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Fertility Transition in India

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Abstract

This paper analyses fertility transition in India during 1985-2020 based on the data from the official sample registration system. The analysis reveals that fertility transition in the country is contingent upon the way age-specific fertility rates are aggregated into a single composite indicator of fertility. When the simple arithmetic mean of age-specific fertility rates is used as a composite indicator of fertility, fertility in India has decreased almost linearly. However, when the geometric mean of age-specific fertility rates is used as the composite indicator of fertility, fertility transition in India appears to have stalled the period 2011-2013. The analysis also reveals that the change in marital fertility accounted for only about 35 per cent of the change in the simple arithmetic mean of age-specific fertility rates but more than half of the change in the geometric mean of age-specific fertility rates. The paper suggests that fertility transition should not be analysed in terms of the trend in the simple arithmetic mean of age-specific fertility rates or, equivalently, total fertility rate but should be analysed in terms of the trend in the geometric mean of age-specific fertility rates.

Background

The total fertility rate (TFR) in India has now decreased to below replacement level (Government of India, 2022a; Government of India, 2022b; United Nations, 2022). According to the official sample registration system of the country, the TFR in the country decreased from 4.3 births per woman of childbearing age in 1985 to 2 births per women of childbearing age in 2020 (Government of India, 2022a). The latest (2019-2021) round of the National Family Health Survey (NFHS) has also estimated a TFR of about 1.99 births per woman of childbearing age during the period 2017-2019 (Government of India, 2022b) compared to a TFR of 3.4 births per woman of childbearing age during the period 1990-1992 (Government of India, 1995). The National Population Policy 2000 of India had targeted to achieve the replacement fertility (TFR=2.1) by the year 2010 (Government of India, 2000). This goal could be achieved only after a lag of almost 10 years. The delay in achieving the replacement fertility has implications for population stabilisation in India. The National Population Policy 2000 had projected that population of the country would stabilise by the year 2045 under the assumption that the replacement fertility would be achieved by the year 2010. The latest population projections prepared by the United Nations suggest that it is the most likely that the population of the country will continue to increase at least up to 1960 (United Nations, 2024).

The decrease in the TFR to the replacement or below replacement level has raised interest of demographers in the analysis of fertility transition in India. A recent study has concluded that India has followed an alternative pathway to low TFR which is different from the pathway followed by high-income countries (Park et al, 2023). Indian women continue to marry and produce births at young ages while the age at last birth has decreased so that births have increasingly got concentrated in the younger ages of the childbearing period. An increasing proportion of married Indian women go for sterilisation following the birth of two children to stop childbearing so that average fertility has decreased because of termination of childbearing at a young age (Park et al, 2023). The study has, however, not discussed the implications of fertility transition pathway followed by India for population stabilisation which is the medium-term goal of the National Population Policy 2000 (Government of India, 2000). It is well-known that population continues to increase for some time even after the achievement of replacement fertility because of the momentum of growth built in population age structure (Frejka, 1982; Keyfitz, 1971; Merrick, 1989). The impact of momentum on future population growth cannot be eliminated as it is the result of past trend in fertility and mortality but can be delayed through the increase in the mean age at childbearing with the decrease in fertility through increasing the age at first birth and the period between successive births (Bongaarts, 1994).

Achievement of below replacement fertility in India also masks variation in TFR within the country, across states and Union Territories. The sample registration system provides estimates of TFR for 22 states of the country and, in 2020, the TFR ranged from 1.4 births per woman of childbearing age in the National Capital Territory of Delhi, Tamil Nadu and West Bengal to 3 births per woman of childbearing age in Bihar in these states. The latest (2019-2021) round of NFHS provides estimates of TFR for all 36 states/Union Territories of the country and informs that TFR ranged from 1.05 births per woman of childbearing age in Sikkim to 2.98 births per woman of childbearing age in Bihar during the three years prior to the survey (2017-2019). There are five states in the country where TFR remains above the replacement level. These include Uttar Pradesh, the most populous state of the country and Bihar (Government of India, 2022b). District level estimates of TFR are not available from either the sample registration system or the NFHS. In the past, district level estimates of TFR were prepared using data from decennial population censuses (Government of India, 1988; 1997; Guilmoto and Rajan, 2002; 2013; Mishra et al, 1994) but there has been no population census in the country after 2011. An indirect approach, using data from the latest round of NFHS, however, suggests that TFR was below replacement level in only 326 of the 707 districts of the country.

TFR is a measure of the fertility experience of women of childbearing age but in a hypothetical context only. It is the sum of the fertility rate in different ages of the childbearing period (ASFR) or the average ASFR multiplied by 35, the length of the childbearing period. The ASFR is the ratio of the number of births to the number of women in particular age and, therefore, TFR is the sum of ratios which is mathematically appropriate as the sum of the ratios is not equal to the ratio of the sum of the numerator and the sum of the denominator of different ratios. It is because of this very reason that TFR is interpreted in a hypothetical perspective only and is popularly termed as a synthetic measure of fertility. TFR does not reflect the actual fertility experience of the women of childbearing age but reflects the number of births to a woman during her entire childbearing period if she follows a regime of fertility characterised by a set of age-specific fertility rates. The TFR reflects the prevailing fertility experience of women of childbearing age only when the number of women is the same in all ages of the childbearing period.

The TFR may also be viewed as a composite measure of the fertility with the simple arithmetic mean of ASFRs as the aggregation function. The use of simple arithmetic mean as the aggregation function for the construction of composite measures has been widely discussed in the context of the human development index (Desai, 1991, Kovacevic, 2010; Klugman et al, 2011). The simple arithmetic mean embodies perfect substitutability. The contribution of different values in the distribution to the simple arithmetic mean is different – the higher the value the higher the contribution and vice versa. This implies that the simple arithmetic mean is biased by the inequality in the distribution. This biasedness has implications in measuring the change as the change in the simple arithmetic mean is also biased towards the change in those values which are high compared to the change in those values which are low. The values in the distribution may not change in the same direction so that the change in the simple arithmetic mean is the algebraic sum of the change in the individual values. It may happen that the increase in some values of the distribution offset the decrease in other the distribution so that the algebraic sum of the change is zero. In this case, there is no change in the simple arithmetic mean despite the change in the individual values of the distribution. In this case, the change in the simple arithmetic mean of the change depicts a misleading picture of the change in individual values of the distribution.

There are two problems in analysing fertility transition in terms of the change in TFR. The first is the loss of some information in using an aggregate number for a set of age-specific fertility rates or using a scalar quantity for a vector. The second is that it overlooks the age-pattern of fertility. The TFR is sensitive to the shift in the age pattern of fertility or the timing of fertility (Hajnal, 1947). The postponement of births leads to an increase in the mean age at childbearing which affects age-specific fertility rates and hence TFR (Hajnal, 1947; Feeney, 1983; Ryder, 1964). The change in TFR, therefore, may be affected by the change in the timing of births or the tempo effect and the number of births women have when they end childbearing or the quantum effect (Ryder, 1964; Bongaarts and Feeny, 1998). There is, however, no way of capturing the entire wealth of information embodied in a set of numbers in one real number (Anand and Sen, 1994). It is, however, important to minimize the loss of information to the extent possible.

The TFR synthesises the fertility experience of the fertility experience of women of childbearing age or women who are biologically capable of producing a birth. However, only those women can deliver birth who are sexually active. Sexual activity outside the institution of marriage is not socially accepted in India and, therefore, virtually all births in India are confined within the institution of marriage. The latest (2019-2021) round of NFHS informs that around 1.268 million births that were reported by women of childbearing age in India during the year before the survey, only 684 births were reported by women who were not married at the time of the survey. TFR, therefore, is influenced by both fertility of married of women and proportion of married women in different ages of the childbearing period. TFR may decrease despite the increase in marital fertility because of the decrease in the proportion of married women and vice versa. The fertility experience of married women of childbearing age may be synthesised in the total marital fertility rate (TMFR) in the same way as TFR. Estimates of TMFR in India available from the sample registration system suggest that TMFR decreased from about 5.5 births per married woman of childbearing age during 1985-1987 to around 4.2 births per married women of childbearing age during 2012-2014 but then increased to around 5.1 births per married women of childbearing age during 2018-2020. During 1985-2014, the decrease in TFR in India has been associated with the decrease in TMFR but TFR decreased during 2012-2020 despite an increase in TMFR.

One approach to address the problems associated with the simple arithmetic mean in synthesising the fertility experience of the women of childbearing age is to use the power or the generalised mean with the power less than 1 (Bullen, 2000). When the power of the mean is equal to zero, the generalised mean is the geometric mean. The most important property of the geometric mean is that the geometric mean of a set of ratios is equal to the ratio of the geometric mean of the numerators of the ratios to the geometric mean of the denominators of the ratios. Geometric mean also addresses the problem of perfect substitutability associated with the simple arithmetic mean. The change in the geometric mean of age-specific fertility/ marital fertility rates gives equal weight to the change in fertility/marital fertility in different ages of the childbearing period. The geometric mean of the age-specific fertility/marital fertility rates is equal to the simple arithmetic mean of age-specific fertility/marital fertility rate only when fertility/marital fertility is the same in all ages of the childbearing period. Otherwise, the geometric mean is always less than the simple arithmetic mean of age-specific fertility/marital fertility rates. The ratio of the simple arithmetic mean to the geometric mean of the age-specific fertility/marital fertility rates, therefore, reflects the variation in fertility/marital fertility by age – the higher the ratio the larger the variation in fertility/marital fertility by age across the childbearing period. The increase in this ratio, therefore, implies an increase in the inequality of fertility/marital fertility across ages and vice versa. The concentration of fertility/marital fertility, in the younger ages of the childbearing period along with the decrease in fertility has implications for population stabilisation. From the perspective of population stabilisation, it is imperative that, with the transition, fertility/marital fertility should be more evenly distributed across the childbearing period. This means that the ratio of the simple arithmetic mean to the geometric mean of age-specific fertility/marital fertility rates should decrease with fertility transition.

In this paper, we show that fertility transition in India during 1985-2020 has been different when reflected through the trend in the simple arithmetic mean of ASFRs as compared to when it is reflected through the trend in the geometric mean of ASFRs or fertility transition is contingent upon how the age-specific fertility/marital fertility rates are aggregated. Our analysis suggests that it is more appropriate to analyse fertility transition in terms of the trend in the geometric mean of ASFRs rather than in terms of simple arithmetic mean of ASFRs. The trend in the geometric mean of ASFRs highlights issues in fertility transition in India from policy and programme perspective. These issues are not revealed by the trend in the simple arithmetic mean of ASFRs.

The rest of the paper is organised into seven sections. The next section outlines the methods employed. We assume that the trend in fertility during 1985-2020 has changed at least once so that the entire period can be divided into more than one time-segment with different trend in different time-segments. The third section describes the data source. We have used the data from the official sample registration system of the country which is the only source that gives annual estimates of indicators of fertility. The fourth section presents results of the trend analysis while the fifth section factors the change in the simple arithmetic mean/geometric mean of ASFRs into the change in ASMFRs and in age-specific proportion of married women. The sixth section presents the trend in the ratio of the simple arithmetic mean to the geometric mean of ASFRs and the mean age of childbearing to analyse the change in the age pattern of fertility. The last section summarises the findings of the analysis and their policy and programme implications in the context of population stabilisation.

Methods

Let f_i denotes the fertility rate in age i of the childbearing period. Then, f_i can be summarised in terms of both simple arithmetic mean, f_a, and geometric mean, f_g, of f_i. In symbols

$$f_a = \frac{\sum_{i=15}^{49} f_i}{35} \quad (1)$$

and

$$f_g = \left(\prod_{i=15}^{49} f_i\right)^{\frac{1}{35}} \quad (2)$$

Here 35 is the length of the childbearing period. Similarly, if g_i denotes the fertility of married women in age i, then g_i can be summarised in terms of simple arithmetic mean, g_a, and geometric mean, g_g. of g_i.

$$g_a = \frac{\sum_{i=15}^{49} g_i}{35} \quad (3)$$

and

$$g_g = \left(\prod_{i=15}^{49} g_i\right)^{\frac{1}{35}} \quad (4)$$

Notice than $m_i=f_i/g_i$ is, by definition, the proportion of married women in age i. We analyse fertility transition in terms of the trend in f_a and f_g assuming that the trend is not linear but might have changed at least once so that the entire trend period can be divided into more than one time-segments of varying length with different trend in different time-segments. The first step in the trend analysis, therefore, is to identify the time(s) or the year(s) when the trend has changed or the joinpoint(s). The annual per cent change (APC) in different time-segment may then be calculated assuming a linear trend within the time-segment. The APC in different time-segments has then been aggregated into the average annual per cent change (AAPC) in the entire trend period as the weighted average of APC with weights proportional to the length of time-segments (Clegg et al, 2009). This approach best summarises the trend that varies over time (Marriot, 2010).

Several methods have been proposed to statistically determine the number of times the trend has changed. These include permutation test method (Kim et al, 2000); Bayesian Information Criterion (BIC) method (Kim et al, 2009); BIC3 method (Kim and Kim, 2016); modified BIC method (Zhang and Siegmund, 2007); weighted BIC method; and data dependent selection method (Kim et al, 2022). The permutation method is the gold standard. It uses the sequence of permutation tests to ensure that the approximate probability of the overall Type I error is less than the specified significance level. Assuming that the default value of the minimum number of joinpoint(s) is 0, "the overall Type I error" is the probability of incorrectly concluding that the underlying model has at least one joinpoint when, in fact, the true underlying model has no joinpoint. In the present analysis, we have used the data dependent selection method to identify joinpoint(s). This method internally determines the model selection, BIC or BIC3, based on the characteristics of the data. The basic idea is to use BIC if change sizes are relatively small and BIC3 otherwise.

Actual calculations have been caried out using the open-source software Joinpoint Regression Program (National Cancer Institute, 2024). The software requires specification of minimum (0) and maximum number of joinpoints (>0) in advance. We have specified the minimum number of joinpoints as 0 and the maximum number of joinpoints has been set to 5. The programme starts with the minimum number of joinpoints and tests whether more joinpoints are statistically significant and must be added to the model (up to the pre-specified maximum number of joinpoints). The tests of significance are based on a Monte Carlo Permutation method (Kim et al, 2000). The grid search method has been used to identify joinpoints (Lerman, 1980). This method allows a joinpoint to occur exactly at time t. A grid is created for all possible positions of the joinpoint(s) or of the combination of joinpoint(s) and then the model is fitted for each possible position of the joinpoint(s), Finally, that position of joinpoint(s) is selected which minimises the sum of squared errors (SSE).

The change in f_a between time t_1 and t_2 ($t_2>t_1$) can be factored into the change in g_i and the change in m_i. We can write

$$\nabla f_a = f_a^2 - f_a^1 = \frac{1}{35}\sum_{i=15}^{49} f_i^2 - \frac{1}{35}\sum_{i=15}^{49} f_i^1 = \frac{1}{35}\sum_{i=15}^{49} f_i^2 - f_i^1 \quad (5)$$

Now

$$f_i = g_i \times m_i \quad (6)$$

so that

$$\nabla f_a = \frac{1}{35}\sum_{i=15}^{49}\left(g_i^2 \times m_i^2\right) - \left(g_i^1 \times m_i^1\right) \quad (7)$$

Now

$$\left(g_i^2 \times m_i^2\right) - \left(g_i^1 \times m_i^1\right) = \frac{\left(g_i^2 \times m_i^2\right) - \left(g_i^1 \times m_i^1\right)}{ln\left(\frac{\left(g_i^2 \times m_i^2\right)}{\left(g_i^1 \times m_i^1\right)}\right)} \times ln\left(\frac{\left(g_i^2 \times m_i^2\right)}{\left(g_i^1 \times m_i^1\right)}\right) = L_{f_i} \times ln\left(\frac{g_i^2}{g_i^1}\right) + L_i \times ln\left(\frac{g_i^2}{g_i^1}\right) \quad (8)$$

where

$$L_{f_i} = \frac{\left(g_i^2 \times m_i^2\right) - \left(g_i^1 \times m_i^1\right)}{ln\left(\frac{\left(g_i^2 \times m_i^2\right)}{\left(g_i^1 \times m_i^1\right)}\right)} = \frac{f_i^2 - f_i^1}{ln\left(\frac{f_i^2}{f_i^1}\right)} \quad (9)$$

is the logarithmic mean of f_i at times t_1 and t_2 and $t_2>t_1$ (Bhatia, 2008; Carlson, 1966). In other words,

$$\nabla f_a = \frac{1}{35}\sum_{i=15}^{49} L_{f_i} \times ln\left(\frac{g_i^2}{g_i^1}\right) + \frac{1}{35}\sum_{i=15}^{49} L_{f_i} \times ln\left(\frac{m_i^2}{m_i^1}\right) \quad (10)$$

$$\nabla f_a = \frac{1}{35}\sum_{i=15}^{49} L_{f_i} \times \partial g_i + \frac{1}{35}\sum_{i=15}^{49} L_{f_i} \times \partial m_i \quad (11)$$

where

$\partial g_i = ln\left(\frac{g_i^2}{g_i^1}\right)$ and $\partial m_i = ln\left(\frac{m_i^2}{m_i^1}\right)$

Similarly, the change in f_g, between time t_1 and t_2 ($t_2>t_1$) can be written as

$$\nabla f_g = f_g^2 - f_g^1 = \frac{f_g^2 - f_g^1}{ln\left(\frac{f_g^2}{f_g^1}\right)} \times ln\left(\frac{f_g^2}{f_g^1}\right) = L_{f_g} \times ln\left(\frac{f_g^2}{f_g^1}\right) \quad (12$$

where

$$L_{f_g} = \frac{f_g^2 - f_g^1}{ln\left(\frac{f_g^2}{f_g^1}\right)} \quad (13)$$

is the logarithmic mean of f_g at times t_1 and t_2 ($t_2>t_1$). Now

$$f_g = \left(\prod_{i=15}^{45} f_i\right)^{\frac{1}{35}} = \left(\prod_{i=15}^{45} g_i \times m_i\right)^{\frac{1}{35}} \quad (14)$$

$$ln\left(\frac{g_g^2}{g_g^1}\right) = \frac{1}{35}\sum_{i=15}^{49} ln\left(\frac{g_i^2}{g_i^1}\right) = \frac{1}{35}\sum_{i=15}^{49} \partial g_i \quad (15)$$

$$ln\left(\frac{m_g^2}{m_g^1}\right) = \frac{1}{35}\sum_{i=15}^{49} ln\left(\frac{m_i^2}{m_i^1}\right) = \frac{1}{35}\sum_{i=15}^{49} \partial m_i \quad (16)$$

so that

$$\nabla f_g = L_{f_g} \times \sum_{i=15}^{45} \partial g_i + L_{f_g} \times \sum_{i=15}^{45} \partial m_i \quad (17)$$

The decomposition of the change in f_g given by equation (17) is different from the decomposition of the change in f_a given by equation (10) in terms of the multiplying factor of the change in the marital fertility rate and the change in the proportion of married women in different ages of the childbearing period. In the decomposition of the change in f_g given by equation (20), this multiplication factor is the same for all ages of the childbearing period. In the decomposition of the change in f_a given by equation (11), this multiplying factor varies by age. The change in f_a gives more importance to the change in marital fertility and the change in the proportion of married women in those ages in which fertility is high as compared to those ages in which fertility is low. This means that the analysis of the change in fertility in terms of the trend in the simple arithmetic mean of age-specific fertility rates, f_a, is biased towards the change in those ages in which fertility is high relative to those ages in which fertility is low. This is not the case with the analysis of the change in fertility in terms of the trend in the geometric mean of age-specific fertility rates, f_g, which gives equal importance to the change in fertility in different ages of the childbearing period. Since both marital fertility and the proportion of married women vary by age, it is logical to argue that the analysis of fertility transition should give equal weight to the change in fertility and the change in the proportion of married women in different ages of the childbearing period. This is possible only when the fertility experience of women of childbearing age is summarised or the age-specific fertility rates are aggregated using the geometric mean of age-specific fertility rates rather than the simple arithmetic mean of the age-specific fertility rates. The trend in the simple arithmetic mean of age-specific fertility rates and hence in the total fertility rate is biased towards the trend in fertility in those ages of the childbearing period in which fertility is high compared to ages in which fertility is low. It is imperative in the analysis of fertility transition that importance is given to fertility change in different ages of the childbearing period irrespective of the level of fertility. For this very reason, the trend in the simple arithmetic mean age-specific fertility rates or in total fertility rate may depict a misleading picture of fertility transition. It is more appropriate to use the geometric mean of age-specific fertility rates to analyse fertility transition.

Data

The analysis is based on the annual estimates of age-specific fertility rates and age-specific marital fertility rates available from the official sample registration system of India. The sample registration system was launched by the Government of India on a pilot basis in 1964-1965 and was expanded to cover the entire country in 1969-1970. It is a large-scale survey of a sample of households in the country. The revision the sampling frame is carried out after every decennial population census in the country. The first revision of the sampling frame was carried out in 1977-1978 while the last revision was carried out in 2014. In 1969-1970, the system covered 3722 sampling units throughout the country. This number has increased to 8853 in 2014 (Government of India, 2022b). The households for the survey under the system are selected through a uni-stage, stratified simple random sampling without replacement approach with some variations in specific cases. In 2020, the system covered more than 8.3 million population throughout the country. The system collects information about the vital events in the household through a dual record system - continuous enumeration of births and deaths in the sampled villages/urban blocks by a resident part-time enumerator, and an independent six-monthly retrospective survey covering all households in the village/urban block by a full-time supervisor. The information about vital events obtained from the two sources are matched and the unmatched and partially matched vital events are re-verified in the field to get an unduplicated count of the correct number of vital events in the village/urban block. In addition, a base-line survey is also carried out prior to the start of continuous enumeration in each sampled village/block to prepare a notional map of the area to be surveyed, and for house numbering and house listing (Government of India, 2022a).

The sample registration system is the only system in India which provides annual estimates of selected indicators of fertility and mortality for the country and for the constituent states and Union Territories of the country. The system is, however, not designed to provide district level estimates of the indicators of fertility and mortality. The registration of births and deaths in India are mandatory under the Registration of Births and Deaths Act of 1969 which has been amended recently in 2023 (Government of India, 1969; 2023). However, the completeness of birth and death registration in the country remains far from satisfactory to provide statically reliable estimates of indicators of fertility and mortality. Estimates of the indicators of fertility in India are also available from the National Family Health Survey (NFHS) Programme launched by the Government of India in 1992-1993. The latest round of NFHS was carried out in 2019-2021 (Government of India, 2022b). The NFHS, however, is not carried out annually d, therefore, does not provide estimates of selected demographic indicators on an annual basis.

Annual estimates of the birth rate, age-specific fertility rates and the total fertility rate (TFR) in India are available from the sample registration system for the period 1970-2020. However, estimates of age-specific marital fertility rate and total marital fertility rate (TMFR) are available for the period 1985-2020 only. The present analysis has, therefore, been confined to the analysis of the change in fertility in the country during the period 1985-2020 only. Estimates of demographic indicators available from the sample registration system are also known to be associated with random errors of unknown origin. It is, therefore, customary to use three-year moving average in place of the annual estimates of demographic indicators available from the system for the analysis of the trend in indicators. We have also followed the same convention in the present analysis. Three-years moving average has been used to iron out the random errors of unknown origin associated with the estimates of demographic indicators derived from the sample registration system. We have assumed that the three-year average of the demographic indictor is located at the mid-point of the three-year interval. For example, the average of the TFR for the years 1985, 1986 and 1987 available from the sample registration system is assumed to be the TFR for the year 1986. It may, however, be noticed that this average TFR for the three-year period may be different from the actual TFR derived directly from the data available from the system. The average of the TFR for the period 1985-1987 may not be the same as the TFR for the year 1987 estimated directly from data available from the system.

Trend in f_a and f_g

Figure 1 depicts the trend in the simple arithmetic mean (f_a) and geometric mean (f_g) of the age-specific fertility rates. The trend in the two aggregate measures of age-specific fertility rates is different. The trend in f_a or, equivalently in TFR, suggests that fertility in India has decreased consistently during the period 1985-2020 whereas the trend in f_g suggests that the decrease in fertility has stagnated after the period 2011-2013. Figure 1 shows that the trend in fertility is contingent upon the function used to aggregate the age-specific fertility rates. The arithmetic mean of age-specific fertility rates show an almost linear decrease in fertility whereas the geometric mean of age-specific fertility rates suggests that fertility in the country has stopped decreasing after 2011-2013 and has shown an creasing trend during the period 2011-2020. Since, fertility rate is not the same in all ages of the childbearing period, but varies by age, the geometric mean is the more appropriate function to aggregate the age-specific fertility rates than the simple arithmetic mean.

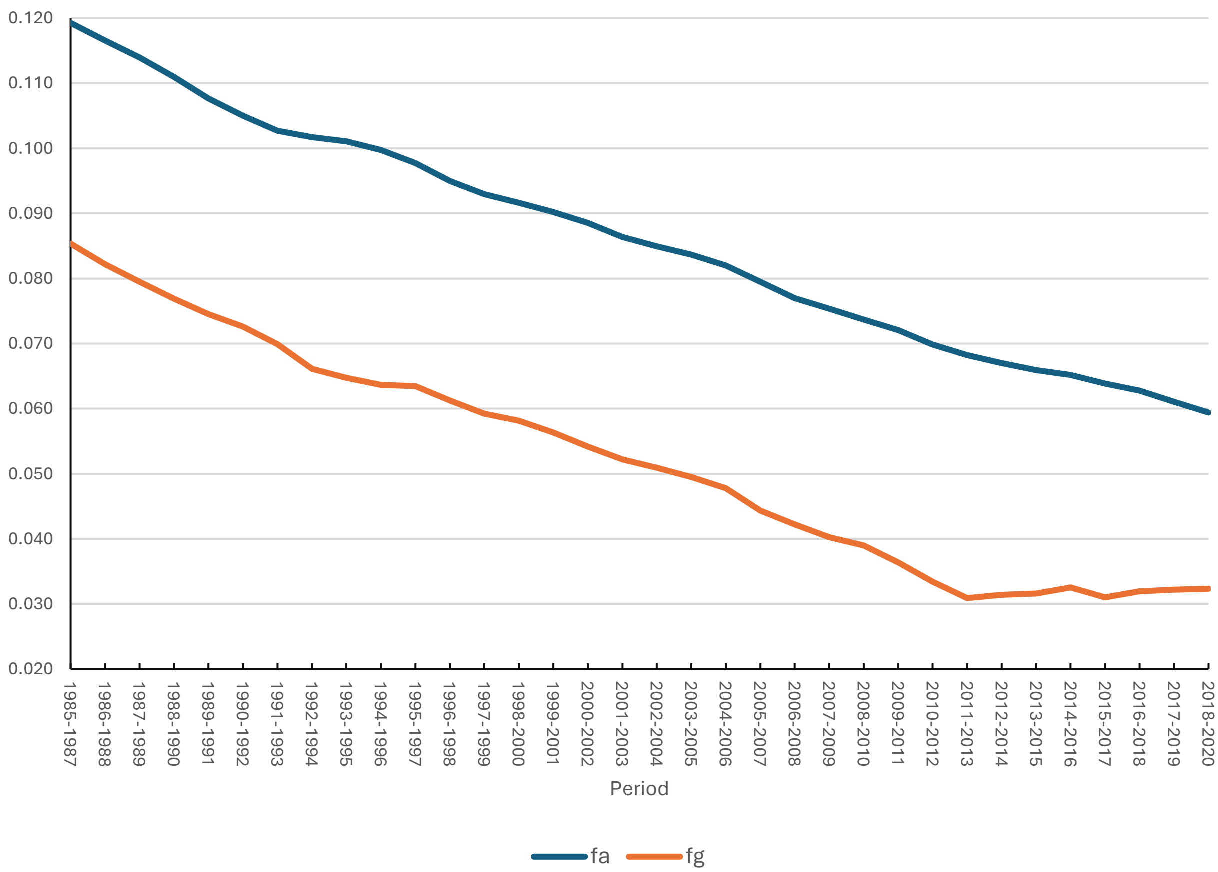

Figure 1: Trend in f_a and f_g in India, 1985-2020.
Source: Author, based on the data from the sample registration system.

Figure 1 also indicates that the trend in fertility in the country has not been uniform during the period 1985-2020 irrespective of whether fertility is measured in terms of f_a or f_g. identify the joinpoint(s) or the year(s) when the trend has changed, we have applied the joinpoint regression analysis of the trend in both f_a and f_g and the results are presented in table 1. The maximum number of joinpoints or the number of times the trend has changed was set to five the joinpoint regression analysis and the data driven selection method was used to identify the joinpoints or the time when the trend has changed.

Table 1 reveals that the trend in both f_a and f_g changed at least five times during the trend period 1985-2020. The time when the trend in f_a change and the time when the trend in f_g changed was, however, different. Table 1 also reveals that the average annual per cent change (AAPC) during the period 1985-2020 in f_a and f_g has also been different. Table 1 confirms that the change in fertility reflected by the trend in the simple arithmetic mean of age-specific fertility rates, f_a, is different from the change in fertility reflected by the trend in the geometric mean of age-specific fertility rates, f_g. This difference in the trend in f_a and f_g is particularly marked during the period 2011-2020 when the annual per cent change (APC) in f_a was negative meaning a decrease in f_a but the APC in f_g was positive meaning an increase in f_g and the increase was statistically insignificantly different from zero. Before the period 2011-2013, however, the trend in both f_a and f_g has been similar, although the times when the trend has changed in f_a are different from the times when the trend in f_g has changed and the annual per cent change (APC) in f_a and f_g during different time-segments has been different. Another observation of table 1 is that change in fertility reflected through the trend in f_a is slower than the change in fertility reflected through the trend in f_g.

Table 1: APC in different time-segments and AAPC during 1985-2020 in simple arithmetic mean (f_a) and geometric mean (f_g) of age-specific fertility rates in India.

f_a				f_g			
Time-segment	APC/ AAPC	't'	'P'	Time-segment	APC/ AAPC	't'	'P'
1985-1987 to 1991-1993	-2.489	-24.066	0.000	1985-1987 to 1993-1995	-3.377	-22.942	0.000
1991-1993 to 1994-1996	-1.070	-2.486	0.024	1993-1995 to 1996-1998	-1.684	-1.028	0.318
1994-1996 to 2004-2006	-1.953	-33.094	0.000	1996-1998 to 2003-2005	-3.112	-13.437	0.000
2004-2006 to 2011-2013	-2.540	-25.354	0.000	2003-2005 to 2008-2010	-4.781	-10.718	0.000
2011-2013 to 2016-2018	-1.621	-9.554	0.000	2008-2010 to 2011-2013	-6.874	-4.309	0.000
2016-2018 to 2018-2020	-2.750	-6.295	0.000	2011-2013 to 2018-2020	0.489	2.638	0.017
1985-1987 to 2018-2020	-2.094	-33.083	0.000	1985-1987 to 2018-2020	-2.901	-12.522	0.000

Source: Author, based on the data from the sample registration system.

Table 1 also shows that the slowdown in the decrease in simple arithmetic mean of the age-specific fertility rates, f_a, or, equivalently, in TFR during the time-segment 1991-1996 and again during the time-segment 2011-2018 was primarily responsible for the delay in achieving the replacement fertility in India. If the annual per cent change (APC) in f_a and hence in TFR observed during 1985-1993 would have been maintained during the post 1993 period, the TFR would have decreased to the replacement level by the year 2013 or about three years later than the target date set in the National Population Policy 2000. The decrease in f_a, or in TFR, accelerated during the period 1994-2013 but the decrease in fertility decelerated again during the period 2011-2018 which also contributed for the delay in the achievement of replacement fertility in the country.

Table 1 confirms that the function used to aggregate age-specific fertility rates matters in analysing fertility transition. When simple arithmetic mean is used, fertility in India appears to have decreased throughout the period 1985-2020. However, when geometric mean is used, transition in fertility appears to have reversed during 2011-2020. The simple arithmetic mean embodies perfect substitutability. The rapid decrease in fertility in some ages appears to have offset increase in fertility in other ages of the childbearing period so that f_a, or TFR continued to decrease during 2011-2020. In case of geometric mean, this substitution effect is minimal, although not fully eliminated, so that the increase in fertility in some ages cannot be fully offset by the decrease in fertility in other ages. It is obvious that the difference in the change in fertility reflected by the trend in f_a and the trend in f_g is not because of the difference in the fertility experience of women of childbearing age but because of the limitation of the simple arithmetic mean to aggregate the age-specific fertility rates because the simple arithmetic mean embodies perfect substitutability.

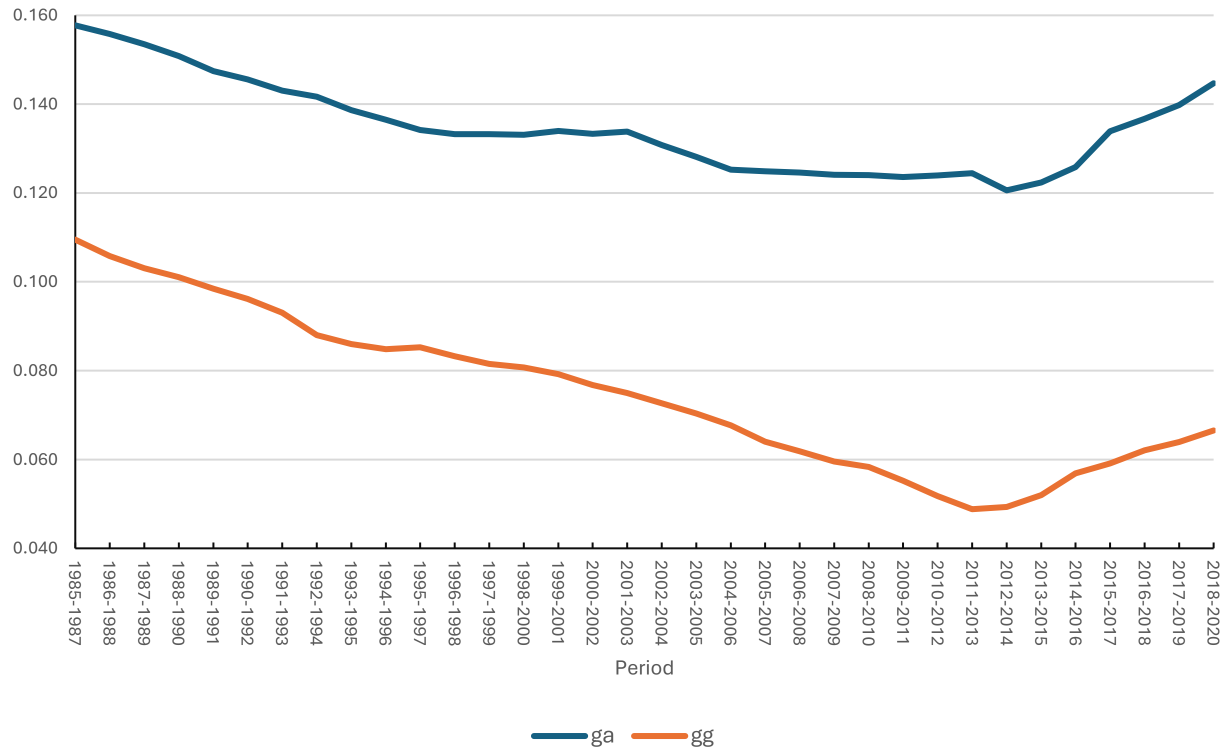

Figure 2: Trend in simple arithmetic mean (g_a) and geometric mean (g_g) of age-specific marital fertility rates in India, 1985-2020.
Source: Author, based on the data from the sample registration system.

The trend in marital fertility has also been found to be sensitive to selection of the aggregation function (Table 2). The average annual per cent change (AAPC) in the simple arithmetic mean of age-specific marital fertility rates, g_a, was -0.280 per cent during 1985-2020 but -1.478 per cent in the geometric mean of age-specific marital fertility rates. The sensitiveness of the trend in marital fertility to the aggregation function used to aggregate the age-specific marital fertility rates is obvious. The trend in the simple arithmetic mean of age-specific marital fertility rates, g_a, and the geometric mean of age-specific marital fertility rates, g_g, has also been different as may be seen from the times when the trend has changed and the annual per cent change (APC) in g_a and g_g in different time-segments of the period 1985-2020.

Table 2: APC in different time-segments and AAPC during 1985-2020 in simple arithmetic mean, g_a, and geometric mean, g_g, of age-specific marital fertility rates in India, 1985-2020.

g_a				g_g			
Time-segment	APC/ AAPC	't'	'P'	Time-segment	APC/ AAPC	't'	'P'
1985-1987 to 1996-1998	-1.577	-39.186	0.000	1985-1987 to 1993-1995	-2.921	-13.186	0.000
1996-1998 to 2001-2003	0.201	9.948	0.357	1993-1995 to 1999-2001	-1.346	-3.159	0.005
2001-2003 to 2004-2006	-2.168	-2.525	0.022	1999-2001 to 2008-2010	-3.460	-13.818	0.000
2004-2006 to 2013-2015	-0.293	-4.400	0.000	2008-2010 to 2011-2013	-5.983	-3.889	0.001
2013-2015 to 2016-2018	3.987	4.503	0.000	2011-2013 to 2018-2020	4.815	17.333	0.000
2016-2018 to 2018-2020	2.390	2.603	0.019				
1985-1987 to 2018-2020	-0.280	-2.145	0.032	1985-1987 to 2018-2020	-1.478	-7.775	0.000

Source: Author, based on the data from the sample registration system.

Trend in Age-specific Fertility/Marital Fertility Rates

The sensitiveness of the change in fertility to the aggregation function used for aggregate age-specific fertility rates – simple arithmetic mean or geometric mean - suggests that any analysis of the change in fertility based on the trend in the aggregate measures of age-specific fertility rates may be fraught with problems and may even be misleading. Otherwise also, the trend in aggregate measures of age-specific fertility rates presents only a rounded assessment of the change in fertility and masks the change in age-specific fertility rates. There may be a situation where the direction of the change in age-specific fertility rates is not the same and the direction of the change in fertility rate in some ages is opposite to the direction of the change in the aggregate measure of fertility. It is, therefore, imperative for a fuller understanding of the change in fertility that the analysis of the trend in the aggregate measure of fertility is accompanied with the analysis of trend in age-specific fertility rates. The analysis of the trend in the age-specific fertility rates is necessary to avoid the pitfalls in interpreting the change in fertility, especially when the simple arithmetic mean is used as the aggregation function.

Figure 3 depicts the trend in fertility rates in the conventional five years age-groups in India during the period 1985-2020. The most revealing observation of the figure 3 is that the trend in different age-specific fertility rates in the country has not been the same, especially, after the period 2012-2014. Fertility has decreased in some age-groups during the period 2012-2020 but has increased in other age-groups. There has been a marked decrease in fertility of women aged 20-24 years but a marked increase in fertility of women aged 15-29 years after 2012-2014. D has been different prior to 2012-2014 as fertility decreased in all age-groups, although the pace of decrease in fertility has varied by age. The trend in age-specific fertility rates has also not been linear during the period 1985-2020 but has changed at least once so that the pace of change has been different in different time-segments. The joinpoint regression analysis has been used to identify the time when the trend has changes and to calculate annual per cent change (APC) in different time-segments.

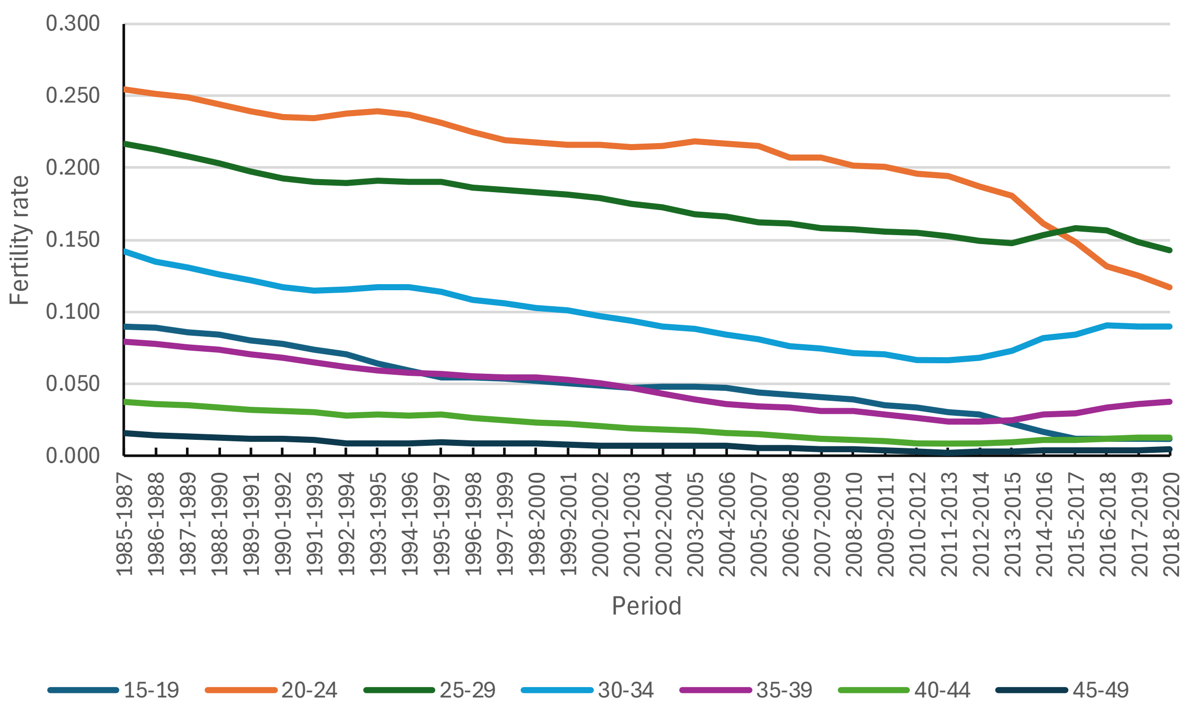

Figure 3: Trend in age-specific fertility rates in India, 1985-2020.
Source: Author, based on the estimates available from the sample registration system.

Table 3: Average annual per cent change (AAPC) during 1985-2020 and annual per cent change (APC) in different time segments in age-specific fertility rates and age-specific marital fertility rates in India.

<table>
<tr><th>ASFR/ ASMFR</th><th>1985-1987</th><th>1986-1988</th><th>1987-1989</th><th>1988-1990</th><th>1989-1991</th><th>1990-1992</th><th>1991-1993</th><th>1992-1994</th><th>1993-1995</th><th>1994-1996</th><th>1995-1997</th><th>1996-1998</th><th>1997-1999</th><th>1998-2000</th><th>1999-2001</th><th>2000-2002</th><th>2001-2003</th><th>2002-2004</th><th>2003-2005</th><th>2004-2006</th><th>2005-2007</th><th>2006-2008</th><th>2007-2009</th><th>2008-2010</th><th>2009-2011</th><th>2010-2012</th><th>2011-2013</th><th>2012-2014</th><th>2013-2015</th><th>2014-2016</th><th>2015-2017</th><th>2016-2018</th><th>2017-2019</th><th>2018-2020</th><th>AAPC</th></tr>
<tr><td colspan="36">Fertility</td></tr>
<tr><td>f_{15-19}</td><td colspan="6">-3.143
-7.293
0.000</td><td colspan="4">-7.589
-0.060
0.000</td><td colspan="10">-1.873
-8.010
0.000</td><td colspan="7">-6.111
-14.401
0.000</td><td colspan="3">-25.751
-11.371
0.000</td><td colspan="4">-1.142
-0.882
0.390</td><td>-6.067
-18.402
0.000</td></tr>
<tr><td>f_{20-24}</td><td colspan="5">-1.694
-4.864
0.000</td><td colspan="3">0.751
0.383
0.706</td><td colspan="5">-2.099
-4.182
0.001</td><td colspan="6">0.040
0.115
0.910</td><td colspan="8">-1.587
-7.956
0.000</td><td colspan="7">-8.072
-32.377
0.000</td><td>-2.394
-10.962
0.000</td></tr>
<tr><td>f_{25-29}</td><td colspan="6">-2.217
-11.793
0.000</td><td colspan="4">0.092
0.177
0.862</td><td colspan="17">-1.444
-32.206
0.000</td><td colspan="4">1.415
2.690
0.014</td><td colspan="3">-4.903
-5.096
0.000</td><td>-1.272
-11.085
0.000</td></tr>
<tr><td>f_{30-34}</td><td colspan="6">-3.445
-11.255
0.000</td><td colspan="3">1.325
0.608
0.550</td><td colspan="17">-3.463
-52.253
0.000</td><td colspan="5">6.847
11.002
0.000</td><td colspan="3">-0.375
-0.172
0.865</td><td>-1.344
-5.149
0.000</td></tr>
<tr><td>f_{35-39}</td><td colspan="9">-3.730
-22.700
0.000</td><td colspan="6">-1.907
-4.455
0.000</td><td colspan="4">-8.521
-2.842
0.000</td><td colspan="4">-4.086
-3.861
0.001</td><td colspan="4">-6.332
-6.054
0.000</td><td colspan="7">8.600
25.787
0.000</td><td>-2.239
-9.010
0.000</td></tr>
<tr><td>f_{40-44}</td><td colspan="7">-3.885
-27.128
0.000</td><td colspan="3">-0.501
-0.341
0.738</td><td colspan="9">-5.956
-52.662
0.000</td><td colspan="7">-9.530
-53.959
0.000</td><td colspan="3">10.011
6.467
0.000</td><td colspan="5">4.544
11.842
0.000</td><td>-3.226
-16.085
0.000</td></tr>
<tr><td>f_{45-49}</td><td colspan="23">-4.698
-15.238
0.000</td><td colspan="3">-20.095
-2.485
0.020</td><td colspan="8">9.737
5.547
0.000</td><td>-3.365
-3.317
0.000</td></tr>
<tr><td colspan="36">Marital fertility</td></tr>
<tr><td>g_{15-19}</td><td colspan="7">-0.943
-3.639
0.002</td><td colspan="3">-4.125
-1.957
0.064</td><td colspan="15">1.403
15.546
0.000</td><td colspan="3">-2.918
-1.376
0.184</td><td colspan="6">7.372
16.078
0.000</td><td>0.862
2.929
0.003</td></tr>
<tr><td>g_{20-24}</td><td colspan="12">-0.511
-6.900
0.000</td><td colspan="4">1.769
2.288
0.033</td><td colspan="3">-2.096
-1.116
0.278</td><td colspan="7">0.747
3.333
0.003</td><td colspan="8">-0.137
-0.778
0.446</td><td>-0.038
-0.181
0.856</td></tr>
<tr><td>g_{25-29}</td><td colspan="6">-2.010
-11.575
0.000</td><td colspan="10">-0.526
-5.550
0.000</td><td colspan="4">-2.436
-4.795
0.000</td><td colspan="8">-0.286
-2.061
0.055</td><td colspan="3">4.372
4.195
0.001</td><td colspan="3">-1.809
-1.789
0.091</td><td>-0.617
-4.456
0.000</td></tr>
<tr><td>g_{30-34}</td><td colspan="6">-3.348
-12.695
0.000</td><td colspan="3">0.441
0.238
0.815</td><td colspan="6">-2.909
-8.238
0.000</td><td colspan="11">-3.578
-30.393
0.000</td><td colspan="5">7.329
13.667
0.000</td><td colspan="3">0.434
0.233
0.819</td><td>-1.225
-5.241
0.000</td></tr>
<tr><td>f_{35-39}</td><td colspan="9">-3.826
-20.249
0.000</td><td colspan="6">-1.910
-3.903
0.001</td><td colspan="4">-8.398
-7.247
0.000</td><td colspan="4">-4.099
-3.458
0.003</td><td colspan="4">-6.534
-5.583
0.000</td><td colspan="7">8.549
22.198
0.000</td><td>-2.286
-8.181
0.000</td></tr>
<tr><td>g_{40-44}</td><td colspan="7">-4.093
-29.402
0.000</td><td colspan="3">-0.737
-0.516
0.613</td><td colspan="9">-5.917
-53.713
0.000</td><td colspan="7">-9.632
56.072
0.000</td><td colspan="3">9.347
6.231
0.000</td><td colspan="5">4.337
11.631
0.000</td><td>-3.380
-17.347
0.000</td></tr>
<tr><td>g_{45-49}</td><td colspan="23">-4.711
-14.738
0.000</td><td colspan="3">-20.887
-2.565
0.016</td><td colspan="8">9.246
5.134
0.000</td><td>-3.552
-3.866
0.000</td></tr>
</table>

Source: Author

Remarks: The first value in the cell is the APC, the second value is the 't' statistic while the third value is the significance probability.

Results of the joinpoint regression analysis of the trend in age-specific fertility rates and age-specific marital fertility rates are presented in table 3. The change in fertility has been the fastest in the age-group 15-19 years. Fertility decreased at an average annual per cent decrease of more than 6 per cent during the period 1985-2020 in this age group. This age-group is the only age-group in which fertility decreased in all the time-segments of the period 1985-2018 identified through the joinpoint regression analysis. In all other age-groups of the childbearing period, fertility increased at least in one time-segment of the period 1985-2020. The table also shows that fertility increased quite rapidly in the ages 30-49 years after 2011-2013 with the only exception of decrease in fertility in the age group 30-34 years during 2016-2020.

On the other hand, there is no age-group in which fertility of married women decreased in all time-segments of the period 1985-2020 identified through the joinpoint regression analysis. Marital fertility increased very rapidly during the time-segment 2013-2020 in the age group 15-19 years so that the marital fertility in this age group increased, instead decreased during the entire trend period 1985-2020. The average annual per cent change (decrease) in fertility has been faster than the average annual change in marital fertility in the age-group 15-39 years but, in the age group 40-49 years, the average annual per cent change in marital fertility has been faster than that in fertility.

Table 3 also confirms that the change in fertility in India has been different during the period 1985-2012 and during the period 2011-2020. During the period 1985-2012, fertility decreased in all ages of the childbearing period with only a few exceptions, although with varying pace of decrease. However, during the period 2011-2020, fertility, in general, increased in the age-group 25-49 years with some exceptions and the increase in fertility has been quite rapid. During the post 2011-2013 period, fertility transition in the country has virtually been confined to the younger ages of the childbearing period only. In the older ages of the childbearing period, there has apparently been a reversal in fertility transition in the post 2011-2013 period. In case of marital fertility, on the other hand, the reversal in fertility transition in almost all ages of the childbearing period is very much evident from table 3. Marital fertility decreased in the age group 20-24 years only during the post 2011-2013 period. The marital fertility in the age group 15-19 years increased during the time-segment 1995-2011 and again during the time-segment 2013-2020 so that marital fertility in this age-group increased, instead decreased during the entire trend period 1985-2020.

Decomposition of the Change in Fertility

The change in both f_a or f_g is due to the change in marital fertility rate and the change in the proportion of married women in different ages. Table 4 gives the change in the age-specific marital fertility rates (g_i) and the change in the age-specific proportion of married women (m_i) during 1985-2020. The marital fertility increased, instead decreased, in the age-group 15-24 years but decreased in other age-groups during the period 1985-2020 and the decrease was the most rapid in the age group 40-49 years. The change in marital fertility in different age-groups was, however, different in different time-segments. It was during 1985-1993 only when marital fertility decreased in all ages of the childbearing period. By contrast, marital fertility increased in all ages of the childbearing period, except 20-24 years, during 2011-2018. Similarly, marital fertility also increased in all ages of the childbearing period, except 25-29 years, during 2016-2020. In both these time-segments, increase in marital fertility was the most rapid in the age group 45-49 years.

On the other hand, the proportion of married women decreased during 1985-2020 in ages below 35 years but increased in ages 35 years and above. The decrease in the proportion of married women was very rapid in the age-group 15-19 years and decreased in all time-segments. This has, however, not been the case in other age-groups. The time-segment 1994-2006 is the only time-segment in which the proportion of married women decreased in all age-groups of the childbearing period whereas the time-segment 1991-1996 is the only time-segment in which the proportion of married women increased in all age-groups except the age group 15-19 years.

The contribution of the change in fertility and the change in the proportion of married women to the change in the arithmetic mean of age-specific fertility rates (f_a) and the geometric mean of the age specific fertility rates (f_g) has been different. The change in marital fertility during 1985-2020 accounted for a change of 35 per cent in f_a which means that the change in the proportion of married women accounted for a change of almost 65 per cent of the change in f_a (Table 5). On the other hand, the change in marital fertility during 1985-2020 accounted for more than 51 per cent in f_g so that the change in the proportion of married women accounted for only about 49 per cent of the change in f_g (Table 6). Summarising the fertility experience of women of childbearing age through the simple arithmetic mean of the age-specific fertility rates leads to the conclusion that most of the decrease in fertility has been the result of the decrease in the proportion of married women while the decrease in the marital fertility has played only a secondary role. However, when the fertility experience of women of childbearing age is summarised through the geometric mean of age-specific fertility rates, both the decrease in the marital fertility and the decrease in the proportion of married women have contributed almost equally to the decrease in fertility. This shows that the contribution of the change in fertility to the change in fertility is also influenced by the selection of the aggregation function for summarising the fertility experience of women of childbearing age.

Table 4: Decomposition of the change in the simple arithmetic mean of age-specific fertility rates, f_a, in India, 1985-2020.

Time-segment	Age group						
	15-19	20-24	25-29	30-34	35-39	40-44	45-49
	Change in marital fertility (∂g_i)						
1985-1987 to 1991-1993	-0.0448	-0.0260	-0.1132	-0.2076	-0.2111	-0.2414	-0.2976
1991-1993 to 1994-1996	-0.1120	-0.0153	-0.0165	0.0117	-0.1199	-0.0678	-0.3241
1994-1996 to 2004-2006	0.0811	-0.0108	-0.1109	-0.3200	-0.4555	-0.5572	-0.2060
2004-2006 to 2011-2013	0.1010	0.0678	-0.0327	-0.2335	-0.4123	-0.6987	-1.0818
2011-2013 to 2016-2018	0.1412	-0.0498	0.1067	0.3233	0.3159	0.3413	0.5008
2016-2018 to 2018-2020	0.1208	0.0454	-0.0226	0.0165	0.1183	0.0790	0.1345
1985-1987 to 2018-2020	0.2873	0.0112	-0.1892	-0.4097	-0.7646	-1.1449	-1.2743
	Change in proportion of married women (∂m_i)						
1985-1987 to 1991-1993	-0.1521	-0.0554	-0.0157	-0.0030	0.0037	0.0112	-0.0444
1991-1993 to 1994-1996	-0.0969	0.0273	0.0176	0.0065	0.0035	0.0071	0.0244
1994-1996 to 2004-2006	-0.3055	-0.0807	-0.0230	-0.0082	-0.0068	-0.0003	-0.0081
2004-2006 to 2011-2013	-0.5587	-0.1765	-0.0549	-0.0086	0.0045	0.0076	0.0270
2011-2013 to 2016-2018	-1.0636	-0.3383	-0.0813	-0.0115	0.0055	0.0208	0.0214
2016-2018 to 2018-2020	-0.1722	-0.1634	-0.0704	-0.0180	0.0007	0.0034	0.0148
1985-1987 to 2018-2020	-2.3490	-0.7869	-0.2277	-0.0429	0.0110	0.0498	0.0352

Source: Author

Tables 5 and 6 also reveal that the contribution of the change in age-specific marital fertility rates to the change in the arithmetic mean of age-specific fertility rates (f_a) and in the geometric mean of age-specific fertility rates (f_g) has been different in different time-segments of the period 1985-2020. During the period 2011-2020, the change in age-specific marital fertility rates contributed to the increase, instead decrease in both f_a and f_g as the age-specific marital fertility rates increased during this period. On the other hand, change in the age-specific proportion of married women contributed to the decrease in both f_a and f_g. However, the contribution of the change in the age-specific marital fertility rates to the change in f_a is offset by the contribution of the change in the age-specific proportion of married women so that f_a decreased during this period. On the other hand, the contribution of the change in the age-specific proportion of married women to the change in f_g could not offset the contribution of the change in age-specific marital fertility rate so that f_g increased during the period.

Table 5 also suggests that the main contributor to the decrease in f_a during 1985-2020 was the decrease in fertility in the age group 20-24 years (33 per cent) whereas decrease in fertility in the age group 15-19 years accounted for a decrease of almost 19 per cent and that in the age group 25-29 years accounted for a decrease of almost 18 per cent. This means that almost 70 per cent of the decrease in f_a is due to the decrease in fertility in the age-group 15-29 years. The contribution of change in marital fertility and in the proportion of married women in different age groups to the change in f_a. has, however, been different. Fertility in the age-group 15-24 years decreased despite the increase in marital fertility in this age group because of the decrease in the proportion of married women aged 15-24 years.

Table 5: Decomposition of the change in the simple arithmetic mean of age-specific fertility rates, f_a, in India, 1985-2020.

Time-segment	Age group							Change
	15-19	20-24	25-29	30-34	35-39	40-44	45-49	in f_a
1985-1987 to 1991-1993	-0.0160	-0.0199	-0.0262	-0.0269	-0.0149	-0.0078	-0.0046	-0.1162
1991-1993 to 1994-1996	-0.0138	0.0028	0.0002	0.0021	-0.0071	-0.0018	-0.0029	-0.0205
1994-1996 to 2004-2006	-0.0120	-0.0208	-0.0239	-0.0327	-0.0213	-0.0121	-0.0016	-0.1243
2004-2006 to 2011-2013	-0.0175	-0.0223	-0.0140	-0.0181	-0.0121	-0.0081	-0.0044	-0.0964
2011-2013 to 2016-2018	-0.0181	-0.0625	0.0039	0.0242	0.0091	0.0035	0.0016	-0.0383
2016-2018 to 2018-2020	-0.0006	-0.0147	-0.0139	-0.0001	0.0042	0.0010	0.0006	-0.0235
1985-1987 to 2018-2020	-0.0780	-0.1373	-0.0738	-0.0516	-0.0421	-0.0251	-0.0112	-0.4190
	Contribution of the change in marital fertility							
1985-1987 to 1991-1993	-0.0036	-0.0064	-0.0230	-0.0265	-0.0152	-0.0081	-0.0040	-0.0868
1991-1993 to 1994-1996	-0.0074	-0.0036	-0.0031	0.0014	-0.0073	-0.0020	-0.0031	-0.0253
1994-1996 to 2004-2006	0.0043	-0.0025	-0.0198	-0.0319	-0.0210	-0.0121	-0.0015	-0.0844
2004-2006 to 2011-2013	0.0039	0.0139	-0.0052	-0.0175	-0.0123	-0.0082	-0.0045	-0.0298
2011-2013 to 2016-2018	0.0028	-0.0080	0.0165	0.0251	0.0090	0.0033	0.0015	0.0501
2016-2018 to 2018-2020	0.0014	0.0056	-0.0034	0.0015	0.0042	0.0010	0.0006	0.0109
1985-1987 to 2018-2020	0.0109	0.0020	-0.0335	-0.0467	-0.0427	-0.0263	-0.0115	-0.1478
	Contribution of the change in the proportion of married women							
1985-1987 to 1991-1993	-0.0123	-0.0135	-0.0032	-0.0004	0.0003	0.0004	-0.0006	-0.0294
1991-1993 to 1994-1996	-0.0064	0.0065	0.0033	0.0007	0.0002	0.0002	0.0002	0.0048
1994-1996 to 2004-2006	-0.0163	-0.0183	-0.0041	-0.0008	-0.0003	0.0000	-0.0001	-0.0399
2004-2006 to 2011-2013	-0.0213	-0.0362	-0.0088	-0.0006	0.0001	0.0001	0.0001	-0.0666
2011-2013 to 2016-2018	-0.0209	-0.0545	-0.0126	-0.0009	0.0002	0.0002	0.0001	-0.0884
2016-2018 to 2018-2020	-0.0020	-0.0203	-0.0105	-0.0016	0.0000	0.0000	0.0001	-0.0343
1985-1987 to 2018-2020	-0.0888	-0.1393	-0.0403	-0.0049	0.0006	0.0011	0.0003	-0.2712

Source: Author

Table 6 suggests that the decrease in fertility in the age-group 15-29 years and in the age-group 30 years and above have contributed, almost equally, to the decrease in the geometric mean of age-specific fertility rates, f_g, during the period under reference. The geometric mean of the age-specific fertility rates, f_g, increased during the period 2011-2020 mainly because of the increase in fertility in the age group 30-49 years as fertility in the age group 15-29 years decreased during this period. It is evident from tables 5 and 6 that the contribution of the change in age-specific marital fertility rates and the change in the age-specific proportion of married women to the change in the fertility experience of women of childbearing ages is different when the simple arithmetic mean is used to aggregate age-specific fertility rates as compared to the contribution to the change in the fertility experience of women of childbearing age when the geometric mean is used to aggregate the age-specific fertility rates. The sensitiveness of the contribution of the change in marital fertility and the change in the proportion of married women to the aggregation function used to aggregate the age-specific fertility rates suggests that the selection of the aggregation function to aggregate fertility rates may lead to radically different interpretation about fertility transition. The problem with using the simple arithmetic mean to aggregate the change in age-specific fertility rates is that it gives different weight to the change in fertility in different ages of the childbearing period. The trend in the simple arithmetic mean of age-specific fertility rates may, therefore, may give a misleading picture of fertility transition. The advantage with using the geometric mean to aggregate the change in the age-specific fertility rates is that it gives equal weight to the change in fertility in different ages of the childbearing period. The selection of the aggregation function, therefore, bears importance in the analysis of fertility change.

Table 6: Decomposition of the change in the geometric mean of age-specific fertility rates, f_g, in India, 1985-2020.

Time-segment	Age group							Change in f_g
	15-19	20-24	25-29	30-34	35-39	40-44	45-49	
	Change in fertility							
1985-1987 to 1991-1993	-0.0022	-0.0009	-0.0014	-0.0023	-0.0023	-0.0025	-0.0038	-0.0154
1991-1993 to 1994-1996	-0.0020	0.0001	0.0000	0.0002	-0.0011	-0.0006	-0.0029	-0.0062
1994-1996 to 2004-2006	-0.0018	-0.0007	-0.0011	-0.0026	-0.0037	-0.0044	-0.0017	-0.0159
2004-2006 to 2011-2013	-0.0025	-0.0006	-0.0005	-0.0013	-0.0023	-0.0038	-0.0058	-0.0169
2011-2013 to 2016-2018	-0.0041	-0.0017	0.0001	0.0014	0.0014	0.0016	0.0023	0.0010
2016-2018 to 2018-2020	-0.0002	-0.0005	-0.0004	0.0000	0.0005	0.0004	0.0007	0.0004
1985-1987 to 2018-2020	-0.0161	-0.0061	-0.0033	-0.0035	-0.0059	-0.0085	-0.0097	-0.0530
	Contribution of change in marital fertility							
1985-1987 to 1991-1993	-0.0005	-0.0003	-0.0013	-0.0023	-0.0023	-0.0027	-0.0033	-0.0126
1991-1993 to 1994-1996	-0.0011	-0.0001	-0.0002	0.0001	-0.0011	-0.0006	-0.0031	-0.0061
1994-1996 to 2004-2006	0.0006	-0.0001	-0.0009	-0.0025	-0.0036	-0.0044	-0.0016	-0.0125
2004-2006 to 2011-2013	0.0006	0.0004	-0.0002	-0.0013	-0.0023	-0.0039	-0.0060	-0.0127
2011-2013 to 2016-2018	0.0006	-0.0002	0.0005	0.0015	0.0014	0.0015	0.0022	0.0075
2016-2018 to 2018-2020	0.0006	0.0002	-0.0001	0.0001	0.0005	0.0004	0.0006	0.0023
1985-1987 to 2018-2020	0.0022	0.0001	-0.0015	-0.0032	-0.0060	-0.0089	-0.0099	-0.0272
	Contribution of change in proportion of women married							
1985-1987 to 1991-1993	-0.0017	-0.0006	-0.0002	0.0000	0.0000	0.0001	-0.0005	-0.0028
1991-1993 to 1994-1996	-0.0009	0.0003	0.0002	0.0001	0.0000	0.0001	0.0002	-0.0001
1994-1996 to 2004-2006	-0.0024	-0.0006	-0.0002	-0.0001	-0.0001	0.0000	-0.0001	-0.0034
2004-2006 to 2011-2013	-0.0031	-0.0010	-0.0003	0.0000	0.0000	0.0000	0.0001	-0.0042
2011-2013 to 2016-2018	-0.0048	-0.0015	-0.0004	-0.0001	0.0000	0.0001	0.0001	-0.0065
2016-2018 to 2018-2020	-0.0008	-0.0008	-0.0003	-0.0001	0.0000	0.0000	0.0001	-0.0019
1985-1987 to 2018-2020	-0.0183	-0.0061	-0.0018	-0.0003	0.0001	0.0004	0.0003	-0.0258

Source: Author

Transition in Age Pattern of Fertility/Marital Fertility

It is well-known that fertility varies by age because both marital fertility and proportion of married women vary by age. Since fertility is not the same in all ages of the childbearing period, the simple arithmetic mean of age-specific fertility rates (f_a) is not equal to the geometric mean of the age-specific fertility rates (f_g). The simple arithmetic mean of the age-specific fertility rates equals the geometric mean of age-specific fertility rates only when fertility rates in different ages of the childbearing period are the same. Otherwise, the simple arithmetic mean of age-specific fertility rates is always greater than the geometric mean of the age-specific fertility rates. The ratio f_a/f_g, therefore, is an indicator of how fertility varies across different ages of the childbearing period. It is also obvious that the increase in this ratio indicates the concentration of fertility in selected ages of the childbearing period while a decrease indicates a more even distribution of fertility across the childbearing period. By the same argument, the ratio g_a/g_g reflects the variation or the inequality in fertility of married women in different ages of the childbearing period. The trend in the ratio f_a/f_g, therefore, reflects the change in the age pattern of fertility with the change in fertility. Similarly, the change in the ratio g_a/g_g reflects the change in the age pattern of marital fertility with the change in the fertility of married women. The change in the age pattern of fertility has implications for future population growth and population stabilisation as concentration of fertility in younger ages has implications for future population growth in terms of population momentum.

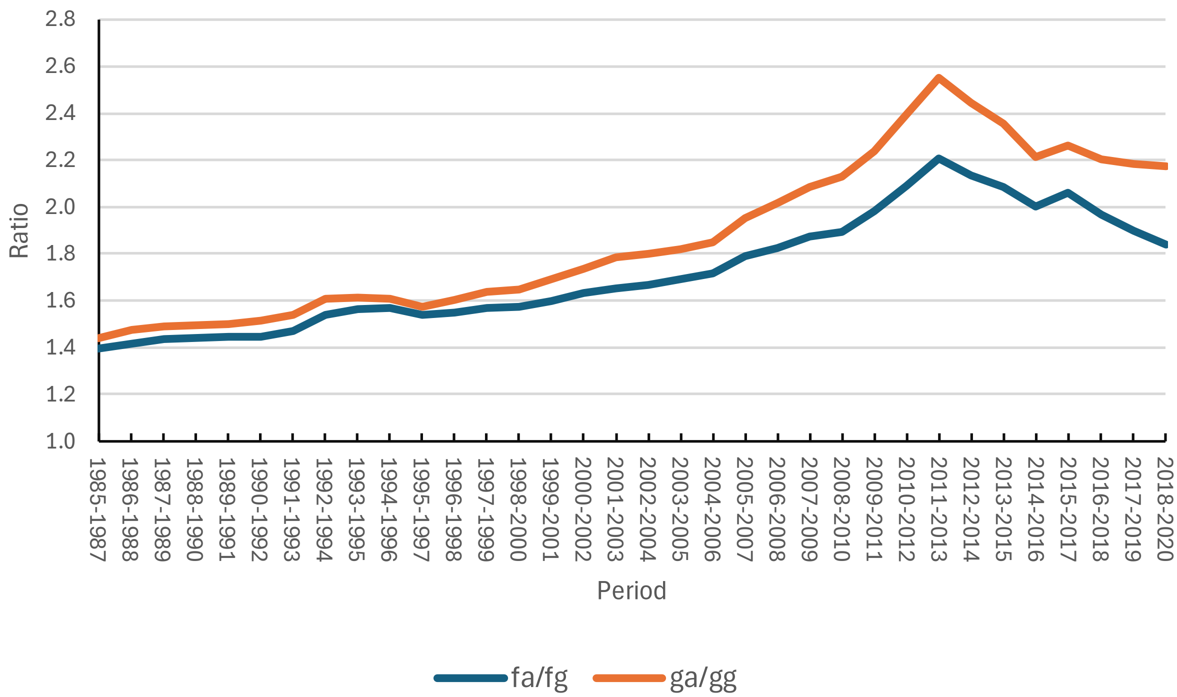

Figure 6: Trend in age inequality of fertility (f_a/f_g) and age inequality of marital fertility (g_a/g_g) in India, 1985-2020.
Source: Author

Figure 6 shows the trend in the ratios f_a/f_g and g_a/g_g in India during 1985-2020. Both the ratios increased during the period 1985-2014 which suggests that there has been an increase in the concentration of both fertility and marital fertility in selected ages of the childbearing period with the decrease in fertility and marital fertility during this period. The inequality in fertility or marital fertility, however, decreased after 2012-2014. The decrease in the age inequality of marital fertility has been associated with the increase in marital fertility. On the other hand, the decrease in the inequality in fertility by age has been associated with the marginal increase in f_g but a decrease in f_a. From the perspective of population stabilisation, it is important that the decrease in fertility should be associated with the increase in dispersion of fertility across childbearing ages as it contributes to lower the impact of momentum on population growth.

The trend in the inequality in fertility and marital fertility by age is supported by the trend in the mean age of childbearing of women ($MACB_w$) and the mean age of childbearing of married women ($MACB_m$). The decreasing trend in both $MACB_w$ and $MACB_m$ during 1985-2013 confirms increasing concentration of both fertility and marital fertility in the younger ages of the childbearing period. After 2011-2013, the $MACB_w$ increased rather sharply but the increase in $MACB_m$ has been relatively modest which indicates a marked shift in the age pattern of fertility, but only a marginal shift in the age pattern of marital fertility (Figure 7). The joinpoint regression analysis reveals that average annual per cent change (AAPC) in $MACB_w$ was 0.084 per cent during 1985-2020 which indicates that there has been only a marginal shift in the age pattern of fertility towards older ages of the childbearing period. The MACBw increased during the time-segments 1992-2000 and 2012-2020 only. On the other hand, the average annual per cent change (AAPC) in the mean age of fertility schedule of married women of childbearing age ($MACB_m$) was -0.283 per cent which indicates that fertility of married women has got increasingly concentrated in the younger ages of the childbearing period with the decrease in marital fertility, although $MACB_m$ increased during the time-segments 1992-1997 and 2011-2016. The $MACB_m$ during 2018-2020 was also markedly lower than $MACB_m$ during 1985-1987, while $MACB_w$ during 2018-2020 was only marginally higher than $MACB_w$ during 1985-1987. It appears that there has been little change in the age pattern of fertility and in the age pattern of marital fertility in the country with the decrease in fertility and marital fertility. This means that the change in fertility in India during 1985-2020 has contributed virtually little to lower the impact of momentum on the future population growth and hence to population stabilization.

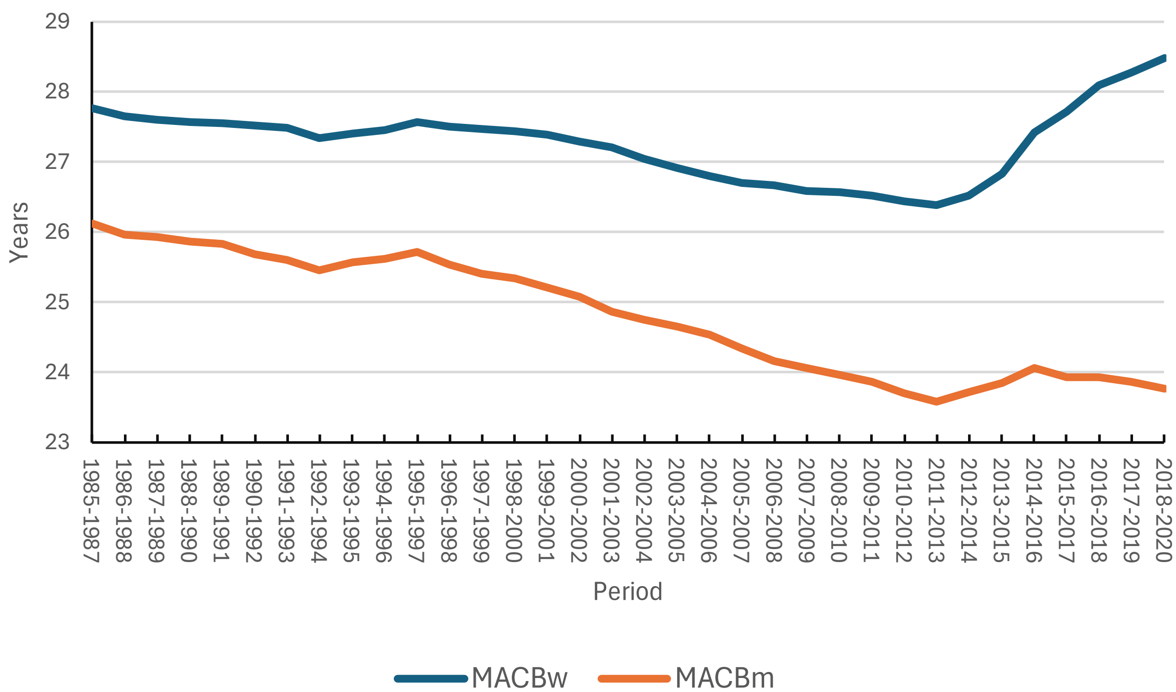

Figure 7: Mean age of childbearing in women of childbearing age and in married women of childbearing age in India, 1985-2020.
Source: Author

Discussions and Conclusions

The present paper highlights the pitfalls in analysing fertility transition in terms of TFR or in terms of the arithmetic mean of age-specific fertility rates. The paper reveals two different perspectives of fertility transition in India depending upon the way the fertility experience of women of childbearing age is summarised. The simple arithmetic mean of age-specific fertility rates suggests that fertility in India has decreased consistently since 1985, although at varying pace. The geometric mean of age-specific fertility rates, however, suggests an increase in fertility after 2011. The reason is that the decrease in fertility during this period has been different in different ages of the childbearing period. Fertility in the age group 15-29 years has decreased throughout the period 1985-2020 but fertility in the age group 30-49 years appears to have increased after 2011-2013. The decrease in fertility in the age-group15-29 years has, however, been more than the increase in fertility in the age-group 30-49 years so that simple arithmetic mean of age-specific fertility rates and hence TFR decreased even after 2011. The change in the simple arithmetic mean of age-specific fertility rates thus hides the increase in fertility in older ages of the childbearing period and, therefore, fertility transition based on the trend in the simple arithmetic mean of age-specific fertility rates may be misleading. This is not the case with the geometric mean. The change in geometric mean weights equally the change in fertility in different ages whereas the change in simple arithmetic mean weights the change in fertility in different ages in proportion to the size of the change. From the perspective of the transition in the fertility experience of women of childbearing age, it is more appropriate to aggregate age-specific fertility rates using the geometric mean rather than using simple arithmetic mean as the aggregation function.

The selection of the function to aggregate the age-specific fertility rates also influences the contribution of the change in the age-specific marital fertility rates and the change in the proportion of married women in different ages to the change in the composite measure of fertility. When the geometric mean is used as the aggregation function, the change in marital fertility and the change in the proportion of married women contributes almost equally to the change in the geometric mean of the age-specific fertility rates. However, when the simple arithmetic mean is used to aggregate age-specific fertility rates, the contribution of the change in marital fertility is substantially lower than the contribution of the change in the proportion of married women leading to the conclusion that transition has been driven primarily by the change in the proportion of married women. The TFR in India has been associated with the decrease in TMFR during 1985-2013 but the decrease in TFR during 2011-2020 has been associated with the increase in TMFR which implies that the entire decrease in TFR during the post 2011 period has been due to the decrease in the proportion of married women. This conclusion appears untenable as marriage is nearly universal in India and female marriage at an early age is quite common despite the fact that marriage of a girl younger than 18 years of age is not legally permitted. In contrast, the geometric mean of age-specific fertility rates indicates that stalling of fertility transition in the post 2011 period has been due to the increase in marital fertility in older ages of the childbearing period.

Another unique feature of fertility transition in India is that the decrease in fertility has been associated with the creased concentration of fertility in selected ages of the childbearing period as is reflected through the increase in the ratio of simple arithmetic mean to the geometric mean of age-specific fertility rates and the decrease in the mean age at childbearing. This trend reflects the typical approach adopted by India to regulate fertility of married women which has always focused on birth limitation rather than birth spacing. The ratio of the simple arithmetic mean to the geometric mean of the age-specific birth rates and the mean age at childbearing increased after 2011-2013 because of the increase in the fertility of older women.

The present analysis highlights some concerns related to fertility transition in India that have policy and programme implications. Fertility transition in the country appears to be contrastingly different during 2011-2020 compared to the period 1985-2013. There is a need to look into the reasons behind the increase in fertility of older women in the country, especially after 2011-2013. There may be a possibility that the decrease in fertility of older married women is small because of low fertility of these women and this small decrease is offset by the increase in fertility attributed to the increase in the proportion of married women because of the improvement in mortality in the older ages of the childbearing period. Another possible factor may be the shift in the focus of the official family planning efforts towards the spacing methods of contraception in place of terminal methods of contraception. The increase in fertility of married women 2011-2013 also needs to be looked in terms of the three proximate determinants fertility within the institution of marriages - breastfeeding behaviour, family planning use, and practice of abortion (Bongaarts, 1978; Preston et al, 2001), The present analysis suggests that the increase in marital fertility appears to be the reason behind the reversal in fertility transition after 2011.

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