Spatial and temporal changes in fertility behavior of cohorts in recent times and future prospects: India

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Abstract

In the present work we have attempted to study fertility experience of cohorts in different regions in India, who are crossing childbearing age in different calendar years in the recent years i.e., 1993-2012 to understand the spatial and temporal changes in their fertility behavior. We have also forecasted fertility behavior of females who are going to cross childbearing age in various calendar years during 2013-2025. For the present study we have used selected portions of data from all the three National Family Health Surveys that were conducted in India. Some of the interesting findings of the present study are (1) fall in cohort total fertility rate(CTFR) during 1993-2012 is expected to be maximum in the Southern India (a fall from 4.69 births per female to 2.97 births per female), (2) the shortest age interval in which most of the births (90% of the total births) occur, defined as effective fertility period, is shrinking (though unevenly) in all the regions of India and (3) estimated CTFR for females who are going to cross childbearing age in 2024 in the South India, the West India, the North-East India, the North India, the East India and the Central India are 2.3, 2.8, 3.2, 3.3, 3.6 and 4.7 respectively.

Key words: fertility model, cohort, effective fertility period, CTFR.

1. INTRODUCTION

One of the most important issues to the world at present is its rapid population growth. Within the last 108 years, world population has increased by more than four times (i.e., from 1.6 billion to 6.7 billion). The importance of studying India's fertility is evident from the fact that a small change in it will have a definite bearing on its population size and in its share in the world's population, given that it consists of 16.87% (1.021 billion) of the world's population (Registrar General of India, 2001). With its current population growth rate (1.6% per year), India, the second populous country in the world after China (whose growth rate is 0.6% per year) at present, will cross China by 2030 (United Nations, 2007). The severity of population growth in India can be understood as its population had reached 1144 millions in 2007 from 352 millions in 1950, which is more than three times the population in 1950. India is one of those 38% of world countries which have reported that their current populations are too high (United Nations, 2008). Many policies have been taken in India starting from 1951 till today to control fertility and thereby the total population size. After initiation of the family planning program in the year 1951, the program has undergone several changes in both policy approach and implementation. Until 1962, the program had been ineffective and it was taken up seriously from the Third Five Year Plan (1961-1966). As a result, Total Fertility Rate (TFR) has fallen considerably from 5.2 in 1971 to 2.8 in 2006(Registrar General of India, 1999, 2007). It is expected that India will reach replacement level fertility by 2016 though the actual target set to attain it is 2010 (Registrar General of India, 2000).

India which is the biggest democratic country in the world has vast heterogeneity in various aspects like culture, religion, economic condition, ethnicity, demographic features, geographic and linguistic characteristics, etc. At present it consists of 29 states and seven small union territories. Geographically, India may be subdivided broadly into the six regions given in Table-1 as per the third National Family Health Survey, popularly known as NFHS-3(International Institute of Population Science and Macro International, 2007).

Table-1: *Different regions of India*

Region	Constituent States
North India	Jammu & Kashmir, Himachal Pradesh, Haryana, Punjab, Delhi, Uttaranchal[1] and Rajasthan
South India	Andhra Pradesh, Kerala, Tamil Nadu and Karnataka
East India	consists of states Bihar, Jharkhand, Orissa and West Bengal
West India	consists of Goa, Maharashtra and Gujarat
Central India	Madhya Pradesh, Chhattisgarh and Uttar Pradesh
North-east India	Sikkim, Meghalaya, Assam, Arunachal Pradesh, Mizoram, Manipur, Nagaland and Tripura

Out of all these regions the states of southern region and specially Kerala and Tamil Nadu are known for high literacy rate, high child survival and high level of woman empowerment. Whereas the northern and the central regions are orthodox societies with strong cultural barriers and low levels of sex ratio, female literacy, woman empowerment. The states of Punjab and Haryana in the North India are well-known for their economic development and strong son preference. The hilly north-eastern states are inhabitated by many tribal groups who are generally backward. The states of Bihar, Madhya Pradesh, Rajasthan and Uttar Pradesh are often referred as "BIMARU" states (BIMARU a Hindi word

[1] Uttaranchal which was carved from Uttar Pradesh in 2000, has been in Central India before 2005 and it is now included in North India as per NFHS-3.

meaning ill health) in demographic context as their demographic indicators like infant mortality rate (IMR), maternal mortality rate (MMR) and fertility rate are all quite high. These BIMARU states which consist of around 40% of India's population (around 50% of population growth during 1991-2001 in India is caused by these states), are the causes major worry for the Indian government in its effort to slowdown the population growth rate. At present all the south Indian states have reached below the replacement level fertility and some of the states in the West India, the North India and the East India are close to the replacement level fertility. Unfortunately, TFR in BIMARU states is still high. In fact, the fate of population stabilization in India is largely in the hands of these BIMARU states as these states consist of 40% of India's population.

At present majority of the population (67.58% of the total population) is concentrated in the three regions South India (20.92%), Central India (24.72%) and East India (21.92%). North-East India consists of just 3.79% of the total population. West India and North India consists of 13.53% and 10.58% of the total population respectively. Changes in population dynamics of Indian regions in the last six decades are quite interesting, e.g. the South India, which consisted of one fourth of the India's population in 1951 (Registrar General of India, 1951) currently has only one fifth of the total population (Registrar General of India, 2008). Changes in population size in different regions of India during 1951-2008 are given in Table-2.

Table-2: *Population of India and its different regions in 1951 and 2008*

Region	Total Population of the Region		Increase by (times)
	1951	2008	
North India	38,188,776	160,493,000	4.202622
South India	94,185,380	240,207,000	2.550364
East India	79,728,197	251,601,000	3.155734
West India	48,861,280	164,930,000	3.375474
Central India	89,291,309	283,816,000	3.17854
North-East India	10,398,096	43,563,000	4.189517
India	361,088,090	1,147,677,000	3.178385

Source: Registrar General of India, 1951 and Registrar General of India, 2008.

This clearly indicates that vital demographic changes have occurred in India in the last six decades. To know the changes that are occurring in fertility behavior of female (and with some more objectives) Sample Registration System (SRS) was established during 1964-65 on a pilot basis. It became a regular source from 1969-70 onwards and started providing information on fertility indicators for India and its bigger states on annual basis. Recently, it has started publishing fertility indicators for smaller states and union territories also. There are also several studies (Adlakha et al., 1974; Jain et al., 1982; Preston et al., 1984; Rele, 1987; Guilmoto et al., 1998; Guilmoto, 2000; Guilmoto et al., 2001; Pathak et al. 1987; Chaudhry, 1987; Bhat et al., 1984; Registrar General of India, 1976 etc.) based on some independent surveys, census, SRS and National sample Surveys to understand the changes in levels of fertility over time in India. Our knowledge on level of fertility prior to 1960 is very rough because of paucity of accurate information on important demographic variables. However, there are some attempts to estimate the level of fertility prior to the above period (see Davis, 1951; Mukherjee, 1976; Ram F et al., 1995).

All these changes were well documented in period perspective only. The females in the reproductive age group at any particular point of time can be sub dived into groups known as cohorts based on their current ages. Generally a cohort refers to all those individuals who were born in the same calendar year. The existing female population at a given time point is the mix of all the survivors of different cohorts of female born during different calendar years. The cohort approach, though largely based on past fertility experience, however makes our understanding about change in fertility behavior of female much clear. The reason is that the fertility indicators here are based on the

maternity history of single age group female in their entire childbearing age and hence there is no ambiguity in interpretation. Where as in period approach fertility indicators (like TFR, GRR etc.) are based on the fertility performance of females of all ages who are in childbearing age in a given calendar year, so there is some ambiguity in interpretation and hence it is relatively difficult to understand fertility behavior change using this approach than that of cohort approach. Apart from this the period rates (like TFR) are not appropriate for long term analysis as they mix up the experience of several cohorts and different cohorts behave differently as they pass through different social, economic, technological, political and demographic conditions (Ramakumar, 1999). Therefore, cohort wise analysis of demographic data is necessary for better understanding of the process of change over long time. At present, we are having variety of demographic data sources like NFHS, Census, National Sample Survey, etc. using which we can understand the changes in the cohort fertility over time, space and by some other characteristics. The availability of longitudinal data on the births history of each female in the three rounds of National Family Health Survey (NFHS) have motivated us to work on these lines to see how changes in fertility behavior of female are occurring in India over cohorts.

2. OBJECTIVES OF THE PRESENT STUDY

I) To understand the spatial and temporal differentials in fertility behavior of the female cohorts who have crossed/going to cross childbearing age in India and its different regions in different calendar years during the recent period (1993-2012).

II) To project the fertility behavior of the females who are going to cross childbearing age in the near future (2013-2025).

3. DATA

As a part of global demographic health surveys, National Family Health Survey has been conducted thrice in India. The first National Family Health Survey (NFHS-1) was conducted in India during 1992-93. A sample of 88,562 households and 89,777 ever-married women in the age group 13-49 was collected from 24 states and the then National Capital Territory of Delhi , which is now a separate state. The second National Family Health Survey (NFHS-2) was conducted in 1998-99. The survey covers a national wide representative sample of 90,303 ever-married women in the age group 15-49. The third National Family Health Survey (NFHS-3) was conducted during 2005-06. The survey covers a sample of more than 2,30,000 women in the age group 15-49 and men in the age group 15-54. The main objective of all these surveys was to collect reliable and up-to-date information on fertility, family planning, mortality and reproductive and child health.

4. FORMATION OF COHORTS FROM NFHS DATA SETS

We have made use of selected portions of NFHS-1, NFHS-2, NFHS-3 data sets for formation of cohorts. Data are censored to the 1 January before the beginning of the interview to avoid the 1 year gap in the interview phase. We consider in each survey the information on each female only up to a base-line time point of January 1 of the year of starting each survey. Thus, we consider for each surveyed woman, the age (in completed years) at the base-line time point of the corresponding survey year. Simultaneously, we consider only the events that had taken place to each surveyed female by her completed years of age, i.e. by the corresponding base-line time point only. We find the number of births to each surveyed female by the exact ages 15,16,17 and so on up to her age (in completed years) at the base-line time point of the corresponding NFHS round.

All the respondents who were in NFHS-1 and whose age was 48 years (in completed years) at the base- line time point of the survey were born in the calendar year exactly 48 years back from 1992 , i.e., these females belonged to the 1943 birth cohort. The females of this cohort would cross childbearing age in the calendar year 1993 and hence by 1st January 1994, these women were out of the childbearing age interval of 15 to 49 years. We call this cohort as a cohort crossing childbearing age during 1993 (symbolically, CC-1993). Similarly, the females who were in NFHS-1 and whose age was 43 years (in completed years) at the base-line time point of the survey (i.e. at 1st January 1992

) were born in the calendar year exactly 43 years back from 1992, i.e. these females are in the 1948 birth cohort. This cohort would cross childbearing age in the calendar year 1998 and by 1st January 1999 they would be out of the childbearing age interval of 15 to 49 years. This cohort is called a cohort crossing childbearing age in 1998 (symbolically, CC-1998).

The females of 1949 birth cohort were covered in both NFHS-1(i.e. the respondents of NFHS-1, whose age had been 42 years at the base line time point of NFHS-1) and NFHS-2 (i.e. the respondents of NFHS-2, whose age had been 48 years at the base-line time point of NFHS-2). But the respondents of NFHS-2, whose age is 48 years at the base-line time point of NFHS-2 survey provide more information on their fertility than the respondents of NFHS-1, whose age is 42 years at the base-line time point of NFHS-1. So, the former group of respondents have been considered for our analysis while taking into account the females who have crossed their childbearing age in 1999. They are symbolically denoted as CC-1999. Similarly, we have labeled several birth cohorts as cohorts crossing childbearing age in the following way shown in Table-3.

Table-3: *Formation of cohorts*

For respondents in the survey	For respondents having following age (age at last birth day)at the base-line time point of corresponding NFHS round	The exact age up to which birth performance history was considered for the present study (K_T)	Years of birth performance information that is lacking in order to have Complete birth performance history in childbearing age	Year of birth of corresponding respondents	Year of crossing childbearing age	Label used for the respondents
NFHS-1	48	48	2	1943	1993	CC-1993
NFHS-1	47	47	3	1944	1994	CC-1994
NFHS-1	46	46	4	1945	1995	CC-1995
NFHS-1	45	45	5	1946	1996	CC-1996
NFHS-1	44	44	6	1947	1997	CC-1997
NFHS-1	43	43	7	1948	1998	CC-1998
NFHS-2	48	48	2	1949	1999	CC-1999
NFHS-2	47	47	3	1950	2000	CC-2000
NFHS-2	46	46	4	1951	2001	CC-2001
NFHS-2	45	45	5	1952	2002	CC-2002
NFHS-2	44	44	6	1953	2003	CC-2003
NFHS-2	43	43	7	1954	2004	CC-2004
NFHS-2	42	42	8	1955	2005	CC-2005
NFHS-3	48	48	2	1956	2006	CC-2006
NFHS-3	47	47	3	1957	2007	CC-2007
NFHS-3	46	46	4	1958	2008	CC-2008
NFHS-3	45	45	5	1959	2009	CC-2009
NFHS-3	44	44	6	1960	2010	CC-2010
NFHS-3	43	43	7	1961	2011	CC-2011
NFHS-3	42	42	8	1962	2012	CC-2012
NFHS-3	41	41	9	1963	2013	CC-2013
NFHS-3	40	40	10	1964	2014	CC-2014
NFHS-3	39	39	11	1965	2015	CC-2015
NFHS-3	38	38	12	1966	2016	CC-2016
NFHS-3	37	37	13	1967	2017	CC-2017

NFHS-3	36	36	14	1968	2018	CC-2018
NFHS-3	35	35	15	1969	2019	CC-2019
NFHS-3	34	34	16	1970	2020	CC-2020
NFHS-3	33	33	17	1971	2021	CC-2021
NFHS-3	32	32	18	1972	2022	CC-2022
NFHS-3	31	31	19	1973	2023	CC-2023
NFHS-3	30	30	20	1974	2024	CC-2024
NFHS-3	29	29	21	1975	2025	CC-2025

5. MODEL USED FOR PRESENT WORK

For any cohort modeling cumulative ASFR gives us scope to interpret the parameters in terms of the characteristics of the fertility behavior of that cohort. The following special form of Gompertz curve that helps in understanding the cumulative progression of births by age, by quantifying the process in terms of the characteristics of the fertility behavior has been used in this study.

The model is

$$G(t) = Fa^{\left(\frac{\log(0.95)}{\log(0.05)}\right)^{\frac{t-t_0}{b}}} \quad \text{, with } F > 0\,, 0 < a < 1\,, b > 0$$

Where $G(t)$ is the cumulative fertility up to exact age t , F is saturation level(Cohort Total Fertility Rate), a is proportion of total fertility attained by age t_0 , a sort of origin which is generally taken as 15 years. Here we have defined the effective fertility period for a cohort as the age interval during which fertility level of that cohort reaches from 5% to 95% of saturation level. It has been established that b represents the length of the effective fertility period.

Let η_ξ be the exact age that is required to reach $100\xi\%$ of saturation level as per the above growth process with $\xi \in (0,1)$.

Hence by definition of η_ξ the following results follow

the age of attaining half of the saturation level is $\eta_{0.5} = t_0 + b\left(\frac{\log\left(\frac{\log(0.5)}{\log(a)}\right)}{\log\left(\frac{\log(0.95)}{\log(0.05)}\right)}\right)$

effective fertility period is

$$(\eta_{0.05}, \eta_{0.95}) = \left(t_0 + b\left(\frac{\log\left(\frac{\log(0.05)}{\log(a)}\right)}{\log\left(\frac{\log(0.95)}{\log(0.05)}\right)}\right)\ ,\ t_0 + b\left(\frac{\log\left(\frac{\log(0.95)}{\log(a)}\right)}{\log\left(\frac{\log(0.95)}{\log(0.05)}\right)}\right)\right)$$

Fit wide since the model is well comparable with other models which are used in this context (see Samba et al., 2008) and the model parameters are directly throwing light on the important characteristics of the fertility behavior we have used this form of Gompertz curve here for

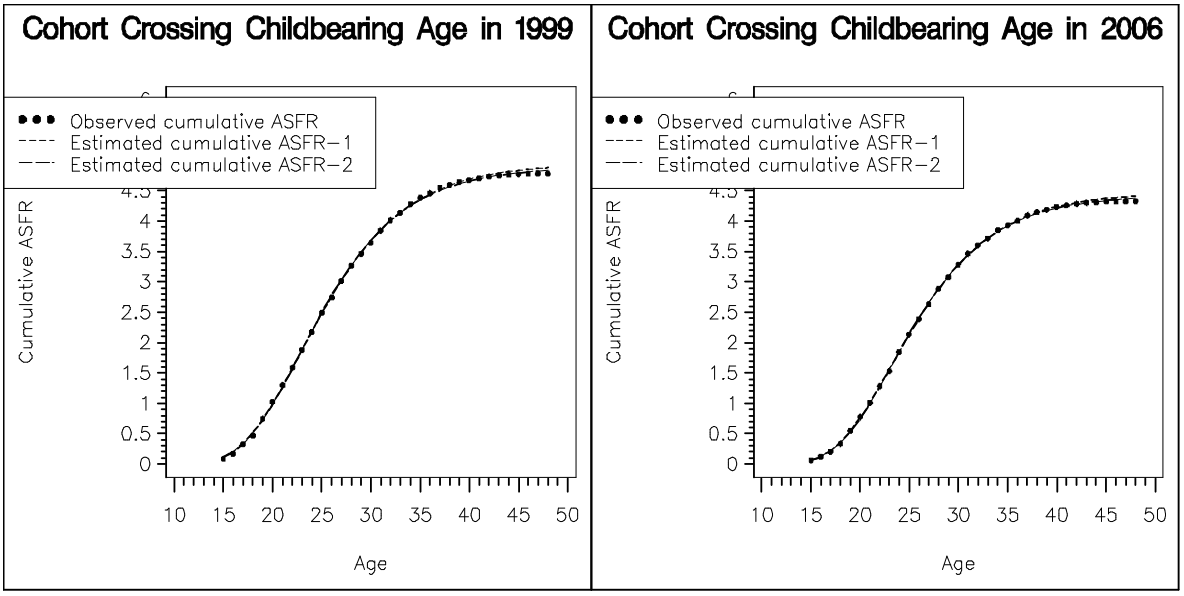
i) parametrising fertility experience
and ii) understanding the differential aspects in fertility behavior

of the females who are crossing/going to cross childbearing age in different regions in India during 1993-2025.

6. METHOD OF ACHIEVING OBJECTIVES

The pattern in which the average number of births progress by age for any cohort (meaning the progression of the cumulative ASFR) looks like a stretched 'S' curve and the Gompertz curve is a very good fit to it (see Figure-1 in Appendix). The important empirical observation that is the pivotal for the present study is that for a female cohort for whom maternity history is known up to the exact age of 48 years, if we estimate the characteristics of fertility behavior of that cohort separately by using the information (i) up to the exact age of 48 years (ii) up to the exact age of 42 years by fitting Gompertz curve to cumulative ASFR then the corresponding estimates of characteristics of fertility behavior are almost same. This fact can be observed from Figure-2.

Figure-2: *Observed and estimated cumulative ASFR for the female cohorts who are going to cross childbearing age in 1999, 2006 in India*



Estimated cumulative ASFR-1: Estimated cumulative age specific fertility rate based on the information up to the exact age of 42 years

Estimated cumulative ASFR-2: Estimated cumulative age specific fertility rate based on the information up to the exact age of 48 years

Here we had compared fits because if the fits are close enough then the corresponding estimates of characteristics of fertility behavior were also expected to be close. If we use the maternity history up to the exact ages of 43, 44, 45, 46, 47 years separately and derive characteristics of fertility behavior of the same cohort in a similar manner by fitting Gompertz curve, then the estimates of resulting characteristics of fertility behavior were also close to those of characteristics of fertility behavior derived based on the maternity history up to the exact ages of 42, 48 years. This is because for all cohorts most of the births are occurring by exact age of 42 years and cumulative ASFR curve which looks like a Gompertz curve (as cumulative ASFR is very closely following Gompertz law) is getting saturated at about age 42 years. So the lesson we have to take from this empirical observation is that for any female cohort for whom maternity history is known at least up to the exact age of 42 years, then we can estimate the characteristics of fertility behavior of that cohort with reasonable accuracy without bothering about the maternity history after age 42 years. For example, in order to estimate the characteristics of fertility behavior of the female cohort who are going to cross childbearing age in India in the calendar year 2011 (females whose age is 43 years at 1st January 2005 and who are in NFHS-3) we have used above result.

In order to satisfy the first objective we have fitted separate models of the form

$$y_t^T(A) = Fa^{\left(\frac{\log(0.95)}{\log(0.05)}\right)^{\frac{t-t_0}{b}}}$$

for each female cohort crossing the childbearing age in India and its different regions and derived some of the important characteristics of fertility behavior from the fitted models. Here, $y_t^T(A)$ is average number of children born to the female cohort who are crossing childbearing age in the calendar year T in region A, by the time when each individual member of the cohort reaches an exact age of t years of their lives. The parameters of the model, namely, F, a and b are so estimated that

$$\sum_{t=1}^{K_T}\left(y_t^T(A) - Fa^{\left(\frac{\log(0.95)}{\log(0.05)}\right)^{\frac{t-t_0}{b}}}\right)^2 \quad \text{is minimum.}$$

Here K_T is the exact age up to which the maternity history of the female cohort crossing childbearing age in the calendar year T is considered, T=1993,1994,……2012.

In order to estimate characteristics of fertility behavior of the female cohorts who are going to cross childbearing age during 2013 (these are the females whose age is 41 years at 1st January 2005) to 2025 (these are the females whose age is 29 years at 1st January 2005) in India and its different regions we had followed the following two step procedure. And, that satisfies the second objective.

Step I : Project age wise the unknown cohort age specific fertility rates of different cohorts up to the age of 41 years.

For example, for all the females who are in NFHS-3 and whose age is 30 years on 1st January 2005(these are the females who are going to cross childbearing age in the calendar year 2024), it is obvious that we do not know their ASFRs at the ages 30,31,32,…42. So in order to estimate ASFR at age 30 years for the above cohort, we can made use of information on ASFR at age 30 years of all the older cohorts that have crossed/going to cross childbearing age during 1993-2023. For all these cohorts we know their cohort ASFR at age 30. By observing the pattern in which ASFR at age 30 is changing over cohorts and by using the appropriate projection methodology(we have used linear projection) we can project ASFR at age 30 for the cohort that is going to cross childbearing age in the calendar year 2024. Similarly for the same cohort (CC-2024) in order to estimate ASFR at age 31 years, we can made use of ASFR at age 31 years of all the older cohorts that are crossing childbearing age during 1993-2022. See Figure-3 in the Appendix to get much better idea about this step I.

Step II : Using these estimates of unknown cohort ASFRs along with the known cohort ASFRs we can find the characteristics of fertility behavior of the cohort by fitting the above mentioned special form of Gompertz curve to cumulative ASFRs by age.

7. FINDINGS AND ANALYSIS

The changes in age pattern of fertility in India and its different regions can be seen in Figure-4, Figure-5, Figure-6 and Figure-7. While, Figure-4 and Figure-6 show the changes in the ASFR over cohorts, Figure-5 and Figure-7 show the changes in the cumulative ASFR over cohorts, based on which the characteristics of fertility behavior have been derived by fitting a special form of Gompertz curve.

Figure-4: *Age pattern of fertility of female cohorts who are crossing/going to cross childbearing age in India during 1993-2025*

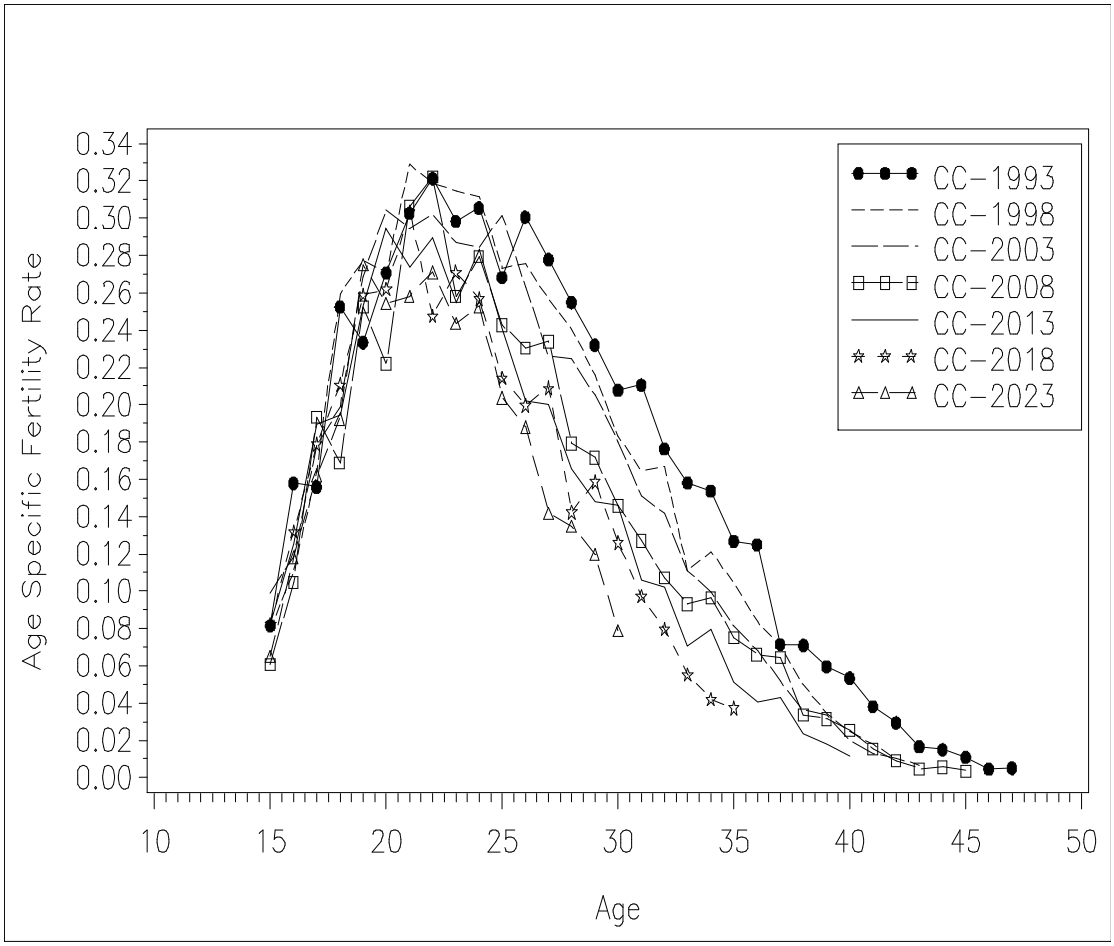


Figure-5: *Cumulative age pattern of fertility of female cohorts who are crossing/going to cross childbearing age in India during 1993-2025*

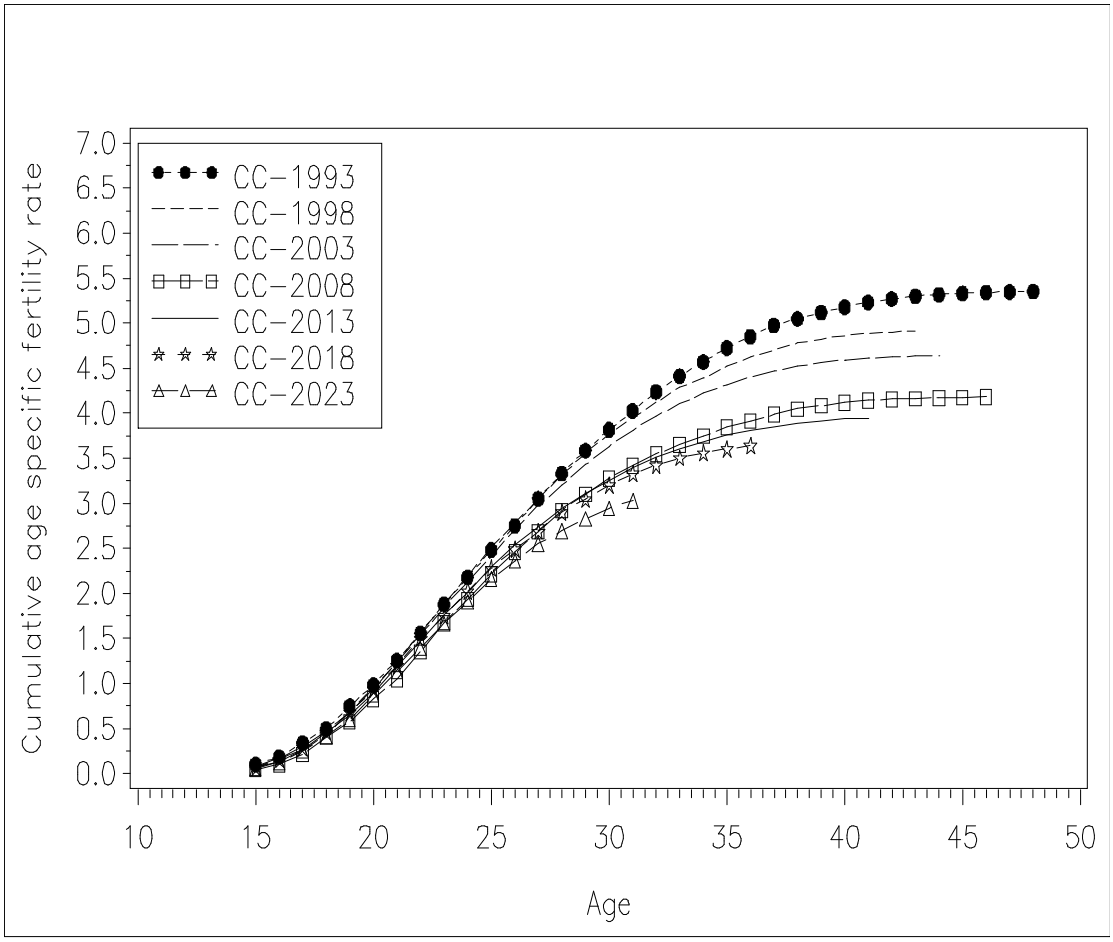


Figure-6: *Age pattern of fertility of female cohorts who are crossing/going to cross childbearing age in different regions in India during 1993-2025*

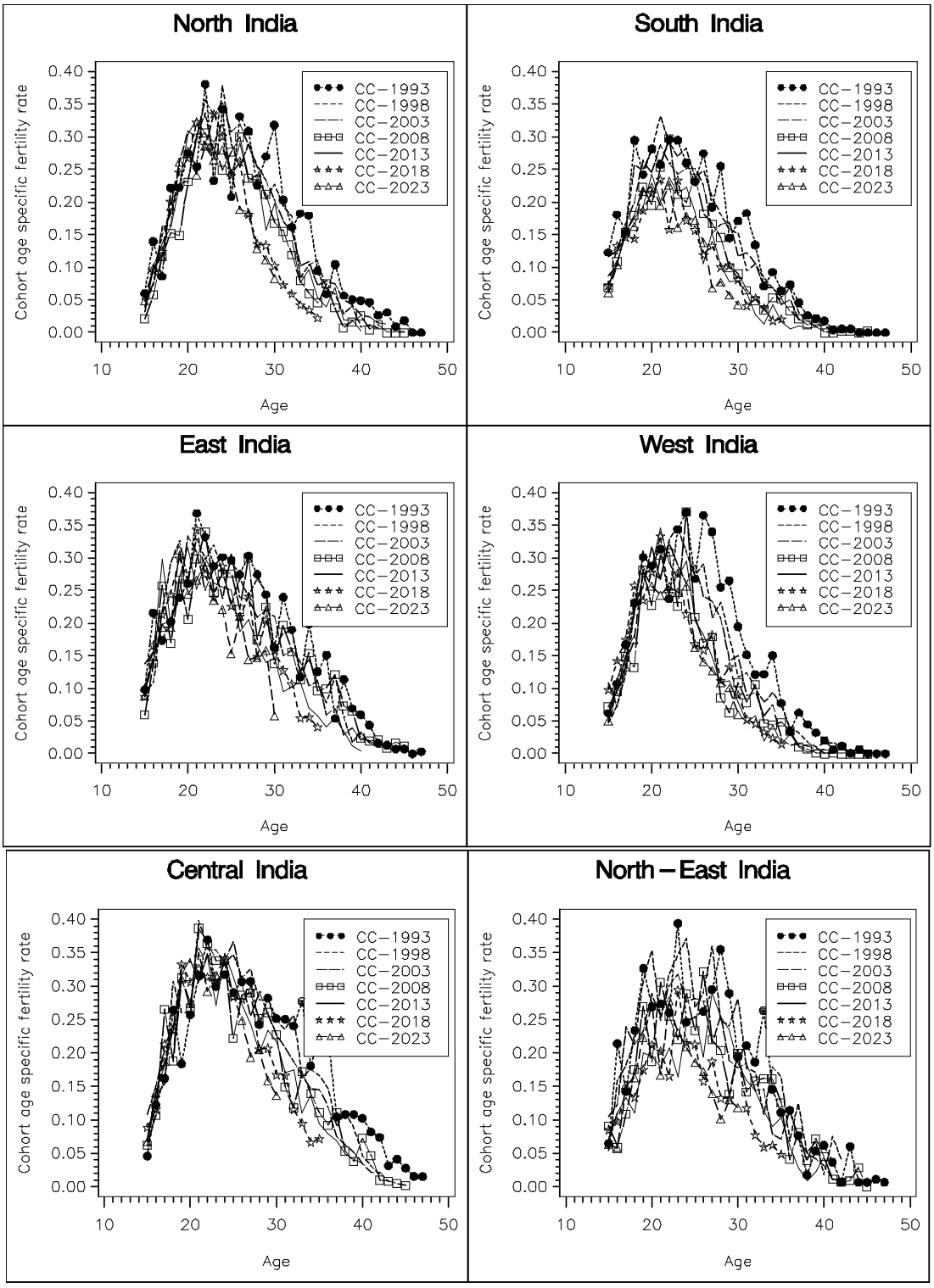


Figure-7: *Cumulative age pattern of fertility of female cohorts who are crossing/going to cross childbearing age in different regions in India during 1993-2025*

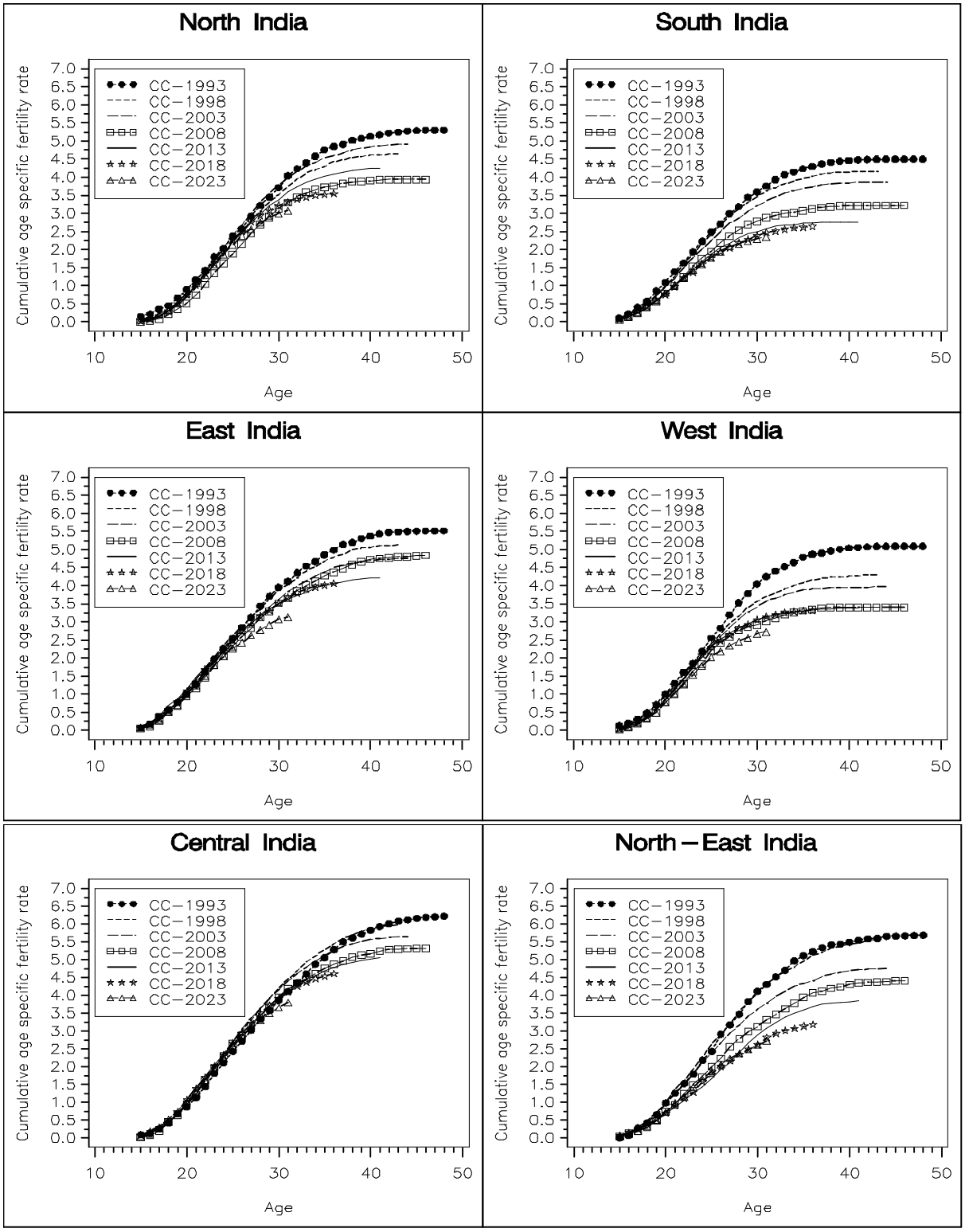


Table-4 summarizes the characteristics of fertility behavior of Indian female cohorts.

Table-4: *Estimates and projected estimates of some important characteristics of fertility behavior of Indian female cohorts crossing/ going to cross childbearing age during 1993-2012 in India*

For cohort crossing childbearing age in the calendar year	India			
	Estimate of CTFR (F)	Estimate of age of giving birth to half of total children ($\eta_{0.5}$) (in years)	Length of effective fertility period(b) (in years)	Effective fertility period ($\eta_{0.05}, \eta_{0.95}$) (in years)
1993	5.55	25.93	26.01	(16.57,42.58)
1994	5.35	25.71	24.54	(16.88,41.42)
1995	5.43	25.82	25.98	(16.47,42.45)
1996	5.33	25.50	25.08	(16.47,41.55)
1997	5.06	25.22	24.19	(16.51,40.70)
1998	5.12	25.19	23.57	(16.71,40.28)
1999	4.90	24.84	23.45	(16.40,39.85)
2000	4.79	24.90	22.67	(16.74,39.41)
2001	4.88	24.63	22.79	(16.43,39.21)
2002	4.79	24.73	22.70	(16.57,39.26)
2003	4.81	24.85	22.90	(16.60,39.51)
2004	4.62	24.43	22.28	(16.41,38.69)
2005	4.65	24.20	21.80	(16.36,38.16)
2006	4.43	25.27	22.75	(17.08,39.84)
2007	4.32	25.17	21.88	(17.30,39.18)
2008	4.27	24.73	22.04	(16.80,38.85)
2009	4.19	24.65	21.59	(16.88,38.47)
2010	4.22	24.66	22.35	(16.62,38.97)
2011	4.14	24.44	21.56	(16.68,38.25)
2012	4.15	24.49	21.73	(16.67,38.40)
2013	**4.06**	**24.01**	**21.03**	**(16.44,37.47)**
2014	**3.93**	**23.91**	**20.79**	**(16.42,37.22)**
2015	**3.91**	**23.67**	**20.66**	**(16.24,36.9)**
2016	**3.96**	**23.67**	**20.7**	**(16.22,36.92)**
2017	**3.9**	**23.71**	**20.36**	**(16.38,36.74)**
2018	**3.84**	**23.54**	**20.01**	**(16.34,36.35)**
2019	**3.7**	**23.54**	**19.89**	**(16.38,36.28)**
2020	**3.57**	**23.18**	**18.96**	**(16.36,35.32)**
2021	**3.51**	**23.2**	**19.07**	**(16.33,35.41)**
2022	**3.42**	**23.09**	**18.33**	**(16.49,34.82)**
2023	**3.38**	**23.03**	**18.14**	**(16.5,34.64)**
2024	**3.43**	**22.79**	**18.09**	**(16.28,34.38)**
2025	**3.29**	**22.57**	**17.74**	**(16.19,33.92)**

N.B. : Bold figures are projected estimates, obtained by using the two step procedure

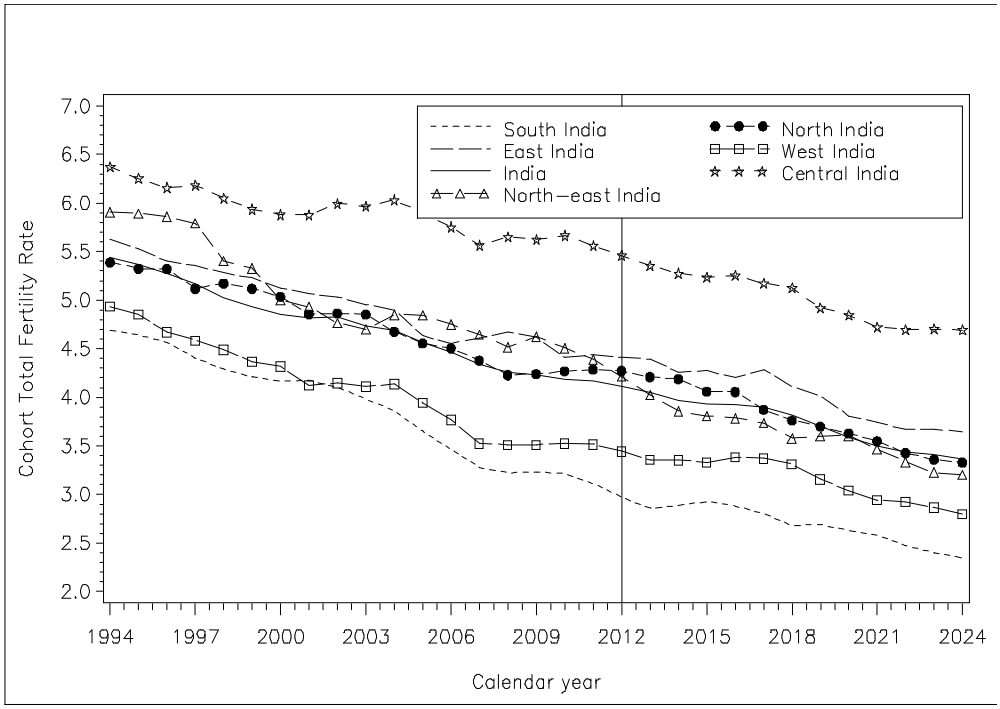
Other characteristics of fertility behavior pertaining to each cohort like the proportion of risky births (which we have defined it as proportion of births by age 20 since infant mortality rate is more among the children born to mothers of age less than 20 years of age) etc. can be easily derived from the information that we have provided. Though we have not provided estimate of parameter 'a' (proportion of births by age 15) but it can be easily calculated based on information from the estimates of parameters F, b and using characteristic like $\eta_{0.5}$(age of giving birth to half of the total children) using the relation

$$\eta_{0.5} = 15 + b\left(\frac{\log\left(\frac{\log(0.5)}{\log(a)}\right)}{\log\left(\frac{\log(0.95)}{\log(0.05)}\right)}\right)$$

The characteristics of the fertility behavior of the cohorts of the North India, the South India, the East India, the West India, the Central India, the North-east India have been shown in Table-5, Table-6 and Table-7 in the Appendix.

For a better understanding about how the fertility behavior of female is changing over time in different regions of India Figure-8, Figure-9 and Figure-10 have been prepared based on Table-4, Table-5, Table-6 and Table-7. Prior to that the fluctuations in the estimates of the characteristics of fertility behavior have been smoothed by using three year moving averages and this data was used for subsequent analysis.

Figure-8: *CTFR of female cohorts crossing childbearing age during 1994-2012 and forecasted CTFR during 2012-2024 (shown after vertical divider line) in India and its different region*



From the above graph it is very clear that there exist wide differentials in completed fertility level in different regions of India. In comparison to all India level, completed fertility level is lower in south-India and west India, very high in central India and little or moderately slightly to moderately higher in all the remaining three regions throughout the period 1994-2012. Though the fertility has

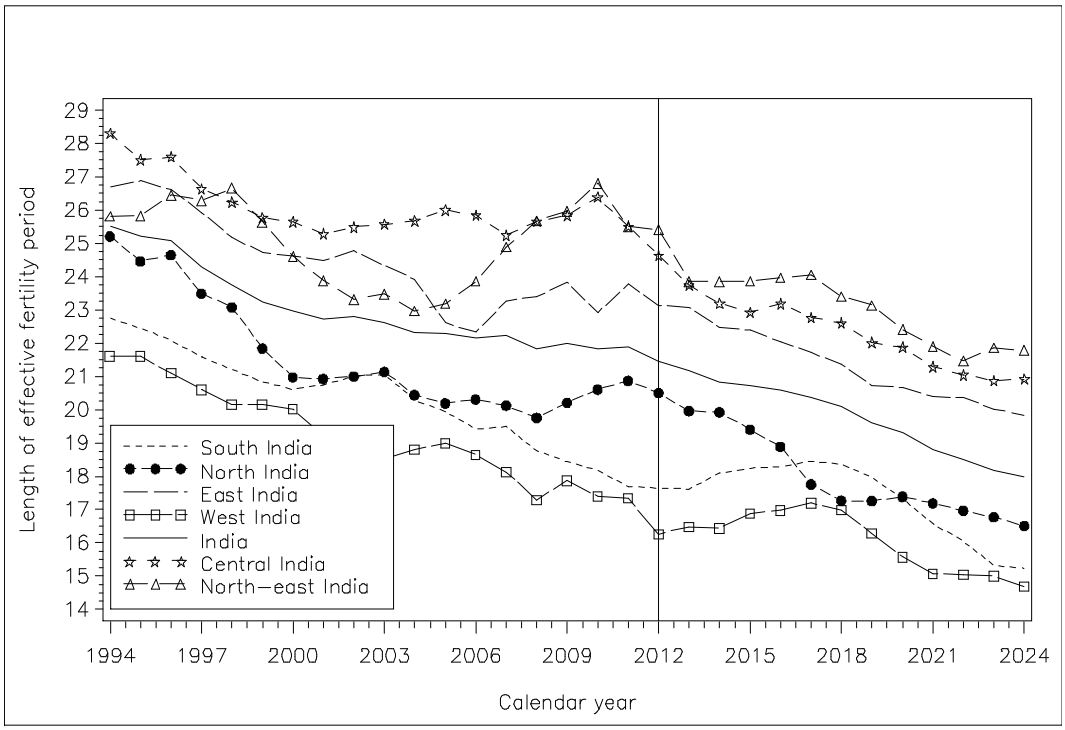
fallen in all the regions of India during 1994-2012 but it is uneven. Fall in CTFR during 1993 to 2012 is expected to be the maximum in the South India (a fall from 4.687 births per female to 2.973 births per female) and the minimum in the Central India (from 6.373 births per female to 5.46 births per female). The estimated percentage fall in CTFR in the South India, West India, North-East India, East India, North India and the Central India in the above period have been 33.57, 28.76, 25.68 , 21.14, 20.47 and 12.71 respectively while it has been 23.39 at all the India level during 1994-2012. Forecasted CTFR for the females who are going to cross childbearing age in 2024 in the South India, the West India, the North-East India, the North India, the East India and the Central India are 2.346, 2.8, 3.203, 3.33, 3.64 and 4.693 respectively. Table-8 shows the estimated changes in CTFR that have occurred during 1994-2012 and the changes that are expected during 2012 to 2024.

Table-8: *Comparison of rate of fall in CTFR Per annum during 1994-2012 and forecasted rate of fall in CTFR per annum during 2012-2024 in India and its different regions*

Region	CTFR			Expected CTFR		
	1994	2012	Change per annum	2012	2024	Change per annum
India	5.44	4.11	1.28%	4.11	3.37	1.40%
North India	5.39	4.27	1.09%	4.27	3.33	1.70%
South India	4.69	2.97	1.92%	2.97	2.35	1.62%
East India	5.63	4.41	1.14%	4.41	3.64	1.33%
West India	4.94	3.44	1.59%	3.44	2.8	1.44%
Central India	6.37	5.46	0.75%	5.46	4.69	1.08%
North-East India	5.91	4.21	1.5%	4.21	3.20	1.84%

What is interesting to observe is that in both South India and West India, where fall in CTFR per annum is higher during 1994-2012, the corresponding rate of falls in CTFR during 2012-2024 is expected to slow down. On the contrary it is expected that fall in CTFR in the rest of the regions will accelerate during 2012-2024.

Figure-9: *Length of effective fertility period for female cohorts crossing childbearing age during 1993-2012 and that forecasted during 2012-2024 (shown after vertical divider line) in India and its different regions*

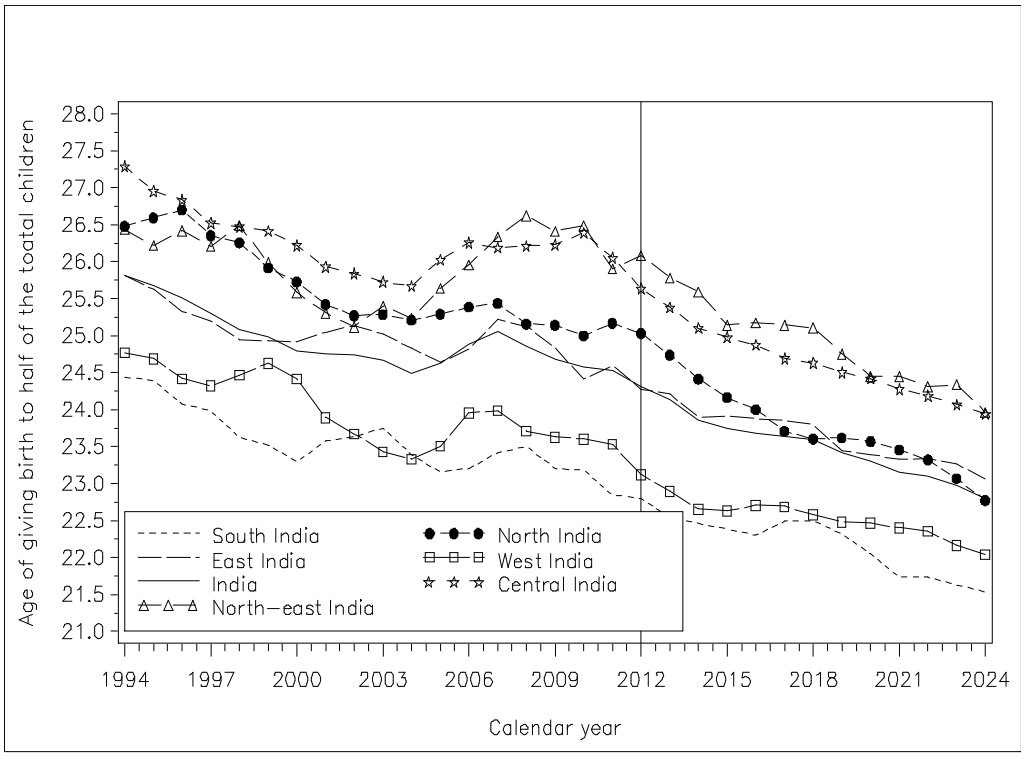


Interestingly the shortest age interval in which most of the births (90% of total births) occur which, we have defined as effective fertility period has been shrinking during the period 1994-2012 in all regions of India except in North East India. It is very interesting to note that in the West India effective fertility period is less when compared with all other regions of India and it is followed by the South India. Effective fertility period is wider in the Central India and in the North-east India. For the females who are crossing childbearing age in the calendar year 1994, the effective fertility period in the North India, the South India, the East India, the West India, the Central India and the North-East India are (17.41,42.62), (16.25,39.0), (16.21,42.91), (16.99,38.6), (17.1,45.41) and (17.15,42.97) respectively. Whereas the same for the females who are crossing childbearing age in 2012 in the above regions the corresponding estimated effective fertility periods are (17.67, 38.53), (16.48,34.17), (16.04,39.81), (17.29,34.63), (16.87,42.38) and (16.73,42.24) respectively. The percentage shrinking in effective fertility period in the West India, the South India, the North India, the East India, the Central India and the North-East India are 24.74, 22.46, 18.65, 13.37, 12.96, 1.51 respectively in the above period while the corresponding fall at all India level is 15.95. Expected Changes in Effective Fertility Period During 2013-2024 were given in Table-9.

Table-9: *Forecast of change in effective fertility period during 2012-2024 in India and its different regions*

Region	Forecasted effective fertility period		
	2012	2024	Percentage Shrinking in effective fertility period during this period
India	(16.59 , 38.04)	(16.32, 34.31)	16.09
North India	(17.65 , 38.16)	(16.83,33.34)	19.47
South India	(16.45,34.09)	(16.05, 31.29)	13.62
East India	(15.95 ,39.09)	(15.92,35.76)	14.27
West India	(17.27,33.53)	(16.76,31.44)	9.69
Central India	(16.77 ,41.41)	(16.42,37.33)	15.11
North-East India	(16.94,42.36)	(16.12,37.91)	14.28

Figure-10: *Estimated* a*ge of giving births to half of the total children for female cohorts crossing childbearing age during 1994-2012 and that forecasted during 2012-2024 (shown after vertical divider line) in India and its different regions*



It interesting to notice that there is a decrease in the age of giving births to half of the total children in all regions in India during 1994-2012 and it is expected that it will decline further during the period 2012-2024 in all the regions. Table-10 summarizes how the age of giving births to half of the total children is changing over time.

Table-10: *Change in age of giving births to half of the total children during 1994-2012 and corresponding forecast during 2012-2024 in India and its different regions*

Region	during 1994-2012			Expected during 2012-2024		
	1994	2012	Change	2012	2024	Change
India	25.82	24.31	1.51	24.31	22.8	1.51
North India	26.48	25.03	1.45	25.03	22.77	2.26
South India	24.44	22.8	1.64	22.8	21.53	1.27
East India	25.82	24.28	1.54	24.28	23.06	1.22
West India	24.77	23.12	1.65	23.12	22.04	1.08
Central India	27.29	25.63	1.66	25.63	23.94	1.69
North-East India	26.44	26.09	0.35	26.09	23.96	2.13

8. CONCLUSIONS

In the past 60 years numerous studies have assed fertility levels, trends and differentials in India. But, all of them are limited to period approach only. The cohort approach, though largely based on past fertility experience, however our understanding about change in fertility behavior of female makes much clear. The availability of longitudinal data on the births history of each female in the three rounds of NFHS have motivated us to work on these lines to see how cohort fertility changes are occurring in India. Hence, in the present work we have modeled fertility experience of Indian female cohorts who are crossing/going to cross childbearing age in different calendar years during 1994-2012 in India and its different regions in order to understand the spatial and temporal changes in fertility behavior and provided estimates of the some of the important characteristics of fertility behavior for each cohort. We have also forecasted fertility behavior of the female cohorts who are going to cross childbearing age in different calendar years during 2012-2025 in India and its different regions by a two step procedure, in the first step we have projected the unknown cohort age specific fertility rates (ASFRs) and in the second step we have used the estimated unknown ASFRs along with the known ASFRs to estimate the characteristics of fertility behavior by fitting Gompertz curve to the cumulative ASFR.

There is a greater heterogeneity in fertility behavior of females by region. Some of the interesting findings of the present study are (1) estimated fall in cohort total fertility rate during 1993-2012 is maximum in the Southern India (a fall from 4.687 births per female to 2.973 births per female) and the minimum in the Central India (a fall from 6.373 births per female to 5.46 births per female), (2) the shortest age interval in which most of the births (90% of the total births) occur which we have defined it as effective fertility period is shrinking (though unevenly) in all regions of India and (3) the age of giving births to half of the total children is also decreasing in all the regions throughout the period 1994-2012 and even in the projected period 2012-2024, (4) After the South India it is the West India where level of fertility is less throughout the period 1994-2012 and even in the projected period 2012-2024, (5) Estimated CTFR for females who are going to cross childbearing age in 2024 in the South India, the West India, the North-East India, the North India, the East India and the Central India are 2.3, 2.8, 3.2, 3.3, 3.6 and 4.7 respectively in comparison to the all India estimate of 3.4.

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Appendix

Figure-1: *Fit of special form of Gompertz curve to cumulative age specific fertility rate for Indian female cohorts crossing childbearing age in the calendar years 1993, 1995, 1997, 1999, 2001, 2003, 2005 and 2007*

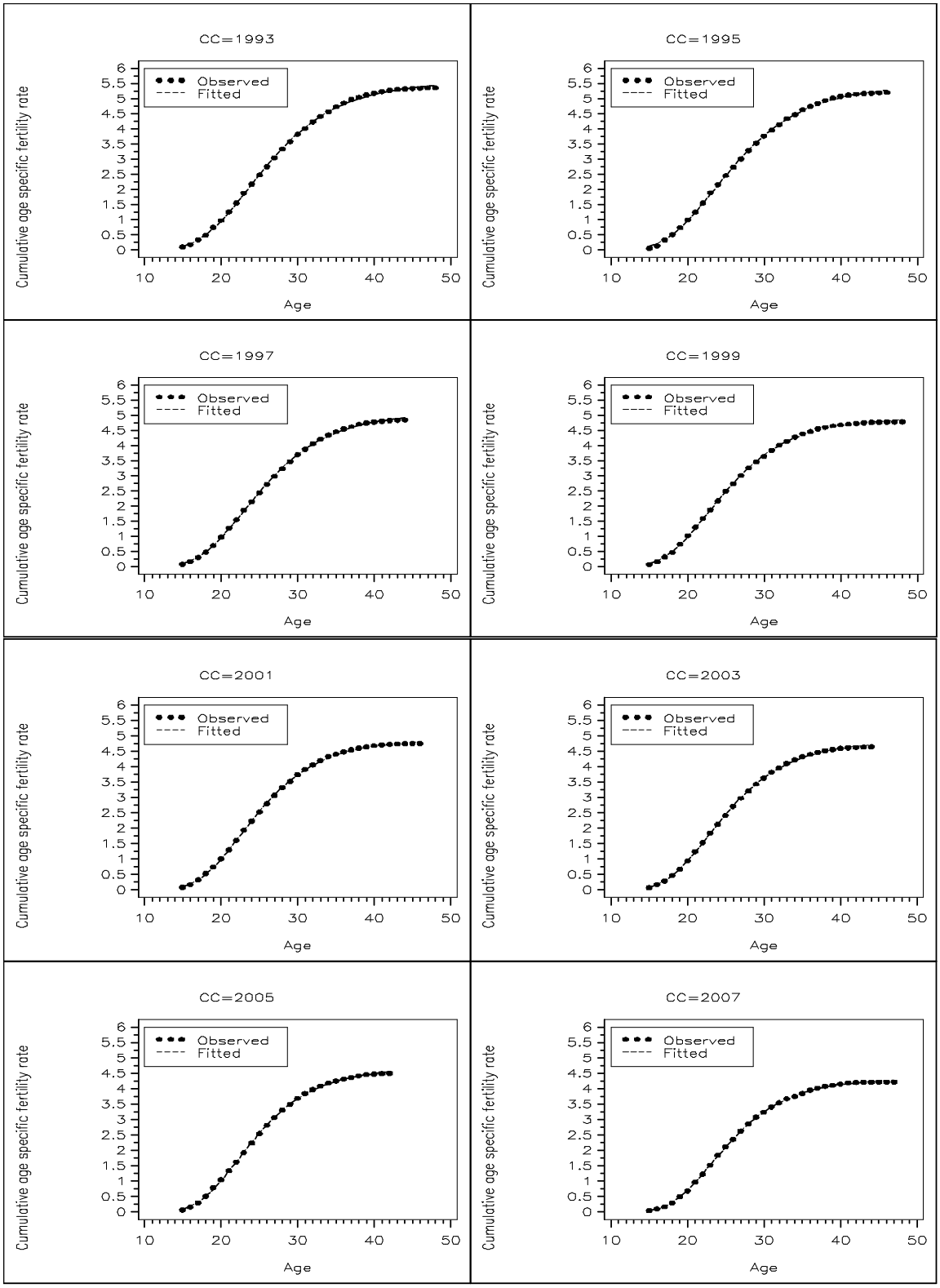
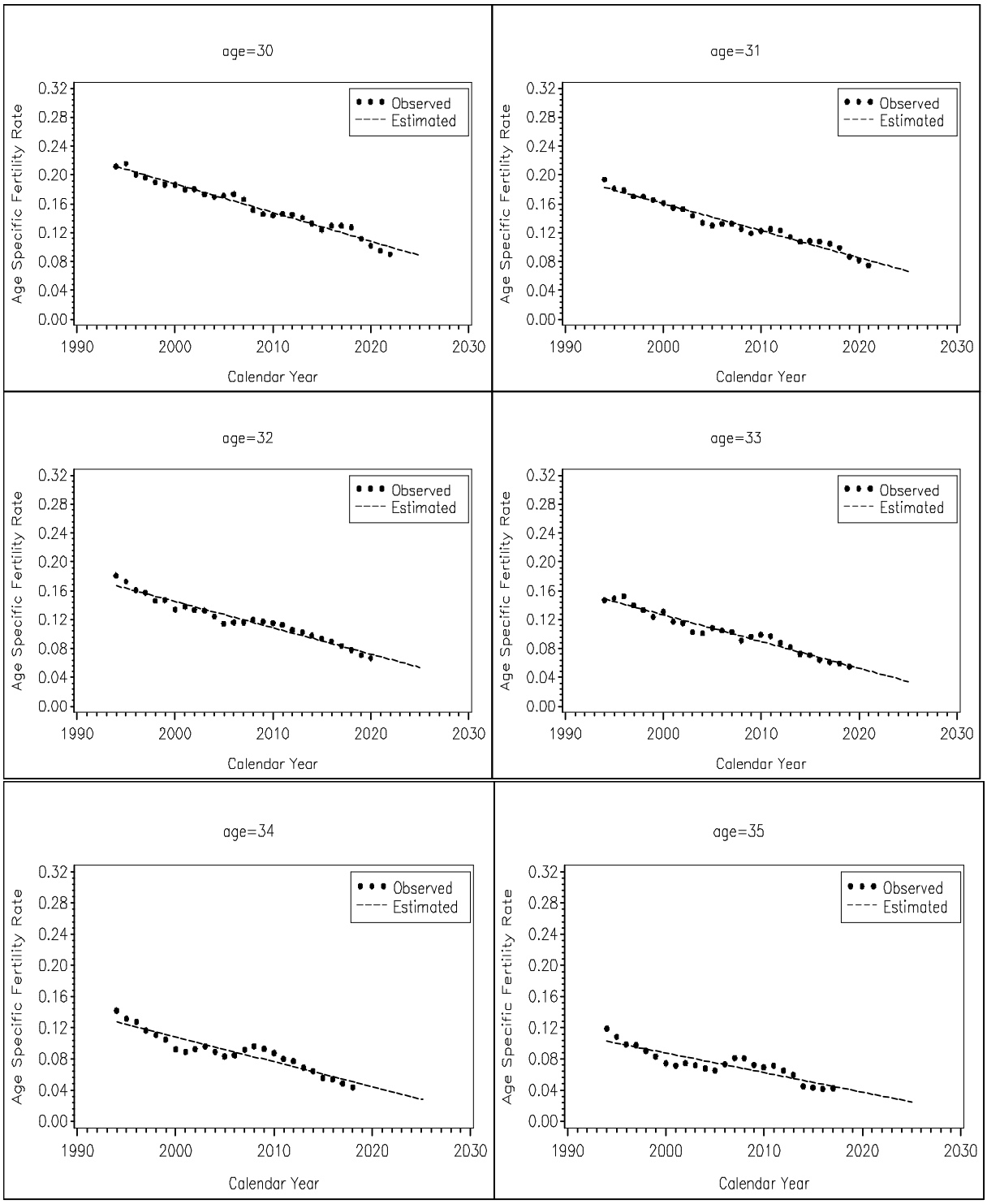


Figure-3: *Projecting unknown cohort age specific fertility rates of Indian female cohorts that are going to cross childbearing age in various calendar years during 2013-2025 at the ages 30, 31, 32, 33, 34 and 35*



Tables

Table-5: *Estimates and projected estimates of some important characteristics of fertility behavior of Indian female cohorts crossing/going to cross childbearing age during 1993-2025 in North India and South India*

For cohort crossing childbearing age in the calendar year	North India				South India			
	Estimate of CTFR (F)	Estimate of age of attaining half of total children ($\eta_{0.5}$) (in years)	Length of effective fertility period(b) (in years)	Effective fertility period ($\eta_{0.05}, \eta_{0.95}$) (in years)	Estimate of CTFR (F)	Estimate of age of attaining half of total children ($\eta_{0.5}$) (in years)	Length of effective fertility period(b) (in years)	Effective fertility period ($\eta_{0.05}, \eta_{0.95}$) (in years)
1993	5.52	26.21	25.73	(16.95,42.68)	4.62	24.23	22.82	(16.02,38.84)
1994	5.19	26.56	24.3	(17.82,42.12)	4.67	24.91	22.87	(16.68,39.55)
1995	5.46	26.67	25.59	(17.46,43.06)	4.77	24.18	22.56	(16.07,38.62)
1996	5.33	26.55	23.49	(18.09,41.58)	4.49	24.08	21.94	(16.18,38.12)
1997	5.18	26.88	24.86	(17.93,42.79)	4.44	23.97	21.77	(16.13,37.9)
1998	4.85	25.63	22.12	(17.67,39.79)	4.28	23.89	21.02	(16.33,37.35)
1999	5.49	26.26	22.26	(18.25,40.51)	4.15	23	20.83	(15.5,36.33)
2000	5.02	25.86	21.15	(18.24,39.4)	4.2	23.67	20.68	(16.23,36.91)
2001	4.6	25.06	19.52	(18.04,37.56)	4.14	23.22	20.32	(15.91,36.23)
2002	4.95	25.35	22.12	(17.39,39.51)	4.19	23.84	21.23	(16.2,37.43)
2003	5.05	25.4	21.36	(17.71,39.07)	3.98	23.83	21.49	(16.1,37.59)
2004	4.56	25.11	19.94	(17.94,37.88)	3.78	23.58	20.48	(16.21,36.7)
2005	4.42	25.12	20.03	(17.91,37.94)	3.83	22.75	18.84	(15.97,34.8)
2006	4.69	25.65	20.62	(18.23,38.85)	3.34	23.14	20.52	(15.76,36.28)
2007	4.41	25.39	20.28	(18.09,38.37)	3.22	23.73	18.87	(16.94,35.82)
2008	4.04	25.27	19.47	(18.26,37.73)	3.27	23.38	19.11	(16.51,35.62)
2009	4.24	24.81	19.53	(17.78,37.31)	3.18	23.39	18.31	(16.8,35.11)
2010	4.44	25.35	21.64	(17.57,39.2)	3.25	22.84	17.88	(16.4,34.29)
2011	4.13	24.84	20.66	(17.41,38.07)	3.22	23.32	18.34	(16.72,35.06)
2012	4.29	25.32	20.31	(18.01,38.32)	2.87	22.38	16.87	(16.31,33.17)
2013	**4.4**	**24.93**	**20.54**	**(17.54,38.08)**	**2.83**	**22.7**	**17.71**	**(16.33,34.03)**
2014	**3.94**	**23.96**	**19.03**	**(17.11,36.14)**	**2.87**	**22.53**	**18.27**	**(15.95,34.23)**
2015	**4.23**	**24.35**	**20.21**	**(17.07,37.28)**	**2.96**	**22.15**	**18.34**	**(15.55,33.89)**
2016	**4.01**	**24.18**	**18.98**	**(17.35,36.33)**	**2.95**	**22.47**	**18.12**	**(15.95,34.07)**
2017	**3.93**	**23.47**	**17.48**	**(17.18,34.66)**	**2.73**	**22.28**	**18.38**	**(15.67,34.05)**
2018	**3.68**	**23.47**	**16.82**	**(17.42,34.24)**	**2.73**	**22.72**	**18.88**	**(15.92,34.8)**
2019	**3.68**	**23.87**	**17.51**	**(17.57,35.08)**	**2.58**	**22.5**	**17.82**	**(16.08,33.91)**
2020	**3.74**	**23.52**	**17.45**	**(17.25,34.69)**	**2.76**	**21.73**	**17.18**	**(15.54,32.72)**
2021	**3.47**	**23.32**	**17.2**	**(17.13,34.33)**	**2.55**	**21.91**	**17.01**	**(15.79,32.81)**
2022	**3.44**	**23.53**	**16.92**	**(17.44,34.36)**	**2.44**	**21.55**	**15.54**	**(15.96,31.5)**
2023	**3.37**	**23.12**	**16.79**	**(17.08,33.87)**	**2.43**	**21.75**	**15.58**	**(16.14,31.72)**
2024	**3.27**	**22.55**	**16.61**	**(16.57,33.18)**	**2.33**	**21.59**	**14.83**	**(16.25,31.08)**
2025	**3.35**	**22.64**	**16.13**	**(16.84,32.97)**	**2.28**	**21.27**	**15.3**	**(15.77,31.07)**

N.B. : Bold figures are projected estimates, obtained by applying the two step procedure

Table-6 : *Estimates and projected estimates of some important characteristics of fertility behavior of Indian female cohorts crossing/going to cross childbearing age during 1993-2025 in East India and West India*

For cohort crossing childbearing age in the calendar year	East India				West India			
	Estimate of CTFR (F)	Estimate of age of attaining half of total children ($\eta_{0.5}$) (in years)	Length of effective fertility period (b) (in years)	Effective fertility period ($\eta_{0.05}, \eta_{0.95}$) (in years)	Estimate of CTFR (F)	Estimate of age of attaining half of total children ($\eta_{0.5}$) (in years)	Length of effective fertility period(b) (in years)	Effective fertility period ($\eta_{0.05}, \eta_{0.95}$) (in years)
1993	5.75	25.98	26.43	(16.47,42.9)	5.23	24.94	21.99	(17.02,39.01)
1994	5.62	25.77	26.19	(16.35,42.53)	4.93	24.77	21.51	(17.03,38.55)
1995	5.52	25.7	27.5	(15.81,43.31)	4.65	24.61	21.33	(16.93,38.26)
1996	5.44	25.4	26.95	(15.7,42.65)	4.99	24.69	21.97	(16.78,38.75)
1997	5.24	24.88	25.38	(15.75,41.13)	4.37	23.96	20	(16.76,36.76)
1998	5.39	25.3	25.45	(16.14,41.59)	4.4	24.32	19.85	(17.18,37.03)
1999	5.22	24.67	24.73	(15.77,40.5)	4.7	25.12	20.61	(17.7,38.31)
2000	5.08	24.83	23.96	(16.2,40.16)	4	24.44	20.03	(17.23,37.26)
2001	5.08	25.24	25.15	(16.19,41.34)	4.25	23.69	19.42	(16.7,36.12)
2002	5.04	25.07	24.35	(16.31,40.65)	4.12	23.54	18.21	(16.99,35.2)
2003	4.98	25.1	24.81	(16.17,40.98)	4.07	23.79	18.81	(17.02,35.84)
2004	4.85	24.88	23.86	(16.29,40.15)	4.15	22.97	18.55	(16.3,34.84)
2005	4.87	24.52	23.07	(16.22,39.29)	4.19	23.24	19.05	(16.39,35.44)
2006	4.18	24.51	20.92	(16.98,37.91)	3.49	24.32	19.37	(17.34,36.72)
2007	4.61	25.42	23.01	(17.13,40.15)	3.63	24.31	17.52	(18,35.52)
2008	5.03	25.72	25.88	(16.41,42.28)	3.45	23.33	17.51	(17.03,34.54)
2009	4.39	24.24	21.31	(16.57,37.88)	3.46	23.49	16.85	(17.43,34.28)
2010	4.44	24.55	24.34	(15.79,40.13)	3.63	24.07	19.25	(17.14,36.39)
2011	4.4	24.46	23.08	(16.15,39.24)	3.48	23.25	16.08	(17.46,33.54)
2012	4.48	24.77	23.88	(16.18,40.06)	3.44	23.27	16.71	(17.26,33.96)
2013	**4.35**	**23.61**	**22.45**	**(15.53,37.98)**	**3.41**	**22.84**	**16**	**(17.08,33.08)**
2014	**4.35**	**24.25**	**22.89**	**(16.01,38.9)**	**3.22**	**22.58**	**16.72**	**(16.56,33.28)**
2015	**4.07**	**23.83**	**22.1**	**(15.87,37.97)**	**3.43**	**22.54**	**16.59**	**(16.57,33.15)**
2016	**4.4**	**23.66**	**22.17**	**(15.68,37.85)**	**3.34**	**22.77**	**17.34**	**(16.53,33.87)**
2017	**4.14**	**24.15**	**21.85**	**(16.28,38.14)**	**3.38**	**22.81**	**17**	**(16.69,33.69)**
2018	**4.32**	**23.74**	**21.14**	**(16.13,37.27)**	**3.4**	**22.49**	**17.26**	**(16.28,33.54)**
2019	**3.88**	**23.5**	**21.12**	**(15.9,37.02)**	**3.16**	**22.43**	**16.7**	**(16.42,33.12)**
2020	**3.84**	**23.08**	**19.91**	**(15.92,35.83)**	**2.9**	**22.51**	**14.92**	**(17.14,32.05)**
2021	**3.7**	**23.6**	**20.99**	**(16.05,37.04)**	**3.07**	**22.46**	**15.1**	**(17.03,32.13)**
2022	**3.69**	**23.29**	**20.25**	**(16,36.25)**	**2.86**	**22.23**	**15.2**	**(16.76,31.96)**
2023	**3.62**	**23.12**	**19.83**	**(15.98,35.81)**	**2.85**	**22.38**	**14.85**	**(17.04,31.89)**
2024	**3.71**	**23.38**	**19.98**	**(16.19,36.17)**	**2.89**	**21.88**	**14.96**	**(16.5,31.45)**
2025	**3.6**	**22.68**	**19.69**	**(15.6,35.29)**	**2.66**	**21.86**	**14.25**	**(16.74,30.98)**

N.B. : Bold figures are projected estimates, obtained by applying the two step procedure

Table-7: *Estimates and projected estimates of some important characteristics of fertility behavior of Indian female cohorts crossing/going to cross childbearing age during 1993-2025 in Central India and North-east India*

For cohort crossing childbearing age in the calendar year	Central India				North-east India			
	Estimate of CTFR (F)	Estimate of age of attaining half of total children ($\eta_{0.5}$) (in years)	Length of effective fertility period(b) (in years)	Effective fertility period ($\eta_{0.05}, \eta_{0.95}$) (in years)	Estimate of CTFR (F)	Estimate of age of attaining half of total children ($\eta_{0.5}$) (in years)	Length of effective fertility period(b) (in years)	Effective fertility period ($\eta_{0.05}, \eta_{0.95}$) (in years)
1993	6.61	27.88	30.01	(17.08,47.09)	5.87	26.07	24.4	(17.29,41.69)
1994	6.21	26.51	25.85	(17.2,43.06)	5.79	26.7	27.11	(16.94,44.06)
1995	6.3	27.48	29.08	(17.01,46.09)	6.06	26.55	25.93	(17.22,43.15)
1996	6.25	26.87	27.6	(16.94,44.54)	5.83	25.42	24.45	(16.62,41.07)
1997	5.93	26.16	26.12	(16.76,42.88)	5.7	27.29	28.98	(16.86,45.84)
1998	6.37	26.54	26.19	(17.12,43.31)	5.85	25.92	25.45	(16.76,42.22)
1999	5.85	26.72	26.41	(17.22,43.63)	4.67	26.25	25.56	(17.05,42.61)
2000	5.59	25.98	24.7	(17.09,41.79)	5.47	25.79	25.92	(16.47,42.39)
2001	6.21	25.96	25.83	(16.66,42.5)	4.87	24.71	22.36	(16.66,39.02)
2002	5.83	25.85	25.33	(16.74,42.07)	4.46	25.42	23.36	(17.02,40.37)
2003	5.95	25.71	25.3	(16.61,41.91)	4.96	25.23	24.21	(16.52,40.73)
2004	6.12	25.62	26.09	(16.23,42.32)	4.69	25.56	22.86	(17.34,40.2)
2005	6.03	25.69	25.63	(16.47,42.1)	4.9	24.93	21.86	(17.06,38.92)
2006	5.55	26.76	26.28	(17.3,43.58)	4.95	26.44	24.84	(17.51,42.34)
2007	5.68	26.33	25.64	(17.1,42.75)	4.41	26.5	24.89	(17.54,42.43)
2008	5.47	25.47	23.81	(16.9,40.71)	4.59	26.06	24.93	(17.09,42.02)
2009	5.8	26.84	27.52	(16.93,44.46)	4.55	27.3	27.21	(17.5,44.72)
2010	5.61	26.38	26.18	(16.96,43.14)	4.74	25.88	25.76	(16.61,42.38)
2011	5.59	25.95	25.45	(16.79,42.24)	4.24	26.29	27.44	(16.42,43.86)
2012	5.49	25.83	24.9	(16.87,41.76)	4.19	25.55	23.32	(17.16,40.48)
2013	**5.3**	**25.13**	**23.58**	**(16.65,40.22)**	**4.21**	**26.42**	**25.51**	**(17.24,42.74)**
2014	**5.27**	**25.18**	**22.74**	**(17,39.74)**	**3.68**	**25.38**	**22.73**	**(17.2,39.93)**
2015	**5.26**	**24.99**	**23.25**	**(16.63,39.88)**	**3.69**	**24.98**	**23.32**	**(16.58,39.91)**
2016	**5.18**	**24.77**	**22.8**	**(16.57,39.37)**	**4.06**	**25.07**	**25.53**	**(15.88,41.41)**
2017	**5.32**	**24.86**	**23.5**	**(16.4,39.9)**	**3.61**	**25.48**	**23.07**	**(17.17,40.25)**
2018	**5.02**	**24.45**	**22.01**	**(16.53,38.54)**	**3.54**	**24.88**	**23.57**	**(16.39,39.96)**
2019	**5.04**	**24.58**	**22.32**	**(16.55,38.87)**	**3.59**	**24.95**	**23.56**	**(16.48,40.03)**
2020	**4.71**	**24.48**	**21.72**	**(16.66,38.39)**	**3.67**	**24.42**	**22.28**	**(16.4,38.69)**
2021	**4.79**	**24.19**	**21.61**	**(16.41,38.03)**	**3.56**	**23.98**	**21.42**	**(16.27,37.69)**
2022	**4.67**	**24.16**	**20.53**	**(16.77,37.3)**	**3.17**	**24.95**	**22.01**	**(17.03,39.04)**
2023	**4.63**	**24.21**	**21.01**	**(16.65,37.66)**	**3.28**	**24**	**20.97**	**(16.45,37.42)**
2024	**4.81**	**23.83**	**21.08**	**(16.25,37.32)**	**3.23**	**24.07**	**22.59**	**(15.94,38.53)**
2025	**4.64**	**23.79**	**20.67**	**(16.35,37.02)**	**3.1**	**23.81**	**21.82**	**(15.96,37.78)**

N.B. : Bold figures are projected estimates, obtained by applying the two step procedure