person years lived in the age group 40-65 years decreased in Rajasthan and person-years lived in the age group 45-65 years decreased in Utter Pradesh during the period under reference and, therefore, decelerated the increase in e_0.

The relative contribution of the change in person-years lived in different age groups to the change in e_0 has been different in females as compared to males. Almost 80 per cent of the increase in the female e_0 is attributed to the increase in person-years lived in the first 15 years of life. This proportion is only 70 per cent in males. By contrast, increase in person-years lived in the age group 60-75 years accounted for an increase of 0.73 years in male e_0 but only 0.53 years in female e_0. On the other hand, decrease in person-years lived in the age group 75 years and above accounted for a decrease of 0.81 years in female e_0 but 0.90 years in male e_0. Similarly, increase in person-years lived in the first five years of life accounted for almost two-third increase in e_0 in the rural areas of the country but only around 43 per cent in the urban areas. Increase in person-years lived in the age group 1-5 years of life accounted for more than 34 per cent of the increase in rural e_0 but only around 18 per cent increase in urban e_0.

Discussions and Conclusions

The present analysis reveals volatile trends in e_0 in India and in its different population groups and 17 states between 1998-2002 and 2013-2015.There has been a deceleration in the increase in the later years compared to the earlier years of the period 2000-2015 which is quite marked in females. The deceleration in the increase in

e_0 during the period under reference is estimated to have costed more than 2 years in the gain in e_0. The increase in e_0 has also decelerated in most states of the country leading to retarded increase in e_0. The reason for the observed deceleration in the increase in e_0 has been the deceleration in the increase in female e_0 as the increase in male e_0 has accelerated during this period. The deceleration in the increase in female e_0 is estimated to have costed more than 3 years in the gain in female e_0 and has resulted in narrowing the gender gap in e_0.

The analysis also reveals that the increase in urban e_0 has stagnated during 2003-2007 and this stagnation has primarily been responsible for relatively slower increase in urban e_0 as compared to the increase in rural e_0. Unlike the urban areas, there has been no stagnation in the increase in e_0 in the rural areas of the country. Because of the stagnation in the increase in urban e_0, the urban-rural gap in e_0 was the narrowest during 2007 (2005-2009). The urban-rural gap in e_0 narrowed down again in the recent past because of the increase in urban e_0 decelerated again. The deceleration in the increase in urban e_0 has not been confined to a particular sex but is evident in both sexes.

The increase in e_0 in the country has largely been the result of the improvement in the survival probability in the first five years of life. However, the contribution of the improvement in the survival probability in the first five years has varied in different time segments as identified through the joinpoint regression analysis. In recent years, contribution of the improvement in the survival probability in the first five years of life to the increase in e_0 has decreased substantially. On the other hand, the number of person-years lived in the age group 75 years and above has decreased during the period under reference which contributed to the decrease in e_0. Although, survival probability increased in the age group 75-80 and 80-80 years, yet improvement in the survival probability in these age groups has not been large enough to ensure a decrease in the number of deaths so that the number of person-years lived in these age groups decreased leading to decrease in e_0.

The deceleration in the increase in female e_0 in the country in recent years is a matter of concern from the perspective of population health. The decrease in person-years lived in the age group 40-65 years appears to be responsible for the deceleration in the increase in female e_0 in the country. Although, the probability of death in females of this age group has decreased during 2000-2015, yet the decrease in the probability of death has not been sufficient enough to ensure the decrease in the number of deaths and hence increase in person-years lived in this age group. To ensure that improvement in survival probability results in the increase in person-years lived and increase in e_0, it is imperative that the improvement in survival probability is large enough to ensure an increase in person-years lived in the age group.

Reasons for volatile trends and deceleration in the increase in e_0, especially in females in India are not known at present. To accelerate the increase in e_0, it appears imperative to increase the investment in the health of the people. The current investment in health does not appear to be adequate to accelerate the pace of the increase in e_0 which remains slow by international standards. India has not been able to achieve the goal of an e_0 of 75 years by the year 2015 set at the 1994 International Conference on Population and Development. The National Health Policy 2017 has scaled down the goal of e_0 to 70 years by the year 2025 which will be achieved even without any acceleration in the current rate of increase in e_0.

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