Spatial and Temporal Changes in the Dynamics of Tubal Sterilization Practice in India

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Abstract

There have been great shifts in the contraceptive acceptance levels in India in the last five decades. In particular, tubal sterilization acceptors have increased many folds. In fact, role of tubal sterilization has been considered vital in India's fertility decline. In this study we investigate changes in the dynamics of tubal sterilization practice in India and its different regions, over cohorts. This will offer better explanation for variation in fertility level, across the regions of India and over cohorts. Also, it will help to understand the changing position of women in the country. A special form of the Gompertz model has been proposed and made use of to study the dynamics of tubal sterilization practice in India and its different regions. Two indices that are intended to measure the amount of reproductive period averted due to tubal sterilization have been used to explain the variation in fertility level, across the regions of India and over cohorts.

Key words: Tubal sterilization, median age at sterilization, model age at sterilization, sterilization models, re-parameterized models and reproductive period averted

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1. Introduction

Tubal sterilization or female sterilization is the most popular contraceptive method in India (IIPS 1995; Koenig 1999), like many of the developing countries (Seiber et al. 2007; Rutenberg and Landry, 1993). It accounts for more than 70% of all the contraceptive methods couples use in the country (IIPS and Macro International 2007). Its use has steadily risen from less than 1% in 1960 to the present date. According to the latest National Family Health Survey, about 37% of women in the reproductive period are protected by sterilization (IIPS and Macro International 2007). Apart from that, it is the only contraceptive method which many couples use in the country (Zavier and Padmadas 2000; Padmadas et al. 2004; IIPS and Macro International, 2007). Sterilization is the commonest method, even among the younger married couples (Pachauri and Santhya 2002).

Prevalence of tubal sterilization practice in a population is often measured in terms of percentage of women in the reproductive period who are protected by sterilization. But, this measure masks huge variation in the practice of tubal sterilization by age of women, i.e. this measure masks huge variation in tubal sterilization practice over cohorts. Therefore, its application is limited. Nonetheless, it is the widely used because of its simplicity. Using this conventional indicator, many studies found that the acceptance of tubal sterilization has increased over time in India (IIPS 1995; IIPS and ORC Macro 2000; IIPS and Macro International 2007). But, for greater understanding of the actual changes in the pattern of acceptance of tubal sterilization, it is essential to study how the tubal sterilization practice has changes over cohorts and what changes have occurred in the age pattern of acceptance of it. Trends in the dynamics of tubal sterilization practice, the method that contributed significantly to reduce fertility in India (Pathak et al. 1998), are of considerable importance to policy makers, health workers and researchers. A detailed study on tubal sterilization trends over cohorts along with the corresponding changes in the age pattern of acceptance of tubal sterilization is expected to offer better explanation for variation in fertility levels. It will also help to understand the changes in couples planning regarding their family size and the timing of their decision to end their reproductive period, from older cohorts to the current ones. It will also help to understand the increasing participation of women in the work force in the country.

In this study, changes in the dynamics of tubal sterilization practice across the regions of India and over cohorts are investigated. Also, their causes and consequences are discussed.

2. Background and objectives

Adoption of family planning methods by couples gets significantly influenced by government policy, law and programmes related to family planning. It also depends upon the availability and the quality of family planning services, among many other important factors. In the following paragraph, brief details regarding India's family planning program are given. These details provide necessary background to the rise of tubal sterilization practice in the country.

With the aim of controlling fertility and thereby the population size, an official Family Planning Program (FPP) was launched in 1951, the first of its kind in the world. The program was reviewed time to time and modified to achieve desired goals (Visaria and Chari, 1998; Donaldson, 2002). In the first decade of FPP, i.e. during 1950-1960, several family planning clinics were opened to provide services for those who need such services voluntarily. This approach was popularly known as 'clinic based approach'. Under this approach, sterilization service was not financed by the FPP. During this period couple protection rate remained less than 1% in India (Maharatna 2002). During the Third Five Year Plan (1961-66), the approach of the FPP was shifted from 'clinic based approach' to an 'extension approach'. As a part of this, health workers were supposed to visit women of childbearing ages and motivate them to use family planning methods to limit their family size. Under this approach, targets were given to each health worker and health department. During the Fourth Five Year Plan (1969-1974), several sterilization camps were conducted in India. Incentives were given to both the tubectomy and the vasectomy acceptors and their motivators. The National Population Policy, formulated in 1976, emphasized to promote sterilization as a major means of population control (Srinivasan 1998). Starting from April 1975, 8.26 million sterilizations were done in the next 12 months, the highest in a year in any country in the world till date. From the Seventh Five Year Plan (1985-90), the number of tubal sterilizations increased significantly. The outlay on FPP in the First Five Year Plan (1951-56) was just Rs 1.45 million. It increased many folds over years and reached Rs 67,920 million during the eighth five year plan (1992-97). Consistent with the outlay on FPP, the performance of FPP had increased sharply over the years. Even after India had adopted target-free approach in 1996 (Visaria et al. 1998), following the Cairo conference in 1994, usage of reversible contraceptive methods remained comparatively poor. Tubal sterilizations, however, had continued to increase (IIPS and Macro International 2007).

In the light of all this development, dramatic changes have occurred both in the magnitude and the timing of sterilization. As a result, the fertility in India, which had been is above five children per woman at the start of 1970, has dropped substantially. However, wide differentials exist in fertility level across the regions of the country, possibly due to the variation in the practice of contraceptive methods, particularly tubal sterilization. In this study, changes in the dynamics of tubal sterilization practice across the regions of India and over cohorts, have been investigated. It provides better explanation for variation in the fertility level across the regions of India and over cohorts.

To start with, three models for *tubal sterilization schedules* (set of age specific sterilization rates are referred as tubal sterilization schedule, throughout this study) are proposed in Section 5.3. This is to provide a better alternative to the data on Age Specific Sterilization Rates (ASSRs), in describing the nature of age pattern of acceptance of tubal sterilization. Since sterilization results in forestalling reproductive period, a brief discussion on the reproductive period averted due to tubal sterilizations and its measurement is provided in Section 5.4. Details of the data used in this study, are given in Section 5.5. Various models that are proposed in Section 5.2 are evaluated in Section 5.6, using the data on tubal sterilization schedules of cohorts of women in India and its different regions. Changes in the dynamics of tubal sterilization practice in India and its different regions are investigated in Section 5.7 with the help of the best fitted model, obtained in Section 5.6. Discussion on the study findings is given in Section 5.8. Finally, the study ends up with a brief summary and conclusion in Section 5.9.

3. Models for age pattern of acceptance of tubal sterilization

Often models developed to describe a particular process may also be useful to describe other processes as well. For instance, Gompertz model (Gompertz 1825) was initially developed to describe age pattern of mortality. Over time, researchers started using it as a growth model (Winsor 1932). Later it was found that the Gompertz model could also describe age pattern of fertility (Wunsch 1966; Martin 1967). Likewise, great resemblance between the shapes of tubal sterilization schedules (see the observed age pattern of acceptance of tubal sterilizations in Figures A1 and A2, in the Appendix) and a typical fertility schedule (both monotonically increasing up to a particular age and then decreasing from there onwards) in India is the prime motivation for the present study to propose and use some of the fertility models to model tubal sterilization schedules in the country.

A variety of fertility models exist in the demographic literature. However, in this study, re-parameterized versions of few parsimonious models like Gamma model, Wald's model and Gompertz models are proposed and used to model tubal sterilization schedules in India. Here it must be remembered that re-parameterized models are no way different from their original models as far as their fits are concerned. However, they are generally advantageous over the original models in terms of parameter interpretations and few other aspects (Pasupuleti and Pathak 2010a). The re-parameterized models that are proposed in this study are given below.

I) *Wald's model*

The model is

$$f(x;R,\mu,\sigma^2) = R\frac{1}{\sigma\sqrt{2\pi}}\left(\frac{\mu}{x}\right)^{\frac{3}{2}}\exp\left(-\frac{1}{2}\left(\frac{\mu}{x}\right)\left(\frac{x-\mu}{\sigma}\right)^2\right) \qquad [1]$$

Where, $0 \le R \le 1, \quad \mu > 0, \quad \sigma^2 > 0, \quad x > 0.$

This model is a re-parameterized version of the inverse Gaussian distribution, proposed by Wald (1947). In this model, $f(x;R,\mu,\sigma^2)$ is an analytical function for describing a tubal sterilization schedule. Parameter μ is the mean and σ^2 is the variance of the tubal sterilization schedule. Parameter R can be interpreted as the proportion of women who have ever undergone sterilization in the considered cohort. It is worth mentioning in this context that Gilje (1969) and Yntema (1969) have shown independently that the

Hadwiger fertility model (Hadwiger 1947) is a particular form of the inverse Gaussian distribution.

II) *Gamma model*

This model, which is equivalent to Pearson Type III curve, is

$$f(x;R,a,b) = R\left(\frac{a^b}{gamma(b)}\right)x^{b-1}\exp(-ax) \qquad [2]$$

Where, $0 \le R \le 1, \quad a > 0, \quad b > 0, \quad x > 0.$

In the above model, $f(x;R,a,b)$ is an analytical function for describing a tubal sterilization schedule. Parameters a and b do not have any direct demographic interpretation. Parameter R can be interpreted as the proportion of women who have ever undergone sterilization in the considered cohort. Hoem *et al*. (1981) have used this model with one additional parameter, representing lower age limit of fertility, to model Danish fertility schedules.

III) *Gompertz model*

The form considered for Gompertz model in this study is

$$f(x;R,a,b) = R\left(\frac{1}{2}\right)^{\left(\frac{\log\left(\frac{3}{4}\right)}{\log\left(\frac{1}{2}\right)}\right)^{\frac{x-a}{b-a}}} \qquad [3]$$

Where, $R > 0, \quad a > 0, \quad b > a, \quad x > 0.$

(Here, $R\left(\frac{1}{2}\right)^{\left(\frac{\log\left(\frac{3}{4}\right)}{\log\left(\frac{1}{2}\right)}\right)^{\frac{x-a}{b-a}}}$ can be re-written as

$$R\left(\left(\frac{1}{2}\right)^{\left(\frac{\log\left(\frac{3}{4}\right)}{\log\left(\frac{1}{2}\right)}\right)^{\left(\frac{-a}{b-a}\right)}}\right)^{\left(\left(\frac{\log\left(\frac{3}{4}\right)}{\log\left(\frac{1}{2}\right)}\right)^{\left(\frac{1}{b-a}\right)}\right)^{x}}$$

, which is in the form RA^{B^x} , where $A = \left(\left(\frac{1}{2}\right)^{\left(\frac{\log\left(\frac{3}{4}\right)}{\log\left(\frac{1}{2}\right)}\right)^{\left(\frac{-a}{b-a}\right)}} \right)$ and $B = \left(\left(\frac{\log\left(\frac{3}{4}\right)}{\log\left(\frac{1}{2}\right)} \right)^{\left(\frac{1}{b-a}\right)} \right)$

)

Here $f(x; R, a, b)$ is an analytical function for describing cumulative tubal sterilization schedule (cumulative ASSRs). Parameter R is the saturation level (upper asymptote), which can be interpreted as the proportion of women who have ever undergone sterilization in the considered cohort. Parameter a is the median age at acceptance of tubal sterilization and b is the age by which three-fourth of the total sterilizations occur (see Appendix A for detail).

4. Measuring reproductive period averted due to tubal sterilization

In general, women are potential of giving births to children in between the ages of 15 and 49 years (this period is known as biological reproductive period), i.e. for a period of 35 years. But, due to delayed entry into sexual union, usage of temporary or permanent methods of contraception, death of partner, abstinence from sex due to various other causes, the actual duration of their reproductive period is well below to it. If detailed data are available on the timing of tubal sterilization for the women of our concerned population then it is possible to quantify the duration of the reproductive period that has been averted due to tubal sterilization. For instance, consider a cohort of women of size N, who have completed their reproductive period. Of them, let N_x is the number of women who have been sterilized at age x. Also, let $M \, (= \sum_{x=15}^{49} N_x)$ be the total number of women who have ever been sterilized in the considered cohort. A woman who has been sterilized at age x can not give births after that age. Therefore, she will loose $50 - x$ reproductive years. Since N_x women of the considered cohort have been sterilized at age x, therefore a total of $N_x(50 - x)$ reproductive years have been lost by them. Proceeding in the same way, it can be shown that the total number of reproductive years lost by the women of the considered cohort due to tubal sterilization is $\sum_{x=15}^{49} N_x(50 - x)$. Hence, average number of reproductive years lost by a woman of the considered cohort is $\left(\frac{\sum_{x=15}^{49} N_x(50-x)}{N} \right)$, which is equal to $\sum_{x=15}^{49} \left(\frac{N_x}{N}\right)(50 - x) = \sum_{x=15}^{49} f(x)(50 - x)$, where $f(x)$ is the proportion of women have been sterilized at age x.

The age interval [15,50) is further referred in this study as the total reproductive period and the average number of reproductive years lost per woman in between the ages of 15 and 49 years due to tubal sterilization is referred as the *Total Reproductive period Averted (TRA) due to tubal sterilization.*

However, a woman has greater potential of giving births in between the ages of 15 and 35 years (this our general observation based on many natural fertility schedules in the world). Therefore, reproductive period that was averted in between the ages of 15 and 35 years is more to do with the reduction in fertility level than the *TRA* due to tubal sterilization. Hence, it is better to calculate the duration of reproductive period averted, in between the ages of 15 and 35 years of ages, due to tubal sterilizations. The age interval [15,35] is further referred in this study as the Potential Reproductive Period. And the average number of reproductive years lost per woman, in between the ages of 15 and 35 years, due to tubal sterilizations is referred as the *Potential Reproductive period Averted (PRA) due to tubal sterilization.*

$$PRA = \sum_{x=15}^{35} (35 - x) f(x)$$

Following the above procedure, total and potential reproductive periods averted due to tubal sterilizations in different regions of India and over cohorts can be measured.

5. Data

Data on ever married women of selected age groups from the three National Family Health Surveys (NFHSs), conducted in India during 1992-1993, 1998-1999 and 2005-2006, have been used in this study. These surveys are commonly referred as NFHS-1, NFHS-2 and NFHS-3 respectively (IIPS 1995; IIPS and ORC Macro 2000; IIPS and Macro International 2007). In NFHS-1, data had been collected from a sample of 89,777 ever married women in the age group of 13 to 49 years. In NFHS-2, the sample size had been 90,303 ever married women, aged 15-49 years. The sample size for NFHS-3 had been 124,456 women in the age group of 15-49 years. In these surveys, data on sterilization status and age at sterilization were collected from each respondent woman. Data on each respondent woman has been censored to a base-line time point of 1st January of the year of starting each survey. This has been done to avoid non-homogeneity in comparison, arising due to one and half year gap in the interview phase, in all the three surveys. Relevant portions of data on cohorts of ever married women aged 46-48 years in the three NFHSs and cohorts of ever married women aged 36-38 years and 26-28 years in NFHS-3 have been used in this study. The choice behind these cohorts of women is to adequately represent the 35 cohorts of women who born during 1947 to 1982 or alternatively those cohorts of women who have ended/will end their reproductive period during 1993 to 2028. The number of ever married women in NFHS-1, aged 46-48 years at 1st January of 1992, has been 4,284. The number of ever married women in NFHS-2 and NFHS-3, aged 46-48 years at 1st Januaries of 1998 and 2005, have been 3,975 and 4,243 respectively. Again, the number of ever married women in NFHS-3, aged 36-38 years and 26-28 years at 1st January 2005 have been 9,673 and 10,911 respectively. For each of these cohorts of women, the proportions of women sterilized at various ages have been calculated. These age specific sterilization rates or tubal sterilization schedules have been used in this study. Information on tubal sterilization schedules of cohorts of women aged 46-48 years has been more or less complete. On the other hand, sterilization schedules of cohorts of women, aged 36-38 years and 26-28 years in NFHS-3, have been right censored after the ages of 35 years and 25 years respectively.

6 Evaluation of various models and their comparison

Tubal sterilization schedules of cohorts of women in India and its different regions, aged 46-48 years at 1st Januaries of 1992, 1998 and 2005 (i.e. cohorts of women, aged 46-48 years in the three NFHSs), have been used to validate and compare various models that are given in the methodology. In this study the same regional classification as in NFHS-3 has been followed (IIPS and Macro International 2007). Different regions of India and their constituent states are shown in Figure A4 in the Appendix. All the three models, namely, Wald, Gamma and Gompertz models, are fitted based on the principle of least squares and using the Statistical Analysis System (SAS) package.

Age pattern of acceptance of tubal sterilization in India and its different regions are shown in Figures A1 and A2, in the Appendix. Fit of various models to the tubal sterilization schedules are also shown in the same figures. In all the regions of India, a characteristic pattern in the acceptance of tubal sterilization, increasing up to a particular age and then decreasing from there onwards (resembling like a right skewed distribution), can be seen from these figures. This pattern has great resemblance with a typical fertility schedule, which also increases up to a particular age and then decreases from there onwards. In fact, this common characteristic in the shapes of tubal sterilization schedules and fertility schedules is the motivation for the present study to propose and use some of the fertility models for describing the tubal sterilization schedules in the country.

Good fit of all the three models to the tubal sterilization schedules of cohorts of women in India and its different regions can be seen from Figures A1 and A2, in the Appendix. For evaluating the extent of fit of various models, error sum of squares for each model have been calculated. The mean error sum of squares for each model over the considered cohorts has also been calculated to ease the overall comparison of fits of various models. These mean error sum of squares are used in arranging the models in decreasing order of their fit.

Convergence criterion has not been met in the parameter estimates while fitting the Wald's model to the tubal sterilization schedules of cohorts of women in North India and the Central India aged 46-48 years at 1st January 1998. Therefore, error sum of squares of Wald's model are not provided for these two cohorts. Fit statistics of various models (error sum of squares multiplied by 10^{-4}) are given in Table 1. It can be seen from this table that all the error sum of squares are below 10^{-3} , except for few cohorts (cohorts of women in the South, the West and the North-east, aged 46-48 years at 1st January 2005). All the three models are found fitting well to the tubal sterilization schedules and differences in degree of fit of various models are small. This implies that all the proposed models are performing well in describing the sterilization schedules of India and its different regions. Even if small differences in fit of various models are considered, it can be found from Table 1 that the fit of the Gompertz model is better than the remaining two models in twelve out of the twenty one cases. Wald's model is better than the Gompertz model in six out of the twenty one cases and the fit of the Gamma model is better than that of the Gompertz model in three cases. No model fit is inferior to the remaining two models in all the twenty one cases. Based on the mean error sum of squares, given at the bottom of Table 1, it can be concluded that the fit of the Gompertz model is better than the remaining two models and is followed in decreasing order by the Wald's and Gamma models respectively.

Table 1: *Fit of various models to the tubal sterilization schedules of cohorts of women in India and its different regions*

		Error sum of squares[b]		
Region	**Cohort[a]**	**Gamma**	**Hadwiger**	**Gompertz**
North India	1	7.285*	-	7.927
North India	2	2.656	2.564*	3.196
North India	3	8.597	7.681	6.187*
South India	1	4.054	3.727	3.373*
South India	2	4.772	4.542*	4.885
South India	3	15.466	14.536*	15.172
East India	1	3.482	3.397	3.363*
East India	2	4.187	4.046*	4.176
East India	3	6.811	6.548*	6.829
West India	1	15.642	15.207	14.842*
West India	2	9.765	9.221	8.883*
West India	3	21.607	19.855	16.726*
Central India	1	2.308	-	1.938*
Central India	2	5.259*	5.681	6.827
Central India	3	6.947	6.249	5.483*
North-east India	1	5.120	5.041	4.950*
North-east India	2	6.904	6.762	6.531*
North-east India	3	15.648*	15.763	16.140
India	**1**	**1.325**	**1.159**	**1.026***
India	**2**	**1.447**	**1.398***	**1.802**
India	**3**	**5.063**	**4.127**	**3.002***
Mean		***7.3498***	***6.8752***	***6.822***

Notes: (a) - 1, 2 and 3 indicate cohorts of women, aged 46-48 years at 1st Januaries of 1992, 1998 and 2005 respectively; (b) - * corresponds to the best fit, within that specific cohort.

7 Results

7.1 Application of Gompertz model to study dynamics of tubal sterilization practice in India and its different regions

Apart from good fit to the tubal sterilization schedules of cohorts of women in India and its different regions, the Gompertz model has several other advantages such as: (1) all the parameters have clear physical interpretation, (2) the model is useful for indirect estimation of sterilization schedules, with proper inputs in the form of parameter estimates, (3) the model is less sensitive to its parameters than the classical form of the Gompertz model, (4) the model parameter estimates can be judged properly (Pasupuleti and Pathak, 2010a). Alongside these advantages, characteristics like peak age at acceptance of tubal sterilization (mode) and age by which one fourth of the total sterilizations occur (first quartile) can also be derived analytically from this model (Appendix B). These two characteristics along with the parameters of the Gompertz model (which represents proportion ever sterilized, second quartile and third quartiles of the tubal sterilization distribution) are sufficient to describe the underlying tubal sterilization distribution.

Changes in the age pattern of acceptance of tubal sterilization in India and its different regions, obtained by using the Gompertz model, are shown in Figure A3 in the Appendix. It becomes clear from this figure that there are great shifts in both magnitude and the timing of tubal sterilization in between the cohorts of women aged 46-48 years at 1st Januaries of 1992 and 2005. Parameter estimates of the Gompertz model, fitted to the tubal sterilization schedules of cohorts of women in India and its different regions, are given in Table 2. It could be seen from this Table 2 that the proportion of women who have ever undergone sterilization has increased over cohorts, in all the regions of India. In case of West India, it has increased from 0.58 to 0.76, in between the cohorts of women aged 46-48 years at 1st Januaries of 1992 and 2005. The corresponding changes are from 0.39 to 0.69 in South India, from 0.45 to 0.61 in North India, from 0.30 to 0.59 in East India, from 0.28 to 0.51 in Central India and from 0.16 to 0.42 in North-east India.

Table 2: *Parameter estimates of the Gompertz model, fitted to the tubal sterilization schedules of cohorts of women in India and its different regions*

Region	**Cohort***	**R**	**a**	**b**
North India	1	0.45	34.80	40.22
North India	2	0.46	31.70	35.55
North India	3	0.61	30.78	34.82
South India	1	0.39	31.63	36.36
South India	2	0.46	28.35	32.14
South India	3	0.69	27.46	31.11
East India	1	0.30	33.68	38.66
East India	2	0.37	31.25	35.53
East India	3	0.59	30.53	35.37
West India	1	0.58	31.93	36.15
West India	2	0.61	29.99	34.12
West India	3	0.76	28.44	32.05
Central India	1	0.28	35.71	40.97
Central India	2	0.39	32.43	37.41
Central India	3	0.51	31.41	36.28
North-east India	1	0.16	30.37	35.15
North-east India	2	0.19	30.03	34.43
North-east India	3	0.42	32.38	37.98

India	**1**	**0.37**	**33.16**	**38.14**
India	**2**	**0.44**	**30.32**	**34.68**
India	**3**	**0.61**	**29.47**	**33.79**

* 1, 2 and 3 indicates cohorts of women, aged 46-48 years at 1st Januaries of 1992, 1998 and 2005 respectively.

The median age at acceptance of sterilization for cohorts of women in the North-east, South, West, East, North and the Central India, aged 46-48 years at 1st January 1992 have been are 30.37, 31.63, 31.93, 33.68, 34.8 and 35.71 years respectively. However, it has decreased over cohorts in all the regions of India with the exception of North-east India, where it has increased by two years. Over the next 13 cohorts, i.e. by the time of cohort of women aged 46-48 years at 1st January 2005, the median age at sterilization has decreased to 27.46 years in the South India, 28.44 years in the West India, 30.53 years in the East India, 30.78 years in the North India and 31.41 years in the Central India respectively. The corresponding change is from 33.16 to 29.47 years at all India level.

Some of the characteristics related to the acceptance of tubal sterilization, such as age by which one fourth of the total sterilizations occur and peak age at acceptance of sterilization, are given in Table 3. Wide differentials in the peak age at acceptance of tubal sterilization across the regions of India can be found from this table. However, the peak age at which woman opts for sterilization has decreased over cohorts in all the regions of India with the exception of the North-east India, where there is more than one and a half years increase in it. The peak age at acceptance of sterilization for the cohort of women, aged 46-48 years at 1st January 1992, has been 29.65 years, in the South India. The same for the cohort of women in the South India, aged 46-48 years at 1st January 2005, is 25.94 years. The corresponding changes in the peak age at acceptance of sterilization are from 30.17 to 26.93 years in the West, from 31.61 to 28.52 years in the East, from 32.54 to 29.10 in the North, from 33.52 to 29.38 years in the Central and from 28.38 to 30.05 years in the North-east India respectively. The same has changed from 31.08 to 27.67 years at all India level.

Considerable variation is found in the duration of the age interval in which acceptance of tubal sterilizations increases from one fourth to half of the total sterilizations across the regions of India. For instance, this duration is just 2.85 years in West India, for cohort of women aged 46-48 years at 1st January 2005. The same is 2.88 years in the South, 3.84 years in Central India and 4.42 years in North-east India. Same at all India level is 3.4 years. For the same cohort, the length of the age interval during which proportion of total sterilizations increases from 0.5 to 0.75 is 3.61 years in the West, 3.65 years in the South, 4.87 years in the Central and 5.6 years in the North-east India.

Table 3: *Some of the characteristics related to the practice of tubal sterilization in India and its different regions over cohorts*

Region	Cohort*	First quartile	Peak age at acceptance of sterilization
North India	1	30.52	32.54
North India	2	28.67	30.10
North India	3	27.60	29.10
South India	1	27.90	29.65
South India	2	25.36	26.77
South India	3	24.58	25.94
East India	1	29.76	31.61
East India	2	27.88	29.47
East India	3	26.72	28.52
West India	1	28.60	30.17
West India	2	26.73	28.27
West India	3	25.59	26.93
Central India	1	31.57	33.52
Central India	2	28.50	30.35
Central India	3	27.57	29.38
North-east India	1	26.60	28.38
North-east India	2	26.57	28.20
North-east India	3	27.96	30.05
India	**1**	**29.23**	**31.08**
India	**2**	**26.88**	**28.50**
India	**3**	**26.07**	**27.67**

* 1, 2 and 3 represents cohorts of women, aged 46-48 years at 1st Januaries of 1992, 1998 and 2005 respectively.

7.2 Recent cohorts

Cohort of ever married women, aged 26-28 years at 1st January 2005, represents the present generation of younger married women. Comparison of this cohort behaviour, regarding the acceptance of tubal sterilization, with older cohorts of women helps to understand the present situation in comparison to the past. For this, the percentage of women sterilized on or before the age of 25 years across the regions of India and over cohorts have been calculated and shown in Table 4. It can be found from this table that the percentage of women sterilized, on or before the age of 25 years, has increased from older cohorts to the current ones, irrespective of the regions. At all India level, this is just 3% for the cohort of women aged 46-48 years at 1st January 1992, and it has increased to

36% by the cohort of women aged 26-28 years at 1st January 2005. Similar kinds of changes are observed over the cohorts in all the regions of India. Of the cohort of women aged 26-28 years at 1st January 2005, about 52% in the South, 43% in the West, 32% in the North and the East, 26% in the North-east and 24% in the Central India were sterilized on or before the age of 25 years. If these percentages are compared with the corresponding percentages of older cohorts, given in Table 4, it becomes clear that the percentage of women who got sterilized by age 25 years has increased many folds from older cohorts to the current ones.

Table 4: *Percentage of women sterilized on or before the age of 25 years in India and its different regions over cohorts*

Cohort*	Region						
	North India	South India	East India	West India	Central India	North-east India	India
1	3	5	2	5	1	3	3
2	4	13	5	12	5	3	8
3	8	25	11	22	8	5	14
4	21	38	21	35	12	11	25
5	32	52	32	43	24	26	36

* 1, 2 and 3 indicates cohorts of women, aged 46-48 years at 1st Januaries of 1992, 1998 and 2005 respectively; 4 and 5 indicates cohorts of women aged 36-38 and 26-28 years at 1st January 2005.

7.3 Reproductive period averted due to tubal sterilization and explaining regional variation in fertility

Huge variation in fertility level across the regions of India is well known (Preston and Bhat 1984; Rele 1987; Guilmoto and Rajan 2001; Pasupuleti and Pathak 2010b). It is an undeniable fact that a significant proportion of the regional variation in fertility level is due to differences in magnitude and timing of tubal sterilizations across the regions of India. Total and potential reproductive periods averted due to tubal sterilization aggregate the whole information regarding the timing and the magnitude of tubal sterilizations. Therefore, these indicators are expected to capture the region wise variation in the acceptance of tubal sterilization method in the country. And hence, they are expected to explain a significant proportion of regional variation in fertility level in the country.

Cohort Total Fertility Rate (CTFR), total and potential reproductive periods averted due to tubal sterilization over cohorts in different regions of India are given in Table 5. It can be seen from this table that total reproductive period averted due to tubal sterilization is 6.8 years at all India level for the cohort of women aged 46-48 years at 1st January 1992. The same has increased to 12.8 years by the cohort of women, aged 46-48 years at 1st January 2005. The corresponding changes are from 10.9 to 16.4 years in the West, from 7.6 to 15.6 years in the South, from 8.2 to 12.0 years in the North, from 5.4 to 11.9 years in the East, from 5.0 to 10.0 years in the Central and from 3.2 to 8.3 years in the North-east. On the other hand, changes in the potential reproductive period averted due to tubal sterilizations are from 0.9 to 3.2 years at all India level, from 1.3 to 5.0 in the South, from 1.8 to 4.7 in the West, from 0.6 to 2.6 in the East, from 0.7 to 2.4 in the North, from 0.3 to 1.9 in the Central and from 0.7 to 1.4 in the North-east, in between the cohorts of women, aged 46-48 years at 1st Januaries of 1992 and 2005.

It can also be seen from Table 5 that CTFR varies widely across the regions of India. Further, it can be found that CTFR values are consistent with the values of total and potential reproductive periods averted due to tubal sterilizations. In fact, the total reproductive period averted due to tubal sterilization explains 69.7% of the variation in completed fertility levels (CTFRs) across the regions of India and over cohorts (Table A1 in the Appendix). Whereas the potential reproductive period averted due to tubal sterilization explains 81.3% of the total variation in fertility levels (Table A2 in the Appendix). It is also found that age at marriage explains just 13.5% of the variation in fertility level (this result is not shown here). Therefore, it can be concluded that majority of the variation in fertility across the regions of India and over cohorts, is due to variation in the acceptance of tubal sterilizations.

Table 5: *Total and potential reproductive periods averted due to tubal sterilization and CTFR in different regions of India and over cohorts*

Region	**Cohort***	**TRA**	**PRA**	**CTFR**
North India	1	8.23	0.73	5.13
North India	2	8.69	1.42	4.90
North India	3	11.96	2.42	4.24
South India	1	7.56	1.37	4.56
South India	2	9.99	2.89	4.08
South India	3	15.58	4.95	3.25
East India	1	5.42	0.61	5.37
East India	2	7.15	1.34	4.96
East India	3	11.89	2.63	4.56
West India	1	10.94	1.76	4.80
West India	2	12.30	2.87	4.13
West India	3	16.40	4.69	3.50
Central India	1	4.98	0.28	6.00
Central India	2	7.53	1.18	5.65
Central India	3	9.96	1.90	5.37
North-east India	1	3.16	0.71	5.66
North-east India	2	3.81	0.89	4.94
North-east India	3	8.25	1.40	4.46
India	**1**	**6.83**	**0.90**	**5.23**
India	**2**	**8.86**	**1.98**	**4.72**
India	**3**	**12.77**	**3.23**	**4.25**

* 1, 2 and 3 represents cohorts of women, aged 46-48 years at 1st Januaries of 1992, 1998 and 2005 respectively.

8. Discussion

8.1 Sharp rise in tubal sterilization practice and decreasing age at acceptance of it

Sharp rise in the usage of tubal sterilization in India and its different regions has been shown in Section 7. It is an alarming fact that India is half child away from replacement level fertility (IIPS and Macro International 2007). Therefore, even in the forthcoming decade(s), there is need to reduce India's fertility further, through contraceptive interventions. This need is originating from the fact that India's population is already above 1.21 billion (Registrar General of India 2011) and is next only to China in population size. Also, India is one of those 38% of world countries which have reported that their current population sizes are too high (United Nations 2008). Given the universal knowledge about tubal sterilization and its wide spread availability in all the parts of the country (IIPS and Macro International 2007), it is likely that the usage of this method will increase further before India attains the replacement level fertility.

The rise of tubal sterilizations in India is a good symptom, given the population problem it is facing, and must be welcomed. However, few things that are still causing concern are (1) age at marriage continues to be low in many parts of India (Desai and Andrist 2010), (2) reproductive period is getting bulged around early 20's as a result of increased acceptance of tubal sterilization by the mid 20's (Table 4; Figure A3 in the Appendix), (3) ideal family size remaining above 2.1, even among the younger married couples aged 15 to 29 years (IIPS and Macro International 2007) and (4) tubal sterilization is the only method majority of couples use in their entire life. Under these circumstances, even if India attains the replacement level fertility in the near future with further increase in the percentage of tubal sterilization users, population will continue to grow in the country.

Previous studies have also strongly emphasized the above fact. For instance; Matthews et al. (2009) have opined that the sterilization focused family planning program in India and the neglect of strategies that encourage delaying and spacing of births will fuel population growth in the country. They even estimated that by adopting 'later, longer and fewer' strategy, India can avert about 52 million population by 2050. Also, it has been emphasized in the demographic literature that at any parity level, women with births at earlier ages of reproductive period will contribute more to the population growth than the women with births at later ages of reproductive period (Frejka 1973; Bongaarts and Greenhalgh 1985; Rajaretnam 1990).

The rise in the percentage of tubal sterilization users in India, along with the decrease in the age at acceptance of tubal sterilization, might also explain changing position of women in the country. For instance, until the recent years, the primary role of a woman in India is to rear and care children. But, with former responsibly being relaxed to a good extent, as a result of population pressure, women are completing their families in a short reproductive span. The remaining span of reproductive period is getting allocated to aide their family economically through participation in the workforce. The proportion of women in the reproductive period, who had been working was 34% as per NFHS-1 (IIPS 1995). This has increased to 44% by NFHS-3 (IIPS and Macro International 2007). Similar kind of increase has been observed in almost all the states of the country. This pattern is consistent with the increased use of tubal sterilizations, alongside the decrease in age at acceptance of it, in between the two surveys (IIPS and Macro International 2007).

Other demographers have linked the decrease in age at acceptance of tubal sterilization in India to the stagnation of infant mortality in the country. For instance, Matthews et al. (2009) have opined that the recent stagnation in the reduction of infant mortality in India is due to "*early childbearing practices and the lack of progress in lengthening birth intervals*".

Ross et al. (2002) have shown that improved access to various contraceptive methods will increase their usage. Therefore, if Indian government succeeds to offer various reversible contraceptive methods, by recognizing the fact that the choice of the contraceptive method varies largely with the age and the number of living children (parity) of the users, then the usage of reversible contraceptive methods may increase in the country, in the near future. This is very much needed not only to increase the spacing of births but also to increase the timing of births. For instance; if younger married couples use these methods effectively to avert births in the first few years of their marriage then, timing of births will increase automatically.

8.2 Regional variation in tubal sterilization

Huge variation in the acceptance of tubal sterilization across the regions of India indicates the geographic and the cultural variation across the regions of India. It also indicates the variation in the couples' planning and timing of the decision to stop further births, across the regions of India. Earlier studies have found that woman's education, exposure to mass media and preference for son are the main factors affecting utilization of family planning services in India (Das et al. 2001). They have also found that woman's education is the strongest predictor of utilization of family planning services among the three factors. As far as these three factors are concerned, huge variation is found across the regions of India. For instance, female literacy in India ranges from a minimum of 33% in Bihar to a maximum of 87.72% in Kerala (Registrar General of India 2001). Exposure to the media, which is expected to bring changes regarding the family size ideals and subsequently motivate couple to opt for contraceptives, is substantially higher in all the Southern states than the remaining states of India (Bhat 1996). Preference for son, which is found to influence the usage of contraception (Rajaretnam and Deshpande 1994), is also varying significantly from one region to another. It is found to be the lowest in the South India and the highest in the Central India (Pasupuleti and Pathak 2010b).

The commitment of various state governments in improving health and socio-economic conditions of the people also influence favourably the contraceptive acceptance for reduction of family size. It is widely accepted that the Southern states are ahead of the remaining regions with respect to the social reforms. For instance, the population experts have opined that the primary developments in the public health and universal education both for males and females, land reforms, minimum wages in agriculture and the organized sectors have caused the socio-economic changes in Kerala. This has affected in-turn the cost-benefit ratio of children to parents, which ultimately has resulted in opting for less number of children and successful practice of family planning methods in the southern state of Kerala (Ratcliffe 1978; Zachariah 1984; Krishnan 1986). Similarly, demographers have attributed the high level of contraceptive prevalence and fall in fertility in the southern states of Tamil Nadu and Andhra Pradesh to the efficient administration, better status of women, social reforms and good exposure to print and electronic media (Ramasundaram 1995; Srinivasan 1995; James and Subramanian 2003). The low level of female literacy, the high level of sex preference, the lower levels of exposure to print and electronic media are some of the socio-economic factors that might be associated with the relatively less usage of sterilization in the Central India. On the other hand, the commitment of various state governments in reducing fertility level, coupled with better social and the health conditions of the people, might be responsible to the higher usage of tubal sterilization in South India.

A part of the regional variation in the practice of tubal sterilization may also be due to differences in the efficiency of implementation of family planning programs across the regions of India. Significant regional variation in the unmet need for family limiting provides evidence to this view (IIPS and Macro International 2007).

8.3 Applicability of tubal sterilization models

The tubal sterilization models that have been considered in this paper are very useful in Indian context. However, their application to the sterilization schedules of other countries is beyond the scope of the present work. Nonetheless, it must be remembered that tubal sterilization patterns are largely influenced by the government policies and service provision. Therefore, wide variation is expected in the shapes of tubal sterilization schedules from one country to another country. Hence, the proposed models may or may not fit well in other country contexts.

9. Summary and conclusion

Present study investigated changes in the dynamics of tubal sterilization practice in India and its different regions over cohorts. A characteristic in the age pattern of acceptance of tubal sterilizations – increasing up to a particular age and then decreasing from there onward - in India and its different regions, which resembles with the shape of a typical fertility schedule, is the prime motivation for this study to propose and use some of the fertility models to explore tubal sterilization patterns in the country. Re-parameterized versions of Gamma model, Wald's model and Gompertz model have been proposed and used to explore tubal sterilization patterns in the country. These models have been compared with one another in order to evaluate their appropriateness. It is found that the fit of the Gompertz model is slightly better than the remaining two models. The model has several other advantages such as having nice parameter interpretations and etc. Hence, the study has proceeded with the Gompertz model to study changes in the dynamics of tubal sterilization practice over cohorts in different regions of India. Since sterilization results in forestalling reproductive period, therefore, the duration of reproductive period averted due to tubal sterilization is measured over cohorts across the regions of India. Data on ever married women aged 46-48 years from the three National Family Health Surveys are used in this study, to know how the age pattern of acceptance of tubal sterilization has changed over cohorts. The study also makes use of data on ever married women aged 26-28 years and 36-38 years from the third National Family Health survey to understand the contemporary situation of tubal sterilization practice in India and its different regions.

Some of the interesting findings of the present study are the following. (1) Significant differences are found in both the magnitude and the timing of tubal sterilization, across the regions of India. (2) Age at acceptance of tubal sterilization has decreased in all the regions of India, with the exception of the North-east India, where there is a considerable increase in it. (3) Apart from the wide usage of tubal sterilization, the age at acceptance of it is also lower in the South India and the West India, compared to that in the Central India. This is also one of the significant reasons behind the higher level of fertility in the Central India and the lower levels of fertility in the West and the South India. (4) Median age at acceptance of tubal sterilization and the peak age at acceptance of tubal sterilization have also decreased significantly in all the regions of India, with the exception of North-east India, where these have increased significantly over the cohorts. (5) Majority of the sterilizations are taking place in a relatively short age interval in the South and the West. In the Central and the East India, the intervals are wider. (6) Average number of reproductive years experienced by a woman in between the ages of 15 and 35 years, which has been referred as the potential reproductive period, is decreasing over cohorts in all parts of India due to the increasing usage of tubal sterilizations alongside the decrease in age at acceptance of it. (7) More than 80% of the variation in fertility level across the regions of India and over cohorts, is due to the variation in tubal sterilization practice.

Increasing tubal sterilization practice in India is a good symptom to generate the hope that the country will be attaining the replacement level fertility very soon. But, the decrease in the age at acceptance of it and non-use of other temporary and reversible modern contraceptive methods by vast majority of the couples in the country is a cause of concern. Indian government has to understand one point that even if India attains the replacement level fertility its population growth will not stop due to low timing of births in the country. The government, therefore, has to increase its efforts to promote modern contraceptive methods and make sure that younger married couples get habituated with these methods. Since age at marriage is not likely to increase much in the near future, creating demand for modern reversible contraceptive methods and ensuring adequate supply of such methods is the key to increase the timing and the spacing of births in the country. This in turn can slow down the population growth in the country.

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Appendix

Tables in the Appendix

Table A1: Results of simple linear regression in which CTFR is the response variable and Total Reproductive Period Averted (TRA) due to tubal sterilizations is the explanatory variable

Variable	Parameter estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	6.2657	0.2438	25.7011	0.0000
TRA	-0.1655	0.0249	-6.6404	0.0000

F-statistic value is 44.1 on 1 and 19 degrees of freedom. The corresponding p-value is 2.368e-006.
Model R-Squared value is **0.6989.**

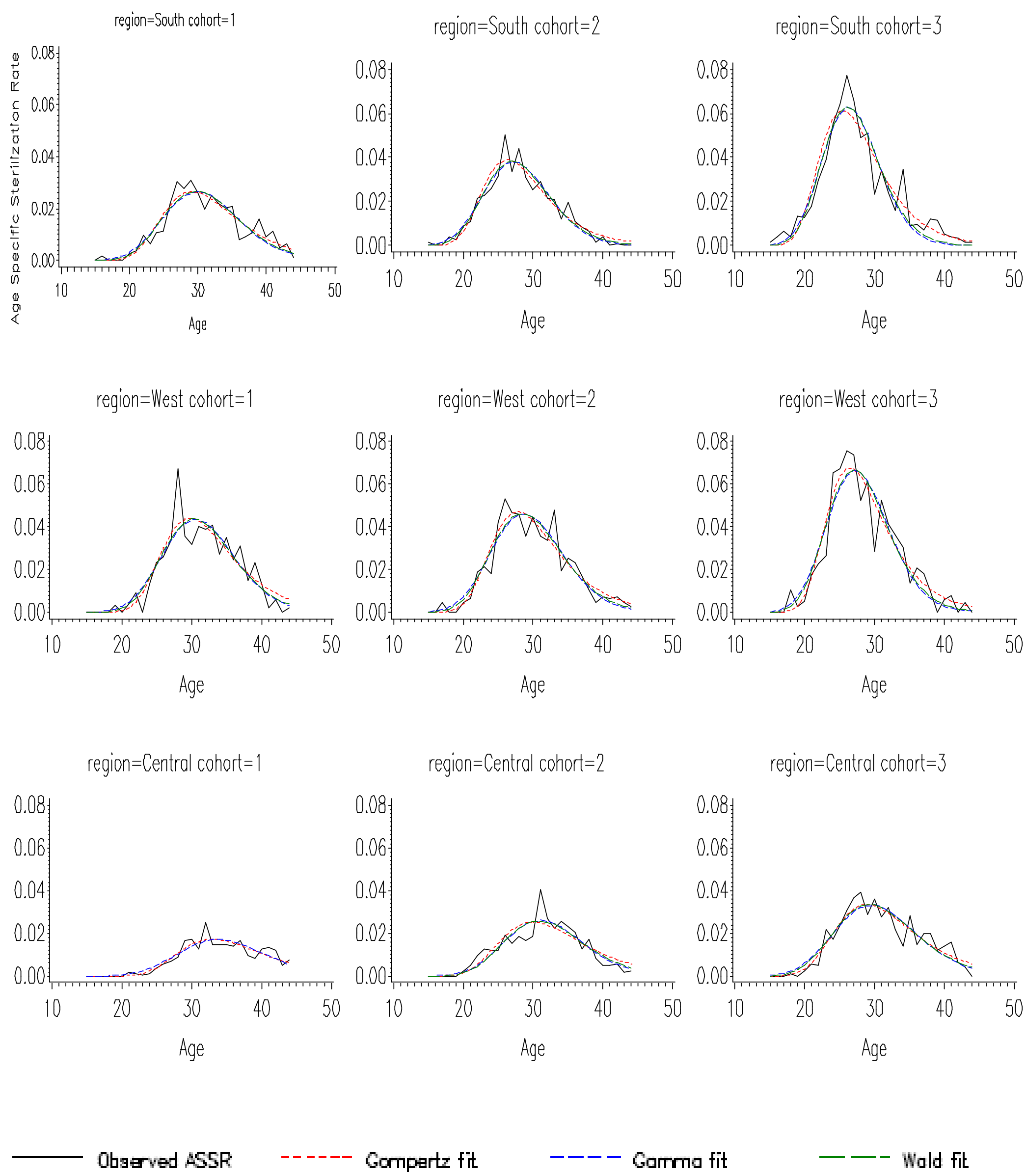
Table A2: Results of simple linear regression in which CTFR is the response variable and Potential Reproductive Period Averted (PRA) due to tubal sterilizations is the explanatory variable

Variable	Parameter estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.6991	0.1239	46.0089	0.0000
PRA	-0.4962	0.0544	-9.1282	0.0000

F-statistic value is 83.32 on 1 and 19 degrees of freedom. The corresponding p-value is 2.24e-008.
Model R-Squared value is **0.8143.**

Figures in the Appendix

Figure A1: *Fit of various models to the tubal sterilization schedules of cohorts of women in the South, West and the Central India*



Note: Cohorts 1, 2 and 3 denote cohorts of women aged 46-48 years, in NFHS-1, 2 and 3 respectively.

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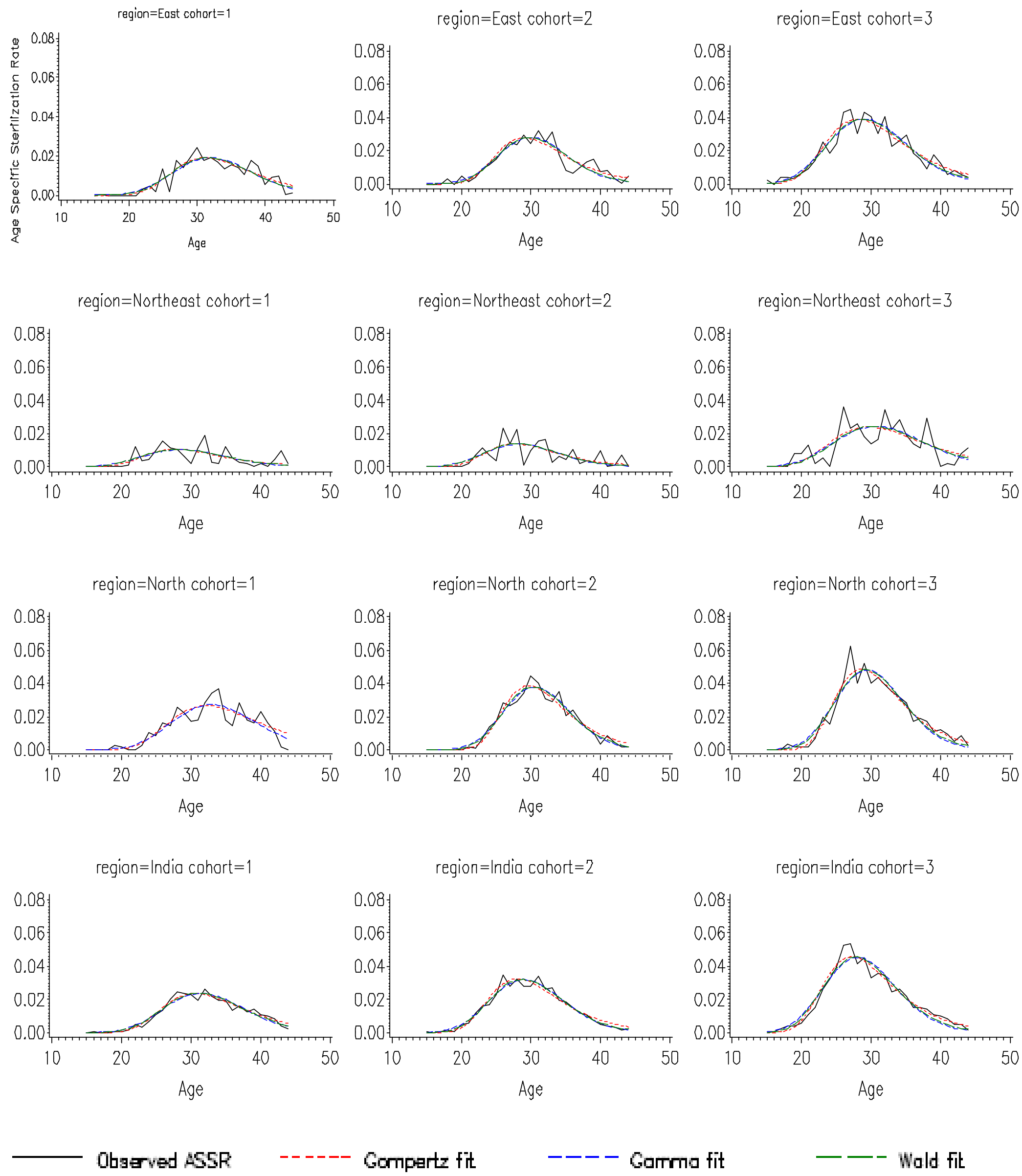
Figure A2: Fit of various models to the tubal sterilization schedules of cohorts of women in East India, North-east India, North India and India as a whole



Note: cohort=1, 2 and 3 denote cohorts of women, aged 46-48 years, in NFHS-1, 2 and 3 respectively.

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Figure A3: *Age pattern of acceptance of tubal sterilization in India and its different regions, obtained by using the Gompertz model*

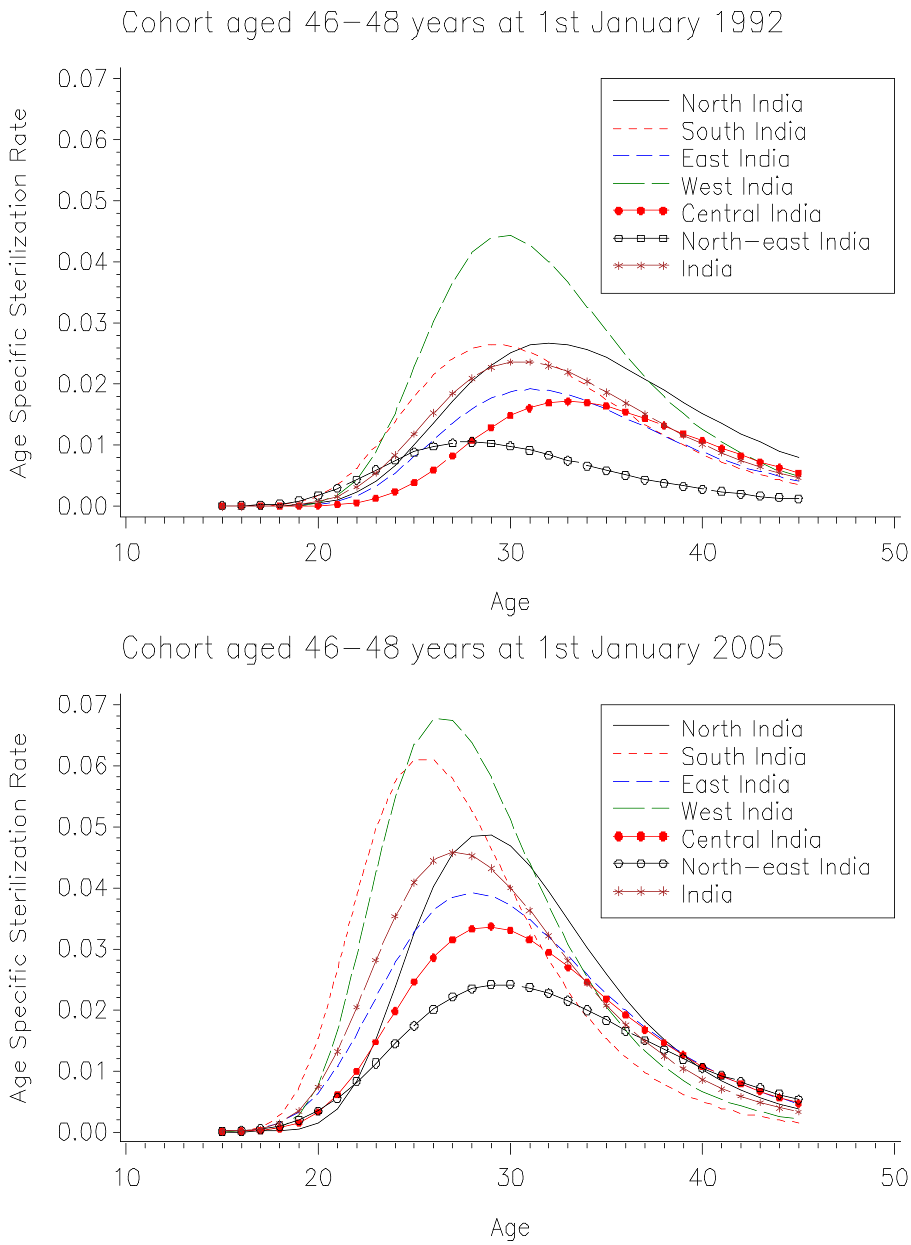
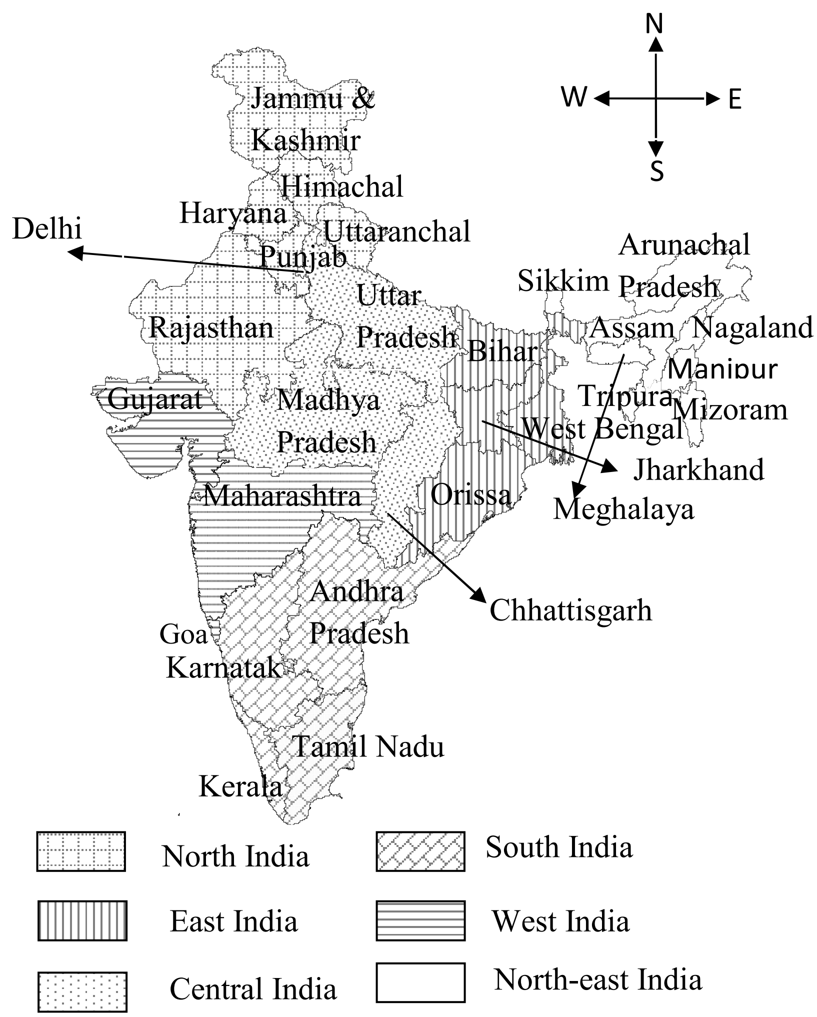


Figure A4: *Different regions of India and their constituent states*[a]



Note: a - At present, India consists of 29 states. Majority of Population of India (67.7% of the total population) is concentrated in the three regions Central India (24.6%), East India (22.3%) and South India (20.8%). West India and the North India consists 13.9% and 14.4% of the total population respectively. North-East India consists of just 3.8% of the total population (Registrar General of India, 2011).

Appendix A

Let x_ξ be the exact age that is required to reach 100ξ% of the saturation level by the growth process [3], where $\xi \in (0,1)$.

Hence by definition, x_ξ satisfies the following equation

$$R\left(\frac{1}{2}\right)^{\left(\frac{\log\left(\frac{3}{4}\right)}{\log\left(\frac{1}{2}\right)}\right)^{\frac{x_\xi - a}{b-a}}} = \xi R \qquad [4]$$

This implies

$$x_\xi = a + (b-a)\left(\frac{\log\left(\frac{\log(\xi)}{\log(1/2)}\right)}{\log\left(\frac{\log(3/4)}{\log(1/2)}\right)}\right) \qquad [5]$$

The following results follow from the above result

i) the age of attaining half of the saturation level is $x_{0.5} = a$ [6]

ii) the age of attaining three fourth of the saturation level is $x_{0.75} = b$ [7]

Appendix B

Using [5] it can be shown that

iii) The age of attaining one fourth of the saturation level is

$$x_{0.25} = a + (b-a)\left(\frac{\log\left(\frac{\log(1/4)}{\log(1/2)}\right)}{\log\left(\frac{\log(3/4)}{\log(1/2)}\right)} \right) \quad [8]$$

Using result of Titus (1972) and using [5] it can shown that

iv) Peak age at acceptance of tubal sterilization is

$$x_{peakster} = a + (b-a)\left(\frac{\log\left(\frac{-1}{\log(1/2)}\right)}{\log\left(\frac{\log(3/4)}{\log(1/2)}\right)} \right) \quad [9]$$