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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 overestimating 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

$$\ln(y_i) = \alpha + \beta_1 t_1 + \beta_1 u_1 + \beta_2 u_2 + \dots + \beta_j u_j + \varepsilon_i \tag{1}$$

where

$$u_{j} = \begin{cases} (t_{j} - k_{j}), & \text{if } t_{j} > k_{j} \\ 0 & \text{otherwise} \end{cases}$$

and  $k_1 < k_2 \dots < k_j$  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

$$\ln(y_t) = \alpha_0 + \beta(t) \tag{2}$$

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

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

$${}_{1}D_{0} = l_{0} - {}_{1}L_{0} \tag{4}$$

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

$$D_1 = \sum_{1}^{N} {}_{1}D_0 = N * {}_{1}D_0 \tag{5}$$

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

$${}_{1}D_{1} = {}_{1}L_{0} - {}_{1}L_{1} \tag{6}$$

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

$$D_2 = \sum_{2}^{N} {}_{1}D_1 = (N-1) * {}_{1}D_1$$
(7)

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

$${}_{N}D_{0} = \sum_{N} D_{i} \tag{8}$$

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

$$e_0 = \frac{N \cdot l_0 - N D_0}{l_0} = N - \frac{N D_0}{l_0}$$
(9)

The change in e<sub>0</sub> between two points in time, 1 and 2 may now be decomposed as

$$e_0^2 - e_0^1 = \frac{N D_0^1 - N D_0^2}{l_0} = \frac{1}{l_0} \sum_N D_i^1 - D_i^2$$
<sup>(10)</sup>

## **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.

Population groups	Total	AAPC	APC in different time-segments									
	increase (years)		2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 20									
Person	6.1	0.622*	0.823* 0.558* 0.738*							0.534*		
Male	5.9	0.613*	0.670	*	0.448*	*		0.750*				
Female	6.4	0.643*	0.962*		0.618* 0.800*					0.606*		
Rural	6.1	0.631*	0.884*		0.573*		0.	596*		0.491*		
Rural male	6.6	0.601*	0.6	53*	0.4	60*			0.6	83*		
Rural female	4.8	0.662*	1.002*		(	0.717*				0.256*		
Urban	5.7	0.455*	0.4	64*	0.099		0.705*			0.385*		
Urban male	5.1	0.498*	0.592	*	0.100	0.715*		0.100			0.506*	
Urban female	4.5	0.416*	0.4	80*	0.143		0.716*			0.256*		

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

Source: Author

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

State	Net	AAPC	APC in diff	erent	time-seg	ment	S		PC in different time-segments								
	increase		2000 2001	2002	2003 20	04 20	05 200	)6 200	07 20	08 20	09 2010	2011	2012 20	13 20	14 2015		
	(years)																
Andhra Pradesh	6.3	0.645*	0.987*		0.495		0.0	065			1.0	)29*			0.440		
Assam	8.2	0.887*				(	0.807*							1.	208*		
Bihar	5.9	0.589*	0.848*		0.0	81				1.015*	÷		(	).436*	*		
Gujarat	4.9	0.457*			0.373*							0.	640*				
Haryana	4.6	0.450*	0.7	'08*			0.0	037				0.725*	+		0.419*		
Himachal Pradesh	4.3	0.416*	0.811*			0.	.124*				0.625*						
Jammu and Kashmir	8.2	0.843*	1.5	54*			0.159	9			0.830*						
Karnataka	4.2	0.417*	0.5	67*			0.129			0.	616*			0.	126*		
Kerala	3.3	0.299*	0.930*		0.445*	ŧ	0.0	030			0.2	240*			0.002		
Madhya Pradesh	7.9	0.828*						0	.828*	ŀ							
Maharashtra	6.3	0.607*	(	0.886	*		0.3	330			0.648*			0.	366*		
Odisha	9.3	0.990*	1.080*			0.71	2*			1.	020*			1.342*	*		
Punjab	5.2	0.511*	0.835	*		0	.128				0.8	826*			0.204		
Rajasthan	5.2	0.532*			0.626*							0.4	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*	0.7	'88*							0.447	*					

Table 2: Trend in *e*<sup>0</sup> in selected states, 1998-2002 (circa 2000) through 2013-17 (circa 2015).

Source: Author's calculations

Remarks:

The shaded cell indicates joinpoint. \* Indicates APC or AAPC are statistically significantly different from zero.

Country/State	Net	AAPC	APC in different time-segments									
	increase (years)		2000 2001 200	2 2003	2004	2005	2006 2007 2	2008 200	9 2010 2	20112	2012	2013 2014 2015
Andhra Pradesh	7.0	0.749	0.872*			0.1	99			1	.090*	
Assam	8.0	0.838		0.668* 1.309*						1.309*		
Bihar	5.8	0.545	0	.118					0	.831*		
Gujarat	4.6	0.479		0.320	*					0.61	9*	
Haryana	3.2	0.282		0.282*								
Himachal Pradesh	3.2	0.287		0.192* 0.430*								30*
Jammu and Kashmir	7.4	0.764	1.596*	1.596* 0.463*								
Karnataka	5.1	0.536	0.690*				0.165		0.833*			0.430*
Kerala	3.5	0.319	0.933*	0.3	348				0.18	37*		
Madhya Pradesh	6.7	0.706					0.70	)6*				
Maharashtra	6.7	0.667	0.88	4*			0.314			0	.707*	
Odisha	8.7	0.913					0.91	13*				
Punjab	5.0	0.526	0.840*			-0.	101			0	.840*	
Rajasthan	4.4	0.457		0.606	*					0.32	28*	
Tamil Nadu	5.7	0.570	0.849* 0.478* 0.637*						0.637*			
Uttar Pradesh	4.4	0.476	0.392* 0.708*						0.708*			
West Bengal	6.1	0.599	0.717*				0.503*					0.700*

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

Source: Author's calculations

Remarks: The shaded cell indicates the joinpoint. \* Indicates APC or AAPC are statistically significantly different from zero.

Country/State	Net	AAPC	APC in diffe	PC in different time-segments										
	increase		2000 2001	2002	2003 20	004 200	5 2006 200	07 2008	2009	2010	2011	2012	2013	2014 2015
	(years)								_					
Andhra Pradesh	5.6	0.559	1.043*	1.043*         0.119         1.029*         0.188									88	
Assam	8.4	0.924		0.924*										
Bihar	6.1	0.614	1.082*		0.2	289*		1.0	)73*				0.1	33
Gujarat	5.3	0.509	0.642*			0.35	8*			0.7	22*			0.298
Haryana	6.4	0.605	1.396		0.62	4	0.063			0.7	23*			0.308
Himachal Pradesh	5.4	0.513	1.158			0	.054					0.83	36*	
Jammu and Kashmir	9.4	0.883	1.327* 0.029 1.366				66*			0.506				
Karnataka	3.1	0.302	0.605*			0.230*			0.541*	+			0.0	01
Kerala	2.9	0.286					0.872*							0.141*
Madhya Pradesh	9.3	0.968			1.062	2*					0	.860*		
Maharashtra	5.8	0.543		0.8	28*				0.40	54*				-0.034
Odisha	10.0	1.046	1.405*			0.	623*					1.42	22*	
Punjab	5.7	0.540	0.950*	κ.		0.	424*			0.7	16*			-0.218
Rajasthan	6.0	0.592	0.627* 0.844* 0.33						32*					
Tamil Nadu	6.5	0.686	0.686*											
Uttar Pradesh	6.2	0.650				0.83	8*						0.1	35
West Bengal	5.2	0.487	1.091*	1.091* 0.732* 0.449* 0.189*										

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

Source: Author's calculations

Remarks: The shaded cell indicates the joinpoint. \* Indicates APC or AAPC are statistically significantly different from zero.

Age	Combine	d		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

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

Source: Author's calculations.

Table 6: Contribu	ition of different	age groups to t	the increase in	$e_0$ in states between	2000(1998-2000	) and 2015 (	2013-2017)
						/ /-	,

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	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
$e_0$	$e_0$																

Source: Author's calculations.

Age			Гime-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

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.

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		-			
	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  $e_0$  as 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  $e_0$ .

#### References

- Akinyede O, Soyemi K (2016) Joinpoint regression analysis of pertussis crude incidence rates, Illinois, 1990-2014. *American Journal of Infection* Control, 44(12):1732–3.
- Chaurasia AR (2010) Mortality transition in India: 1970-2005. *Asian Population Studies*, 6(01):47-68
- Chaurasia AR (2020a) Long-term Trend in Infant Mortality in India: A Joinpoint Regression Analysis for 1981-2018. *Indian Journal of Human Development*, 14(3): 394-406.
- Chaurasia AR (2020b) Fertility Transition in Currently Married Reproductive Age Women in India: 1985-2017. https://doi.org/10.1101/2020.07.16.20155176
- Chatenoud L, Garavello W, Pagan E, Bertuccio P, Gallus S, La Vecchia C, Negri E, Bosetti C (2015) Laryngeal cancer mortality trends in European countries. *International Journal of Cancer*, 842: 833–42.
- Chen H, Qian Y, Dong Y, Yang Z, Guo L, Liu J, Shen Q, Wang L (2020) Patterns and changes in life expectancy in China, 1990-2016. *PLoS ONE* 15(4): e0231007. <u>https://doi.org/10.1371/journal.pone.0231007</u>.
- Chen H, Hao L, Yang C, Yan B, Sun Q, Sun L, Chen H, Chen (2018) Understanding the rapid increase in life expectancy in shanghai, China: a population-based retrospective analysis. *BMC Public Health* 18:256. DOI 10.1186/s12889-018-5112-7
- Clegg LX, Hankey BF, Tiwari R, Feuer EJ, Edwards BK (2009) Estimating average annual percent change in trend analysis. *Statistics in Medicine*, 20 (29): 3670-82.
- Doucet M, Rochette, Hamel D (2016) Prevalence and mortality trends in chronic obstructive pulmonary disease over 2001 to 2011: a public health point of view of the burden. *Canadian Respiratory* Journal, 2016:1–10.
- Gillis D, Edwards BPM (2019) The utility of joinpoint regression for estimating population parameters given changes in population structure. *Heliyon* 5: e02515.

- Government of India (1971) *Sample Registration of Births and Deaths in India* 1969-70. New Delhi, Registrar General.
- Government of India (1983) Report on intensive enquiry conducted in a subsample of SRS units (1980-81). Occasional Paper No. 2. New Delhi, Registrar General.
- Government of India (1988) Report on intensive enquiry conducted in a sub-sample of SRS units. Occasional Paper 1 of 1988. New Delhi, Registrar General.
- Government of India (2000) *National Population Policy*. New Delhi, Ministry of Health and Family Welfare.
- Government of India (2002) *National Health Policy 2002*. New Delhi, Ministry of Health and Family Welfare.
- Government of India (2005) *National Rural Health Mission. Framework of Implementation*. New Delhi, Ministry of Health and Family Welfare.
- Government of India (2013) *National Health Mission. Framework of Implementation.* New Delhi, Ministry of Health and Family Welfare.
- Government of India (2017) *National Health Policy 2017*. New Delhi, Ministry of Health and Family Welfare.
- Government of India (2018) *Economic Survey 2017-18*. New Delhi, Ministry of Finance. Department of Economic Affairs.
- Government of India (2019) *SRS Based Abridged Life Tables 2013-2017*. New Delhi, Registrar General and Census Commissioner of India.
- John U, Hanke M (2015) Liver cirrhosis mortality, alcohol consumption and tobacco consumption over a 62-year period in a high alcohol consumption country: a trend analysis. *BMC Research Notes*, 8(1):822.
- Kim H-J, Fay MP, Feuer EJ, Midthune DN (2000) Permutation tests for joinpoint regression with applications to cancer rates. *Statistics in Medicine*, 19: 335-351.
- Kim H-J, Yu B, Feuer EJ (2009) Selecting the number of change-points in segmented line regression. *Statistica Sinica*, 19(2): 597-609.
- Kim J, Kim H-J (2016) Consistent model selection in segmented line regression. *Journal* of Statistical Planning and Inference, 170: 106-116.
- Lerman PM (1980) Fitting segmented regression models by grid search. *Journal of Royal Statistical Society. Series C (Applied Statistics)*, 29(1): 77–84.
- Mahapatra P (2010) An overview of Sample Registration System in India. http://unstats.un.org/unsd/vitalstatkb/KnowledgebaseArticle50447.asp
- Mahapatra P (2017). The Sample Registration System in India. An overview as of 2017. Hyderabad, Institute of Health Systems.

- Mari Bhat PN (1987) Mortality in India: levels, trends, and patterns. Pennsylvania, University of Pennsylvania.
- Mari Bhat PN (2002) Completeness of India's Sample Registration System. An assessment using the general growth balance method. *Population Studies*, 56(2): 119-134.
- Missikpode C, Peek-Asa C, Young T, Swanton A, Leinenkugel K, Torner J (2015) Trends in non-fatal agricultural injuries requiring trauma care. *Injury Epidemiology* 2(1): 30.
- Mogos MF, Salemi JL, Spooner KK, McFarlin BL, Salihu HM (2016) Differences in mortality between pregnant and nonpregnant women after cardiopulmonary resuscitation. *Obstetrics and Gynecology* 128(4): 880–8.
- National Institute of Health (2020) Joinpoint Regression Program, Version 4.8.0.1. Bethesda, National Institute of Health, National Cancer Institute. Surveillance Research Program. Division of Cancer Control and Population Sciences.
- Pollard JH (1982) The expectation of life and its relationship to mortality. *Journal of Institute of Actuaries* 109: 225-240.
- Puzo Q, Qin P, Mehlum L (2016) Long-term trends of suicide by choice of method in Norway: a joinpoint regression analysis of data from 1969 to 2012. *BMC Public Health* 16:255.
- Qiu D, Katanoda K, Marugame T, Sobue T (2009) A Joinpoint regression analysis of long-term trends in cancer mortality in Japan (1958–2004) International *Journal of Cancer* 124: 443-448.
- Rea F, Pagan E, Compagnoni MM, Cantarutti A, Pigni P, Bagnardi V, Cprrap G (2017) Joinpoint regression analysis with time-on-study as timescale. Application to three Italian population-based cohort studies. *Epidemiology, Biostatistics and Public Health* 14(3): e12616.
- Tyczynski JE, Berkel HJ (2005) Mortality from lung cancer and tobacco smoking in Ohio (U.S.): will increasing smoking prevalence reverse current decreases in mortality? *Cancer Epidemiology Biomarkers Preview. United States* 14(5):1182-7.
- United Nations (2004) *World Population Prospects. The 2004 Revision. Volume III. Analytical Report.* New York, Department of Economic and Social Affairs.
- United Nations Population Fund (2004) *Program of Action Adopted at the International Conference on Population and Development, Cairo 5-13 September 1994.* New York, United Nations Population Fund.
- Zhang NR, Siegmund DO (2007) A modified Bayes Information Criterion with applications to the analysis of comparative genomic hybridization data. *Biometrics* 63: 22–32.